DOI: 10.53469/jerp.2025.07(11).08

Exploring on the Paths and Effectiveness of AI-enhanced Personalized Teaching in Experimental Design and Analysis

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Abstract: ***The Experimental Design and Analysis course often faces challenges in addressing individual students needs due to large-class teaching instruction. Personalized teaching offers a viable solution by accommodating the diverse academic backgrounds and learning conditions of students. This paper analyzes the advantages of personalized teaching and proposes the use of artificial intelligence to empower personalized instruction in Experimental Design and Analysis. By leveraging AI's strengths in information collection, data analysis, and comprehensive evaluation, tailored teaching methods can be designed for the course. Integrating AI into daily teaching and management can enhance learning efficiency, cultivate students' research skills, and better achieve the course's teaching objectives.***

Keywords: Artificial intelligence, Experimental design, Personalized teaching**.**

1. Introduction

Currently, the higher education system in China predominantly employs a large-class teaching model. Under this framework, teachers frequently struggle to closely track individual learning trajectories given high student-to-teacher ratios and limited contact hours. In the contemporary information age, students process unprecedented volumes of information compared to previous generations, resulting in increased complexity and diversity in both personal characteristics and academic requirements. Maintaining conventional pedagogical approaches struggles to address these evolving needs. As a foundational course across multiple disciplines, Experimental Design and Analysis serves to cultivate scientific literacy and strengthen research competencies among undergraduates. Nevertheless, systemic challenges including restricted contact hours and inadequate practical implementation frequently lead to learning outcomes failing to meet expected benchmarks [1].

As a predominantly agricultural country, China relies on the cultivation of scientific and technological talent in agriculture as a crucial step to advance its agricultural development and ensure social stability. Agricultural universities, serving as key platforms for nurturing such talent, bear the fundamental responsibility of supplying the agricultural sector with qualified professionals. However, the textbooks currently used in courses such as Experimental Design and Analysis tend to be overly general, lacking specific focus on agricultural production and the tailored training of agricultural scientists and technicians. By incorporating personalized instructional design into the teaching process, educators can better accommodate students' individual learning characteristics and stimulate their interest. This approach not only enhances students' identification with and passion for the agricultural sector but also strengthens their professional commitment, thereby improving the overall quality of talent cultivation.

Tailoring the teaching process, evaluation system, and learning methods to accommodate students' individual characteristics and academic needs constitutes personalized teaching—an effective approach to enhancing educational outcomes. However, the Experimental Design and Analysis course, typically conducted in large-class settings with numerous students, makes it difficult to extend individualized attention to all learners. In recent years, rapid advancements in computer technology, particularly in artificial intelligence, have demonstrated significant advantages in areas such as learning analytics, knowledge mapping, and case design. These technologies offer powerful tools to support personalized instruction. Based on the significance and benefits of personalized teaching, this paper analyzes methods and effects of leveraging AI technology to empower the personalized teaching process in the Experimental Design and Analysis course. It aims to provide new perspectives on the application of AI in education.

2. The Significance of Personalized Teaching

Traditional teaching methods often employ uniform teaching materials and approaches, guiding students to acquire knowledge in similar contexts, which inevitably overlooks students' individuality. In fact, each student possesses distinct characteristics, preferences, and learning capacities. Personalized teaching, in essence, emphasizes a student-centered approach by designing tailored and diverse teaching processes based on individual circumstances. It analyzes each student's learning outcomes and incorporates feedback into the teaching cycle, thereby providing valuable insights for achieving more effective educational development.

Personalized teaching focuses on teachers' attention to students' individual differences, catering to their unique learning needs, and promoting their academic progress. The traditional Chinese educational concept of "teaching students according to their aptitude," such as Confucius' approach where the same question was addressed with distinct teaching methods for Zi Lu and Ran You, essentially represents a form of personalized instruction. Sukhomlinsky also believed that student's talents and aptitudes could be developed through the educational process. Recently, the concept of personalized

teaching has gained increasing prominence. However, earlier implementations largely relied on teachers' experiential knowledge, lacking systematic and scientific summarization [2]. Under new educational paradigms, where students exhibit varying levels of knowledge and competence, personalized teaching can significantly enhance learning engagement and provide innovative models for cultivating talent in higher education [3]. For different courses, personalized teaching can adapt instructional methods through learning analytics and design tailored content to improve student learning outcomes [4,5]. Emerging technologies, particularly computer science, digital technologies, and artificial intelligence developed since the 21st century, offer new solutions to address challenges in personalized teaching practices [6,7].

With the advancement of the era, the proliferation of new technologies such as informatization and networking has provided students with abundant knowledge, leading to increasingly diverse needs and faster knowledge updates [8]. This poses urgent challenges to traditional teaching methods, particularly since large-class instruction remains the mainstream, resulting in insufficient attention to individual students. Personalized teaching addresses this by analyzing students' backgrounds, learning situations, and needs to deliver tailored instructional content. In the post-class phase, it further enhances learning by matching students with appropriate learning resources and review guidance based on their mastery levels. This approach significantly improves teaching effectiveness and strengthens talent cultivation.

3. Approaches to AI-Empowered Personalized Teaching

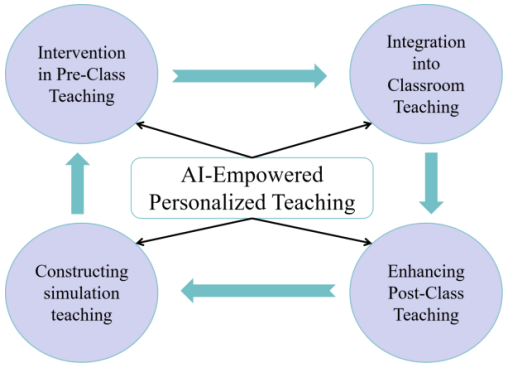

Figure 1: Approaches to AI-Empowered Personalized Teaching

As shown in Figure 1, regarding the processes and approaches of personalized teaching, artificial intelligence technology, leveraging its powerful computational and analytical capabilities, can be deeply involved in the following stages [9].

3.1 Intervention in Pre-Class Teaching

With its robust data collection and analytical capabilities, AI technology can assist teachers in conducting comprehensive student assessments, accurately identifying learning progress and challenges. This enables AI to support personalized lesson planning. Specifically, artificial intelligence can analyze students' previous assignment data, quiz scores, and expected learning outcomes to generate a class learning mastery map and individual student learning reports. Based on these visualizations and reports, AI can aid teachers in designing personalized learning objectives, organizing specialized student groups, and distributing targeted learning resources and assignments.

3.2 Integration into Classroom Teaching

Leveraging the rapid response characteristics of artificial intelligence technology, AI can assist teachers in dynamically adjusting instruction and personalizing interactions with students during class. Specifically, AI tools can be used to design randomized experiments, analyze in-class quiz results, and process real-time classroom data instantly. By displaying common errors and their correlations with learning behaviors to the teachers, AI enables quick responsiveness and timely adjustments to teaching pace and content.

3.3 Enhancing Post-Class Teaching

Leveraging the powerful analytical capabilities of artificial intelligence technology, AI can support teachers in designing personalized assignments and quickly assessing student's comprehension. Specifically, AI enables intelligent homework grading while generating detailed analysis reports for each student. Based on individual student data, it provides tailored recommendations for personalized exercises, learning strategies, and resources. At periodic intervals, AI can compile comprehensive reports for teachers, offering analytical insights and highlighting students facing learning difficulties for prioritized attention.

3.4 Constructing simulation teaching

The paramount objective of instruction is to equip students with the ability to master and apply acquired knowledge. Nevertheless, practical teaching components are frequently absent in numerous courses as a consequence of infrastructural limitations. Artificial intelligence software, possessing formidable integrative and analytical computing capabilities, provides a solution by facilitating the construction of virtual simulation platforms. The deployment of such software affords students convenient and efficient avenues for practical engagement.

4. Advantages of Utilizing Artificial Intelligence to Empower Personalized Teaching in Experimental Design

The Experimental Design and Analysis course often has limited class hours and poses significant practical challenges, generally resulting in relatively low student interest. However, this course is crucial for developing students' scientific research capabilities, technical research and development skills. Therefore, adopting suitable teaching methods to help students master the course content is essential. Personalized teaching, which tailors instruction to individual students' specific needs, can effectively enhance their interest in learning and strengthen overall learning outcomes.

Specifically for the Experimental Design and Analysis course, the following personalized teaching measures can be adopted based on the course characteristics. (1) Establish a data repository of students' learning profiles and personalities to

analyze individual characteristics and design tailored learning objectives and focus areas for each student. (2) Incorporate personalized teaching during instruction by adjusting the pace and emphasis of content delivery according to students' varying levels of comprehension. (3) Replace uniform homework assignments with customized tasks that reflect each student's learning progress and interests, thereby enhancing engagement and relevance.

For the innovation of personalized teaching in the Experimental Design and Analysis course, artificial intelligence can leverage its powerful computational and analytical capabilities to facilitate the achievement of teaching objectives. (1) During the phase of building student data resources, AI technology can be used to design questionnaires, collect learning-related information, analyze the data, and identify key teaching priorities for each student. (2) By utilizing AI software or programs, along with pre-class analysis reports for each student, personalized instructional content for the Experimental Design and Analysis course can be developed. This enables more targeted teaching during classroom sessions, achieving deep integration of AI technology into personalized instruction. (3) With the support of AI tools, student learning data can be correlated with classroom teaching effectiveness to assign "customized" homework and review tasks. Additionally, AI teaching assistants can be employed to conduct one-on-one discussions and tutoring on key and difficult topics in the Experimental Design and Analysis course.

5. Preliminary Exploration of AI-enhanced Personalized Teaching in Experimental Design and Analysis

The implementation of AI-empowered personalized teaching in Experimental Design and Analysis can be conducted through the following approaches.

5.1 Data Collection and Analysis

Utilize AI technology to design survey questionnaires, with the specific content as illustrated in Table 1.

Table 1: Statistics of Students' Basic Learning Information

Phase	Item	Content
Basic Information	Name, Student ID	
	Major, Grade	
Mastered Knowledge	Completed Prerequisite Courses	Completion status of courses such as Probability Theory and Mathematical Statistics, Linear Algebra, Advanced Mathematics, and Statistics-related courses
	Familiarity with statistical concepts	Familiarity with ANOVA, regression analysis, confidence level, etc.
	Familiarity with statistical software	Whether hands-on experience is available
	Familiarity with experimental design	Whether experiments have been conducted and experience in designing experiments
Learning preferences	Preferred teaching methods	Please rate the following instructional formats: systematic theoretical instruction, case analysis, group discussions, practical exercises, independent exploration, etc.
	Preferred methods for group discussions	Select topics for group discussions and roles to play
Course objectives	Primary objectives for taking this course	Select from the options: earn credits, prepare for research, lay the foundation for graduate studies, master skills, interest in experimental design
	Specific skills desired to acquire	
Open-ended questions	The biggest challenge encountered	
	Suggestions for the course	

A mini-program designed with artificial intelligence technology can be used to collect the information listed in Table 1 from students. Based on their response data, it can generate personalized learning profile reports for each student.

5.2 Teaching Process Design

Based on the pre-collected information and learning profile reports of each student, a personalized teaching design can be proposed. For example, the teaching content can be divided into three parts: foundational, personalized, and advanced; while teaching tasks can be categorized into core tasks, elective tasks, and challenge tasks.

The foundational part of the teaching content includes basic concepts such as factors, levels, analysis of variance, and orthogonal experiments, which all students are required to master. The personalized part needs to be further subdivided.

For students with weak mathematical foundations, strengthen the instruction of mathematics-related concepts such as statistics, analysis of variance, and confidence levels. For students with solid foundational knowledge, enhance the explanation of more advanced topics such as the derivation of analysis of variance and robustness analysis. For students without experience in using statistical software, demonstrate the functions of software like Excel, Origin, and Matlab and provide operational guidance. For students with experience in using statistical software, apply statistical software to experimental data analysis. For students without practical experimental experience, explain the application of analysis of variance, single-factor experiments, orthogonal experiments, and response surface experiments in scientific research practice during teaching sessions [10].

Teaching tasks should also be personalized. For students with weak foundational knowledge, design core tasks that emphasize the mastery of basic concepts, highlighting these fundamentals in assignments. For students with strong learning interest, design elective tasks requiring them to additionally complete the design of complex experiments and corresponding analysis assignments. For students capable of exceeding standard requirements, assign challenge tasks that involve implementing designed experiments in practice, which can be counted as extra credit.

5.3 Analysis of Learning Outcomes

Utilize artificial intelligence to analyze students' learning

outcomes, generating progress reports on each student's knowledge mastery and learning process. Comprehensively assess the improvement levels of different students participating in personalized teaching. Compare the differences between personalized teaching and traditional teaching in terms of assignment performance, academic achievements, knowledge mastery, and course evaluations, thereby providing support for the continuous enhancement of personalized teaching and the Experimental Design and Analysis course.

5.4 Construction of Knowledge Graph

Artificial intelligence software can be utilized to support students in synthesizing pedagogical content and establishing the comprehensive knowledge architecture. Concurrently, the strategic implementation of visual aids, such as flowcharts and knowledge networks, serves to incorporate pertinent disciplinary knowledge into the knowledge graph for experimental design. Moreover, intelligent assistants can be deployed to enhance the interactivity and engagement of the educational experience, thereby guiding students toward more active and self-driven learning.

5.5 In-depth Learning Guidance

Personalized instruction must address the dichotomy of student abilities: it should accommodate the pace of those who are struggling while simultaneously providing advanced learning resources for high-achievers. With the help of AI's initial analysis of learning progress data enables the targeted delivery of deeper experimental design and analysis knowledge to proficient students. This approach can be further expanded to introduce practical, application-oriented knowledge, thereby effectively guiding students in the experimental design process.

5.6 Establishment of Virtual Teaching

The constraint of limited teaching hours in the experimental design course often prevents effective practical instruction. To solve this problem, the virtual simulation platform can be constructed for students. This environment permits students to design experimental protocols for given problems and receive simulated outcomes. The artificial intelligence subsequently performs integrated analysis of the student generated results, delivering diagnostic feedback and optimization suggestions. This methodology aids in fostering students' scientific competencies and elevates the overall caliber of instruction.

6. Conclusion

In summary, this paper has reviewed the development and current state of personalized teaching, analyzed the approaches and advantages of AI-empowered personalized instruction, and examined its effectiveness. As a rapidly advancing technology, artificial intelligence is poised to drive transformative changes across various fields. Leveraging AI's capabilities in analysis and intelligent design to enhance personalized teaching in Experimental Design and Analysis can effectively address the existing gaps in this course, improve teaching efficiency, and boost student engagement and learning outcomes.

Of course, integrating new technologies into education is not merely about technological substitution. The current challenges and limitations in practice mainly include: personalized teaching focuses on individual differences, with the key being to achieve highly targeted educational processes. This requires comprehensive evaluation of data from different majors, courses, learning situations, classes, and individuals, making clear and effective data collection quite challenging. Meanwhile, conducting holistic analysis of student data, proposing tailored instructional designs, and realizing these plans in teaching practices present significant difficulties. Although artificial intelligence technology has advanced rapidly in recent years, it still cannot fully overcome these challenges. Technologically, AI can provide analysis and support, but due to the complexity of situations, limitations in data scope, and the duration of statistical cycles, it often falls short of achieving fully personalized outcomes. In implementation, while AI technology can offer assistance, the actual teaching process still relies on teachers. With personalized teaching supported by new technologies, teachers need to adapt their working models and update their teaching philosophies, which increases their workload and poses additional challenges.

However, education serves as the foundation for the development of human society. Imparting knowledge to students and nurturing well-rounded individuals are the responsibilities of teachers and the essence of education. To better leverage artificial intelligence technology in empowering personalized teaching and achieving higher-quality, more efficient student development, all sectors of society must take action. Teachers should actively explore and apply AI tools, schools should proactively build infrastructure, organize teacher training, and encourage the integration of new technologies into teaching. Developers of AI technology should strive to ensure that it better serves the practical needs of education. In the future, AI should continue to deepen its integration with education.

Funding Project

This paper is the outcome of the 2025 Teaching Reform Project of Henan Agricultural University (Project Number: 2025XJGLX190), the 2025 Higher Education Research Project of Henan Province (Project Number: 2025SXHLX085).

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