AI-Empowered Student-Centered Teaching Optimization Path and Empirical Analysis for Mathematics Courses in Private Universities

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Abstract: In light of the digitalization of education, it is of great importance to solve the issue of the lack of student subjectivity in the private university mathematics course. In this paper, we analyze the defects of the teaching in the traditional way, we argue the reason for the value of the AI in the process of the instruction from the side of the student, and we construct the path of optimization in three stages: precise pre-class guidance, in-class inquiry-based learning, and post-class personalized expansion. The quasi-experimental results indicate that in the teaching model empowered by AI, the students' internal learning drive is stimulated, the differentiated teaching and the personalized assessment are achieved, and the academic performance and the ability of self-regulated learning are improved, which provides the paradigm for the teaching reform that can be replicated.

Keywords: Artificial Intelligence; Mathematics Courses; Student-Centered Teaching; Value-Added Assessment; Teaching Reform

1. Introduction

With the development of educational digitalization, the traditional way of teaching advanced mathematics will face much greater problems, so teaching reform is an agreement in academic circle[1]. In private universities, the situation of the traditional teaching model is more obvious: the rigid one-way lecture ignores the application, the students are passive and the classroom is without the life; the foundation is not even, "one size fits all" teaching is not effective, can not meet the different levels; the final exam dominated evaluation has serious lag, can not make the teaching adjustment in time. So, the traditional model can not meet the requirements in the new era anymore. The rapid development of the generative AI gives a strong support for reconstructing the teaching process. Therefore, this paper will try to find the optimization path for the AI empowered student centered mathematics teaching in private universities, and verify its effectiveness by empirical research.

2. The Value Implications of AI-Empowered Student-Centered Mathematics Teaching in Private Universities

With the institutional attributes and student characteristics of private universities, the introduction of AI is deeply changing the teaching philosophy[2-4]. With the main value of core reflected in three dimensions: .

Reshaping Classroom Ecology and Student Subjectivity: AI is responsible for all the tedious calculations, and the class time can be spent on the inquiry and the mechanism of the student lecturer. The teacher is then a guide, and the learning initiative is back to the students, and the passive listening is reversed.

Bridging Student Differences with Personalized Guidance: AI. The AI constructs the so-called, mathematics learning profiles, in order to diagnose the weak knowledge and construct the learning paths. It bridges the gap of student differences with the low cost, large scale personalized guidance, instead of one size fits all type of teaching[5].

Building Data-Driven Value-Added Assessment: Traditional outcome-based assessment will kill the confidence. AI collect full process data to support for value-added assessment. AI is not the absolute score, but the progress of the students. Dynamic trajectory tracks the student fairly reflects the real growth and guides for the teaching optimization.

3. Optimization Path for AI-Empowered Student-Centered Mathematics Teaching in Private Universities

Together with the above value implications and with demands of the digital transformation of the education, this study, based on , builds a student-centered teaching optimization path, which is called as called "AI-Empowered Three-Stage Progression".

3.1 Pre-Class: AI Precise Diagnosis and Teaching Based on Learning

The pre-class period is not only the preview stage, but also the period of learning situation detection. With the powerful processing ability of educational data of AI technology, the teachers change the blind state of "guessing learning situation based on experience" completely. In some concrete operation, the teachers will let their customized pre-study guide and micro-test be issued by the AI teaching platforms (for example, the intelligent modules in Rain Classroom, Chaoxing, etc) before class. The pre-study guide usually contains a short video to introduce those concepts and a few target basic test questions.

After the students finish the preview, the multi-dimensional data will be collected automatically in the background of the AI system, including 1) the completion rate of preview videos, 2) the number of drag and drop replay (the more is the difficulty point), 3) the correct answer rate on the test questions, and 4) the time spent on each question. After that, the two layer data report including the "class-wide learning radar chart" and the "student personal knowledge graph" will be generated immediately in the AI system. When the teacher looks at the report, he/she can exactly find where is the common difficulties of the lesson (e.g.80% students have error when they understand the certain theorem), and what is the individual blind spot, therefore they can achieve the "teaching based on the learning" in the lesson preparation, spend the classroom time on the higher order thinking areas that the students really do not understand. At the same time, the AI system also assists the teacher to find the "seed students" who have the outstanding preview performance and the super coach with unique idea, and group the students heterogeneously according to the personality traits and the cognitive level, which is a preparation of the efficient collaborative inquiry in the class.

3.2 In-Class: Implementing "Student Lecturer" to Deepen Inquiry-Based Learning

The classroom is the main battlefield for the teaching reform. With AI empowered, the core classroom session is realized basically the flip from the one-way teacher lecture to the multi-dimensional student inquiry.

After the intelligent grouping from the pre-class stage, for each group, there is the time-limited collaborative inquiry on the key questions or error-prone cases put forward by the teacher. In this process, the students can use the tablets to call for the AI tools, to check the formula derivation or to take out the idea which can only be expanded by AI tools. After the inquiry, the class has the core mechanism of "student lecturer". In this moment, the represent from each group will go to the podium and just like the teacher, use the projectors to say the problem solving ideas for their group, the analysis of error-prone points, even the strategy for many solution for one problem. This mechanism is so much in line with the teaching reform orientation of the mathematics core courses, that is, the conception inquiry and logic rigor. The students who go to the podium must deeply reorganize and process the knowledge to teach others, such that they have greatly deepened the essence of the mathematical concept.

In this process, the role of the teacher recedes to the background, becoming a of a "host" and "in-depth commentary expert". The teacher uses AI interactive tools (that is, the bullet-screen questions, in-class multiple-choice questions, word cloud generation etc.) to collect in real time in this process the understanding status and the questions of other students of the other students during the listening process. When common confusion is found, the teacher should intervene promptly for in-depth guidance and expansion. At last, this three-dimensional interweaving of "student-student interaction + teacher-student interaction + human-computer interaction" completely eliminates the existence of "invisible people" in the classroom, making it a highly engaging, highly interactive immersive classroom.

3.3 Post-Class: Intelligent Layered Expansion to Consolidate Learning Outcomes

The post-class session is what prevents knowledge forgetting and allows the ability transfer. AI empowerment breaks totally the model of the whole class doing the same exercise book.

Immediately after class, based on the student's pre-class preview data, in-class interactive performance (e.g., quality of bullet-screen questions), in-class quiz scores, and error records, the AI system, using an algorithmic model, automatically generates a very personalized "homework package" for the student immediately. This homework package is divided scientifically in three levels. The first level is the "Basic Consolidation", which is for the knowledge gaps exposed by the student that day, for compensatory practice. The second level is the "Ability Improvement", which is for moderately comprehensive application problems to exercise the mathematical modeling skills. The third level is the "Expansion and Exploration", which is usually combined with the student's major (e.g. marginal analysis in economics, rate of change problems in engineering), to provide open-ended interdisciplinary case study for students with spare capacity to challenge.

If during homework completion the students are stuck in some mental block, then they do not have to wait for fixed weekly office hours. Instead, they can wake up the AI tutoring assistant. The AI assistant does not give directly the final answer. Instead, he helps the students to overcome the obstacle themselves, by somehow asking a heuristic question, by giving some step by step hints or by drawing the function images in a dynamic way. Such an intelligent layered expansion and instant tutoring mechanism is in fact exactly corresponding to the Vygotsky's theory of the so-called Zone of Proximal Development, that is, weak students cannot be freaked, advanced students cannot be fixed, and each one can have the maximum improvement with respect to the original level of him/herself.

4. Practical Case and Effect Analysis

In order to verify the effectiveness of the above optimization path, we implemented a one semester quasi-experimental study at a private university. Two parallel classes (total 120 students) were chosen as research subjects. In the experimental class, the teaching of "AI-Empowered Three-Stage Progression" was implemented, and the control class used the tradition lecture based teaching.

4.1 Implementation Process

A non-equivalent control group pretest-posttest design was adopted. Two parallel classes taught by the same experienced teacher (five years of teaching experience) were selected, with a total of 120 students. Through a preliminary mathematics placement test, it was confirmed that there were no significant differences between the two classes in mathematics foundation, gender ratio, and student origin ($p > 0.05$). One class was randomly selected as the experimental class (60 students), implementing the "AI-Empowered Three-Stage Progression" teaching model. The other class served as the control class (60 students), maintaining the traditional "PPT lecture + blackboard derivation + unified homework" model.

(1)Pre-class Differences: The experimental class teacher used the smart teaching platform to release AI study guides with interactive tests, adjusted the lesson plan based on the automatically generated learning heatmap, omitted content already mastered by students, and completed heterogeneous grouping of 4-6 students based on algorithms. The control class only received a text message in WeChat saying, "Please preview page X of the textbook."

(2)In-class Differences: The experimental class restructured the 45-minute class into "10 minutes of situational introduction and task assignment + 20 minutes of group inquiry and 'student lecturer' presentations + 15 minutes of teacher commentary and AI in-class interaction," with students spending about 40% of the time presenting. The control class still focused on teacher-centered theorem proofs and example explanations, with students occasionally answering simple questions.

3.Post-class Differences: Experimental class students logged into the platform to complete the AI-pushed "three-level homework" and could use the AI assistant for questions at any time. Control class students completed unified written exercises from the textbook, which were collected and graded once a week.

4.2 Teaching Outcomes

(1)Significant Improvement in Academic Performance: The final test showed that the average score of the experimental class (78.5) was significantly higher than that of the control class (65.2) ($p < 0.05$), and the proportion of low-scoring students in the experimental class decreased significantly, proving the effectiveness of this path in solidifying foundations.

(2)Enhanced Self-Regulated Learning

Ability: Using a scale for pretest-posttest comparison, the experimental class scored significantly higher than the control class in dimensions such as goal setting and self-monitoring ($p < 0.01$), indicating that the AI-empowered inquiry process effectively promoted the acquisition of learning strategies.

(3)Qualitative Change in Classroom Participation: Classroom observation data showed that the number of voluntary speeches and questions from students in the experimental class was more than three times that of the control class. The "student lecturer" mechanism allowed over 80% of students to gain opportunities to present at the podium.

Feedback after one semester of practice:

(1) Student Feedback: Students in the experimental class generally felt that "AI preview exposes difficulties in advance, so I don't feel lost in class"; "Presenting problems on the podium is stressful, but to explain clearly, I actively look up information, and my understanding is much deeper than before"; "Layered homework means I don't encounter problems I completely can't solve like before, and I feel more accomplished."

(2)Teacher Feedback: The teacher believed that "AI data analysis makes lesson preparation and comment sessions more targeted"; "The 'student lecturer' mechanism forces me to change my role; after returning the classroom to the students, I found that their potential is greatly stimulated." However, the teacher also noted that designing AI study guides and layered resources in the initial stage required a significant investment of time and effort.

5. Conclusion

For mathematics courses in private universities, the teaching reform is needed in the era of AI-empowered education. In this study, we show that the path of the "AI-Empowered Three-Stage Progression" can solve the problem that there is no student subjectivity. Two major conclusions are drawn as follows.

On the one hand, it is the first time that AI integration gives an implementable way to realize the student-centeredness in the scene of large class, with the precise pre-class diagnosis, in-class student lecturer inquiry and post-class intelligent expansion, then the teaching process reconstruction and the student subjectsivity.

Second, the data-driven value-added assessment mechanism makes up for the shortage of the traditional assessment. As the assessment is based on the students' dynamic progress, it makes sense for the teaching adjustment and can protect the confidence of students learning.

Despite the above challenges in promotion and application, the direction of continuous iteration with AI-empowered teaching is an important way that we can utilize the intelligent technology to give fairer, higher quality and more personalized learning experiences for the students of private university.

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