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Research on AI-Empowered Project-based Learning in Middle School Mathematics Based on the Student-centered Concept

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Abstract: ***This paper aims at the problem of insufficient personalized support in traditional middle school students' mathematics learning and constructs an AI-enabled system based on the student-centered concept to provide students with a project-based learning support framework. This framework integrates multiple aspects such as knowledge graph analysis and student situation analysis, forming a dynamic feedback model. Through the design of this learning framework, the students were verified through group experimental teaching. It was verified that the problem-solving ability of the students in the experimental class increased by 23%, and their learning interest increased by 25%. There was a significant difference between the two groups of students. The project model of AI-enabled mathematics learning provides an operational path for the reform of modern middle school mathematics teaching.***

Keywords: Student-centered concept, AI teaching, Mathematics teaching, Project-based learning.

1. INTRODUCTION

The current junior high school mathematics teaching is facing relatively obvious standardization. The contradiction between teaching and individualized demands [1]. Teachers also face many predicaments in the stages of imparting knowledge and cultivating students' abilities. There is also a deep-seated conflict between the limited resources of teachers and providing precise guidance for students. Under the current digital wave, the ecosystem of middle school mathematics teaching is being reshaped by a series of cutting-edge information tools. Emerging AI tools, abundant online mathematics resources, dynamic geometric drawing software, and intelligent learning resource platforms, etc. They provide new ideas for normal school students to design teaching plans, can present abstract mathematical concepts in an intuitive and vivid way, and inspire endless sources of inspiration. In addition, these tools also contribute to achieving more precise and efficient teaching, significantly enhancing teaching effectiveness [2].

2. DEFINITION OF CORE CONCEPTS

The student-centered concept is an educational theory developed around the humanistic concept, which means that teaching should take the cognitive characteristics, emotional states and development needs of learners as the core basis of instructional design. In the selection of projects, students should be given more autonomy, and they should be provided with sufficient opportunities for project reflection and personalized feedback. Project-based learning mainly provides assistance for students' growth by addressing genuine issues and promotes their acquisition of continuous knowledge and ability to solve problems [3]. During the process of mathematics learning, project-based learning enables students to acquire mathematical model codes of different dimensions through cross-cycle mathematical modeling tasks, including mathematical collection, algorithm construction, verification and improvement, at various stages. This research design aims to apply knowledge graphs to recommend mathematical resources through AI-enabled teaching methods, enabling students to combine natural language processing in artificial intelligence algorithms to accumulate and learn knowledge. It also helps teachers conduct visual process evaluation of the entire process, identify key steps, and assist students in handling the key parts, thereby enhancing the pertinence and guidance of teaching.

3. INSTRUCTIONAL DESIGN AND TEACHING PROCESS

3.1 General Information

A total of 120 middle school students from 8 years were selected and grouped by class. There were 60 students in both Class A and Class B.

3.2 Methods

Class B conducts regular project-based learning in mathematics. Teachers assign project-based learning tasks, students prepare project materials, and teachers and students jointly conduct outcome analyses to form post-class summaries and reflections [4].

Class A conducts project-based mathematics learning empowered by AI, fully implementing the student-centered teaching concept. The specific process is as follows:

(1) Project preparation stage: During the project preparation stage, teachers conduct questionnaire tests on students through their own platform systems. The artificial intelligence platform system adopts the project response theory algorithm, which can accurately identify students' knowledge blind spots within a relatively short period of time. After students complete the test, the artificial intelligence engine will automatically generate a three-dimensional knowledge graph, showing the knowledge level that students have mastered. The depth of the color blocks indicates the reaction time of students when answering such questions. For example, when diagnosing the knowledge of quadratic functions, if students take a long time to reflect on the topic-point transformation, it reflects that the students' skill mastery rate is relatively low, and there is a tendency and characteristic of solving problems in a single way. If students can obtain correct answers quickly and consistently in multiple question verifications, it indicates that they have a relatively proficient understanding and mastery of this part. Teachers also, based on the different situations of students and in accordance with the cognitive style of artificial intelligence graphs, have students perform sequential operations in virtual experiments [5]. For instance, by recording the frequency of using Geometer's Sketchpad and the duration of formula derivation, artificial intelligence algorithms can divide classes into different cognitive groups. Based on students' computational preferences, corresponding mathematics learning resources can be pushed to them. Meanwhile, the results of this part of the analysis can also serve as the basis for teachers to group students. Teachers can compare the growth and progress of different students based on the visual reports formed by such cognitive differences, and thereby push relevant resources to students. For students in the basic module, teachers push micro-lessons from Khan Academy to them, record the duration of their feedback, and help those who have difficulty meeting the standards improve their mastery of basic knowledge. For students at the extended level, teachers provide interdisciplinary teaching cases to help them improve their learning level. As for students at the innovative level, teachers will embed tracking learning modules for them to promote their understanding of the related knowledge between different structures.

(2) Implementation stage: Teachers generate dynamic mathematical modeling tasks through the generation mode of artificial intelligence. For instance, teachers can allow students to independently select modules and projects of interest in aspects such as the morning rush hour passenger flow parameters of subways in second-tier cities, statistics of population density, calculation of traffic data, and statistics of epidemic transmission models [6]. They can also obtain complete datasets and variable relationships in the artificial intelligence data system, enabling students to freely switch the complexity of the models. Ensure that students of different levels can all use the mathematical models of artificial intelligence to select the difficulty level that suits them. Meanwhile, these generated real problem scenarios can also be deeply bound to students' life experiences, ensuring that students have a relatively strong interest in learning. Teachers can capture the process of students' handwritten calculation based on the intelligent engine of artificial intelligence algorithms, and effectively identify the key steps in the process of students' handwritten algorithm based on convolutional neural networks. For instance, when identifying derivative symbols, operation symbols, and trigonometric symbols, the system can automatically compare these key steps with the standard path of the knowledge graph. If a student jumps steps in the derivation, they will receive a vibration reminder from the artificial intelligence system. This feedback duration can be shortened by more than 90% compared to the traditional situation where teachers grade homework after class. Meanwhile, students who follow this teaching path can also receive synchronous micro-lessons to assist in deep learning, thereby promoting the in-depth development of students' abilities. In the implementation stage of project-based teaching, teachers, based on artificial intelligence algorithms, transform abstract problems into models of mathematical interaction [7]. For example, when students drag the curve parameters of a function, the 3D curve interface provided by the artificial intelligence interface will show real-time curvature changes. When students automatically prove through geometric proof problems, the artificial intelligence system can provide auxiliary line options for students, improving the success rate of students' problem-solving. Teachers can also apply generative artificial intelligence to build a disciplinary knowledge base for artificial intelligence, helping students automatically answer conceptual questions and operation step questions, and recommending the best modeling toolchain for them. By using this kind of artificial intelligence to build scaffolding resources, simplify the task interface and activate the problem of virtual incentive roles, students' learning enthusiasm can be effectively

enhanced. Meanwhile, teachers can also apply artificial intelligence to generate virtual industry experts to help students solve some interdisciplinary problems.

(3) Teaching Outcome evaluation: In the teaching evaluation stage, teachers use the educational rule data set configured by artificial intelligence to conduct a comprehensive data budget for students' mathematical logic errors, algorithm complexity, code standardization, comment completeness, and exception handling issues. Understand the completion duration curves of different subjects, mark the problem situations that students encounter in the construction of knowledge structure, and conduct a comprehensive analysis of students' academic performance and learning interests.

3.3 Observation Indicators

The learning interest and academic performance of students were statistically analyzed by using the self-made scale of the AI teaching and research group. A score greater than 80 is considered excellent, 60 to 80 is average, and less than 60 is unqualified. Pass rate = (excellent + average)/number of people *100%.

3.4 Statistical Methods

SPSS 21.0 was used as the main software tool for data processing, and t-test was used as the test method for measurement data, expressed as (x±s). X2 is used as the test method for counting data and is expressed as a rate (%). In terms of comprehensive data judgment, $P < 0.05$ was taken as the criterion for judgment and analysis. If it met the criteria, it indicated that the difference was statistically significant.

4. RESULT

The learning interest and academic performance level of students in Class A were higher than those in the control group, and there was a statistically significant difference between the two groups ($P < 0.05$).

Table 1: Comparison of Learning Conditions between the two groups of Students (points, x±s)

Group	academic performance		learning interests	
	Before	after	Before	after
A	16.12±1.79	29.12±1.89	11.29±1.46	31.89±0.16
B	16.12±1.88	18.11±1.67	11.22±1.79	19.66±0.11
t	2.211	14.656	2.656	14.341
P	>0.05	<0.05	>0.05	<0.05

5. TEACHING REFLECTION

5.1 Deficiencies in Teaching

First, the issue of context setting blurring. Some AI algorithms generate situations that deviate from real-life scenarios. The false situations in project-based learning refer to those that do not exist or rarely occur in the real world, and are artificially created to solve the knowledge in books. In such a situation, students find it difficult to devote themselves fully to their studies, fail to organically connect real life with their studies, and lack interest and contextuality. For example, in the teaching of "The Application of Percentages", due to the influence of the teaching progress, students are unable to investigate bank exchange rates in real life. However, if the scenario designed by AI is still one where students conduct investigations in banks, such a scenario would be a false one that is difficult to achieve. In a false context, problems, tasks and activities all lack authenticity and the flavor of life, and students are unable to organically combine their life experiences with the learning content. Obviously, such project-based learning is of low quality [8].

Second, it is overly structured. Well-structured tasks in project-based learning refer to a series of well-defined, monotonous and closed tasks. Such tasks can easily trap students in the shackles of fixed thinking patterns, making it difficult for them to develop higher-order thinking such as critical thinking, creative thinking, problem-solving, and collaborative communication. In project-based learning practices, well-structured tasks enable students to merely mechanically recall and mobilize existing knowledge when solving problems, without in-depth thinking. For example, when students investigate the number of students in a grade, they often make consecutive additions when the number of students in each class is known, thereby grasping the meaning of consecutive additions. Such tasks are monotonous in form, lacking authenticity, complexity and challenge. They are difficult to drive students to engage in exploration, discussion, debate and explanation, and students lack the divergence and collision of thinking.

Thirdly, project knowledge is difficult to internalize. Project-based learning emphasizes learning through application, that is, the process of solving complex problems by using existing knowledge and experience in real situations. It is difficult to achieve a deep understanding of knowledge and a profound construction of the core concepts of a discipline merely by learning without applying or by learning first and then applying. Research related to subject practice shows that only when students personally participate in practice and experience the process of knowledge creation in practice can they transform "learned" into "mastered", and the propositions, facts and theories in books can become truly understood and internalized knowledge.

Fourth, neglecting students' works. In project-based learning, the presentation of works is a crucial link in examining and judging the learning process and results of students. Project-based learning is no longer evaluated through traditional paper-based tests. Instead, it assesses students' comprehensive performance based on their project works according to appropriate evaluation criteria, and determines whether students have achieved the expected learning goals in project-based learning through comprehensive evaluation tools [9]. The research by Jay McTeague et al. shows that students' real performance in tasks or projects can provide evidence for assessing their ability to understand and apply knowledge. It is evident that project works serve as an important medium for students to showcase their self-understanding and construction, self-explanation and reflection. Although the works are silent, their true charm can be demonstrated through students' powerful explanations. Furthermore, silent works can also enable teachers and other audiences to give feedback based on the works, thereby allowing students to receive comprehensive evaluations from multiple perspectives.

5.2 Teaching Optimization Countermeasures

First, expand the algorithm training database and create real scenarios. Real problem situations are the fundamental conditions for carrying out project-based learning and an important prerequisite for learning to move from the shallow level to the deep level. The real situation means that the driving problems and tasks all come from the real world, fully reflecting the comprehensiveness, complexity and challenge of real life. For a long time, there has been an obvious disconnection and disconnection between students' learning and the real world, resulting in a lack of authenticity in learning. The key to helping students get out of the misunderstanding of "fake learning" and allowing genuine learning to truly occur lies in creating real problem situations. Project-based learning is the process of applying disciplinary knowledge to solve open-ended problems in real life. Such an open process enables students to transition knowledge more naturally and understand the necessity of applying experience and transforming experience in real situations.

Second, set real challenges. The real task is the core element for the implementation of project-based learning and provides the "prerequisite" for achieving deep learning. Real learning tasks mean establishing close connections with the real world, presenting challenging situations, aligning with students' experiences and interests, and having products and performances that can be showcased, etc. Authenticity tasks are of great value in cultivating students' higher-order thinking and core literacy. Grant Wiggins and McTegg proposed the GRASPS model from the perspective of designing authentic learning tasks. They believe that the structural elements of real tasks include: realistic goals, meaningful roles for students, target audiences, situations involving practical applications, final works generated by students, and criteria for judging success. Based on this model, students, on the basis of understanding, carry out in-depth thinking and complete real, clear and challenging learning tasks.

Third, guide students to solve problems wholeheartedly. Problem-driven is the core feature of project-based learning. Students need to fully participate in the process of problem-solving to develop higher-order thinking and core literacy. Project-based learning begins with a problem of authenticity that needs to be solved, which is called the driving problem and is an inevitable requirement for promoting the learning process. The issues discussed here do not refer to those that are closed and well-structured, but rather those that are complex and genuine and have poor structures. Such problems often have no fixed standard answers and are open-ended, requiring students to mobilize their existing knowledge and experience to solve them in real situations. During this process, students usually study in the form of group cooperation. Members within the group have their own roles and divisions of labor, thinking and acting like subject experts. Drive students through the process of finding data, organizing data, analyzing data, generating solutions, and implementing verification, thereby cultivating students' critical thinking, creative thinking, and applying knowledge to solve problems and other higher-order thinking and skills [10].

Fourth, display students' works from multiple dimensions. Project-based learning emphasizes the public display of project works, a feature that is both attractive and challenging for students. The display of learning works can take various forms, including work presentation, speeches, explanations, etc. Through the display of their works, students can fully demonstrate their thoughts and ideas in the process of solving problems and completing tasks, and show their own understanding and thinking. This stage can cultivate students' core competencies such as mastering the content of core disciplines, critical thinking and solving complex problems, collaborative cooperation, effective communication, learning to learn, and developing academic thinking. Therefore, in the specific practice of project-based learning, teachers should attach importance to the display of students' works and conduct a comprehensive and objective evaluation of it. When students present their works to others and provide further explanations during the learning process, it is an experiential process of deep understanding and description. The process of presenting works is not only a symbol of the aggregation and application of knowledge, but also reflects the new transformation of learning methods from traditional passive acceptance to active learning. Teachers can conduct a comprehensive assessment of students' performance through long-term and site-specific observations, thereby forming more genuine, accurate and reliable learning evaluations. In the "Little Financial Planner" case, students held a class presentation and introduced their financial plans to the audience in groups. This activity not only offers students the opportunity to showcase their ideas, viewpoints and thinking, but also provides evidence for teachers and students to conduct a comprehensive and integrated evaluation.

6. CONCLUSION

In conclusion, this study successfully adopted the process of project-based learning through AI technology, guiding students to obtain the zone of proximal development through an adaptive learning system to capture students' learning setbacks and enhance the accuracy of student guidance. Project-based learning that integrates AI technology can further enhance students' mathematics academic performance, improve their mathematics learning level, increase their interest in mathematics learning, and promote the development of their thinking towards higher-order dimensions.

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