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Design and Application of Project-Based Learning Based on Generative Artificial Intelligence

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Abstract. In the era of artificial intelligence, the integration of generative artificial intelligence (GAI) technology with project-based learning (PBL) provides new opportunities for educational practices. Under the perspective of intelligent technology empowering PBL, this study addresses the practical issues in PBL by proposing a shift in learning objectives, themes, contexts, and evaluations. By leveraging the advantages of intelligent technology, high-quality PBL design can be achieved. This research constructs a practical pathway for PBL based on GAI, encompassing three stages: pre-class, in-class, and post-class, with specific applications of human-machine integration. The results indicate that GAI can effectively improve the quality and efficiency of project-based learning by providing systematic intelligent technical support in project-based learning, and realize the collaborative development of "teacher-machine-student".

Keywords: Generative Artificial Intelligence; Project-Based Learning; Instructional Design; Technology Empowerment.

1. Introduction

Under the wave of the artificial intelligence era, generative artificial intelligence (GAI) brings new opportunities and challenges to educational transformation. The "AI + Education" model has gradually become a new trend in the development of the educational field. As an advanced machine learning technology, GAI, with its powerful information processing, content generation, interaction capabilities, and flexibility, demonstrates significant advantages in educational scenarios such as intelligent analysis and feedback, adaptive learning, and personalized recommendations, providing new opportunities for teaching innovation. The effective combination of generative artificial intelligence and the in-depth conduct of project-based learning are the common requirements for the transformation of the education system and social development in the intelligent era.

PBL, as an important learning method for cultivating students' inquiry thinking, promoting deep learning, and fostering intelligent literacy, It is imperative to align with the trends of the intelligent era and leverage the capabilities of intelligent technologies to advance the application and innovation of pedagogical practices. However, there are many problems, such as teachers' lack of systematic understanding of knowledge system, students' one-sided evaluation, lack of targeted strategies, and low efficiency of teaching effect input currently.[1]Whether it is pre-class resource integration, in-class problem exploration, post-class reflection and evaluation,a large amount of data resources is indispensable. In order to solve these problems, generative artificial intelligence is introduced to provide teaching resources for activity design through its massive data repository. Its generative content can provide support for personalized learning;and finally generate information that meets user needs from the information base. Based on this, it is essential to utilize GAI to empower all aspects of PBL.

2. Research Background

Currently, the empowerment of teaching by intelligent technology has become an important trend in educational development, prompting a shift in PBL design from traditional instructional design to information-based instructional design and now to intelligent instructional design. [2]Among these, GAI-empowered teaching aims to promote students' higher-order thinking and

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intelligent literacy. [3]By leveraging its intelligent technical support, it facilitates the construction of diverse scenarios and personalized cultivation of learners.

GAI leveraging rich resources to enhance real-time interaction with students, thereby unleashing students' intelligent thinking and optimizing teaching. In teaching practice, how to transform teaching concepts, design project-driven problems, effectively integrate GAI technology to boost teaching, and find a balance between "technology empowerment" and "humanistic education" have become urgent issues. This paper will discuss the conceptual transformation of GAI-empowered PBL from four elements: learning objectives, learning themes, learning contexts, and learning evaluations.

2.1 Learning Objectives: From Knowledge Construction to Literacy Cultivation

Learning objectives are the key link guiding project activities, providing direction and criteria for the effective implementation of project activities, and serving as the basis for project evaluation. GAI-empowered PBL requires students to efficiently acquire knowledge through human-machine interaction with intelligent technology, enriching their personal knowledge maps, thereby enhancing their comprehensive abilities and intelligent literacy. Therefore, the learning objectives are elevated to the spiral development of knowledge thinking, promoting literacy leaps, enabling students to truly achieve "generative learning."[4]

2.2 Learning Themes: From Knowledge Explanation to Activity Exploration

PBL's learning themes and contexts should be close to students' real-life situations. By using AI models to construct scenario-based learning themes for students, providing resource, activity, and evaluation support, students can master the correct methods of using large language models through human-machine interaction and practical exploration events, achieving efficient human-machine collaboration; helping students internalize knowledge, advance thinking, and enhance literacy.

2.3 Learning Contexts:From Classroom Activities to Multi-Dimensional Contexts

PBL requires students to learn and explore in authentic and contextual learning scenarios. [5]GAI can generate multi-modal data, interact with users in real-time, summarize content and knowledge points, propose countermeasures and suggestions, etc. Teachers can fully utilize intelligent technology, leveraging AI's multi-dimensional learning scaffolding functions to design multi-dimensional learning activities, construct authentic learning contexts suitable for students, and provide intelligent technical support for students' literacy enhancement. Students, relying on the learning scaffolds built by teachers, frequently interact with GAI in real-time, absorbing knowledge and achieving thinking leaps.

2.4 Learning Evaluation: From Single Absolute to Multiple Inspirational

Traditional teaching evaluations are relatively single-dimensional and absolute, mostly focusing on standardized tests of knowledge points, reflecting knowledge mastery levels, with little attention to students' literacy enhancement. The learning evaluation in the digital intelligence era should focus on intelligent literacy, covering multiple dimensions such as knowledge, ability, thinking, application, and attitude, emphasizing the process and diversity of evaluation. [6]GAI can generate multi-modal qualitative data based on user's input, provide personalized recommendations and evaluations, and output high-quality results. [7]At the same time, teachers can use data information to inspire multi-dimensional intelligent performance evaluations of students' learning.

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3. Research Process

3.1 Research Concept

Under the perspective of AI-empowered project-based teaching, from the curriculum and teaching aspects, AI can serve as an intelligent partner for teachers. On one hand, as a guide for PBL, teachers can ask GAI models questions before class to obtain content suggestions, organizational strategies, project cases, and evaluation implementations for current project teaching, thereby helping teachers break through their knowledge limitations,improve project design and teaching research capabilities. On the other hand, as a teaching expert, GAI, with its vast knowledge repository, efficient information retrieval, and intelligent analysis capabilities, provides teachers with rich teaching resources, expands and updates knowledge reserves, and helps teachers integrate across disciplines. [8]Additionally, as a technical supporter, GAI has powerful content generation capabilities, providing real-time feedback to students through intelligent dialogues and virtual experiences, helping teachers adjust teaching strategies promptly and enhance teaching capabilities.[9]

3.2 Research Design

This study adopts design-based research methods and experimental research methods, designing a GAI-empowered PBL activity framework, applying it to actual teaching, and finally measuring the effectiveness of students' project learning activities to test its validity. This study draws on the basic framework of the GAI-integrated teaching model based on self-organized learning environments constructed by Zhu Sha and other scholars, [10]constructing a three-stage learning activity implementation path for GAI-empowered PBL from the teacher and student ends: pre-class human-machine interaction initiation guidance, in-class human-machine collaborative knowledge internalization, and post-class human-machine integration consolidation and enhancement, thereby designing project learning activities and combining them with specific cases to effectively implement PBL activities. The specific activity design framework is shown in Figure 1.

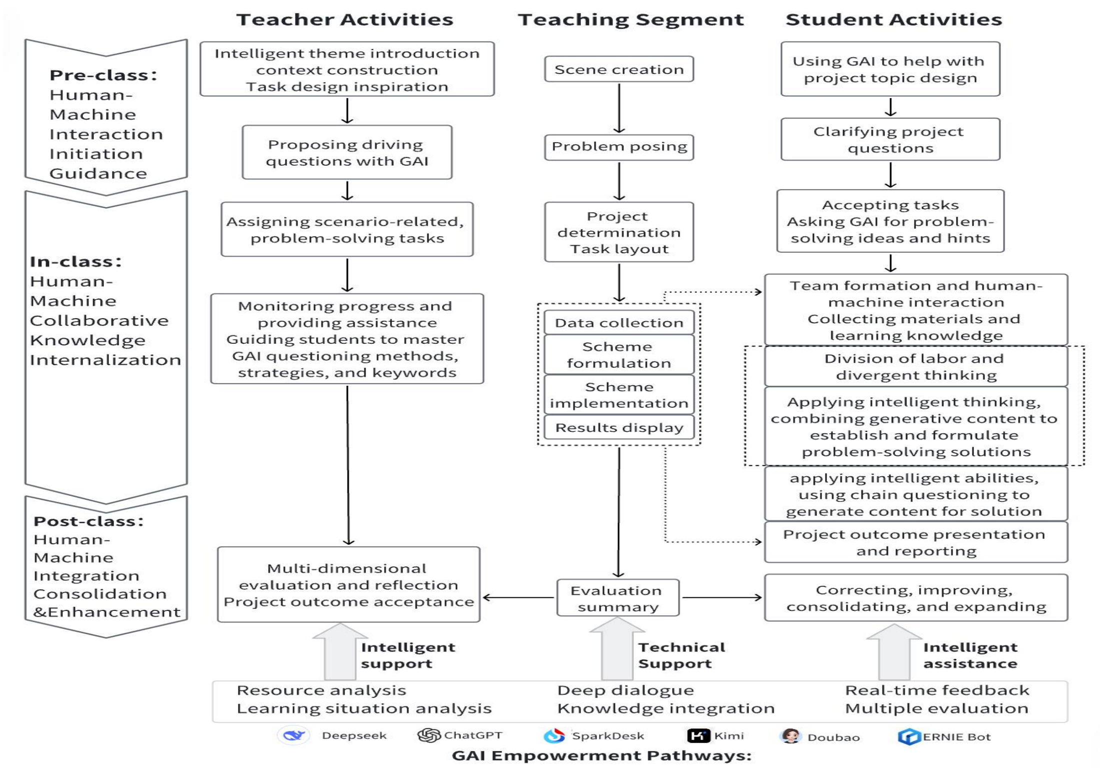

Fig.1GAI-Empowered PBL Activity Design

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First, the experimental students were divided into six groups, and their pre-existing computational thinking and learning effectiveness were assessed. This study draws on the project learning effectiveness evaluation scale developed by Zhang Xuejun and others, [11]including five dimensions: challenging problems, continuous inquiry, product creation, learning support, and reflective improvement. The pre-test results are shown in Table 1:

Table 1.Pre-test of PBL Evaluation

Group	Challenging Problems	Continuous Inquiry	Product Creation	Learning Support	Reflective Improvement	Total Level
①	10	7	6	6	9	Average
②	9	8	8	6	8	Average
③	8	7	7	5	6	Average
④	10	6	6	5	7	Average
⑤	9	6	5	4	7	Average
⑥	10	8	7	7	7	Average
Note:Computational thinking level assessment: High: 12.1-15; Relatively high: 9.1-12; Average: 6.1-9; Relatively low: 3.1-6; Low: 0-3 Project level assessment: High: 53.1-66; Relatively high: 39.1-53; Average: 25.1-39; Relatively low: 13.1-25; Low: 0-13						

The statistical data analysis shows that students generally fall within the average range, with lower scores in the learning support dimension, particularly in peer collaboration, technical tools, and extended resources, indicating a lack of ability in using technology to expand learning resources and assist in problem-solving.

3.3 Pre-class: Human-Machine Interaction Initiation Guidance

The pre-class phase is the preparation stage for teaching, where teachers guide students to actively explore and think. In this stage, teachers use GAI's powerful data collection and content generation functions to present personalized learning resources closely related to the learning theme and recommend them to students through big data, thereby inspiring students to think and guiding them in problem exploration.

This project takes "designing a tissue box using 3D One" as an example, the focus of the project is to require students to design a beautiful, practical, and multifunctional unique tissue box based on the 3D One platform. Teachers and students can use the AI tools shown in Figure 1 to research relevant information for the project. For example, by inputting related questions in Deepseek as shown in Table 2, targeted answers as shown in Figure 2 can be obtained, presenting comprehensive information that can provide different answers based on user constraints. The same question asked in different ways may yield different answers. Therefore, through a series of questions, suggestions for project topic selection can be provided, stimulating students' innovative thinking and problem-solving abilities, which is innovative and practical.

Table 2.Deepseek-Based Question Design

No.	Question	Intent
1	What are the key points to consider when designing a tissue box?	Designing a tissue box using 3D One
2	What features should a tissue box designed with 3D One have?	
3	How should a tissue box be constructed using 3D One?	

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Fig. 2Deepseek-Based Q&A Retrieval Results

All in all, in this project, students can obtain knowledge points from various disciplines through pre-class Q&A with GAI tools, efficiently integrating database resources related to the theme. This allows students to quickly acquire rich background knowledge, subject knowledge, design ideas, and innovative thoughts, saving project preparation time and improving project implementation efficiency. Additionally, during human-machine interaction, through chain questioning, the generated content and GAI collaborative interaction can jointly discover and propose problems.

3.4 In-class: Human-Machine Collaborative Knowledge Internalization

The in-class phase is the key stage of project learning activities, where students independently explore, innovate, and solve problems. Teachers guide students in human-machine collaboration and project implementation, students are the practitioners of the activities, and GAI tools support the entire project learning process.[12]

In this stage, teachers use the driving questions generated by GAI to clarify project tasks for students.Teachers should guide students to engage in deep, continuous dialogues with GAI tools, obtaining more suitable answers through follow-up questions.Each group fully utilizes GAI to quickly generate multiple sketch solutions from practical, innovative, technical, and cultural dimensions, providing rich materials for subsequent in-depth design.

By determining the project plan and implementing learning tasks, students are expected to master basic knowledge of 3D One drawing, some tool functions, and operational skills, cultivating their aesthetic creativity and information extraction and application abilities.Teachers use GAI technology to analyze students' performance, understand their interests and thoughts, and thus propose core questions, promoting students' internalization of knowledge. At the same time, students should master basic operational knowledge and fundamental usage functions of 3D One during the design,the 3D One knowledge related to construction steps generated by GAI is shown in Figure 3.

Fig. 3 GAI-Generated Project-Related Knowledge

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3.5 Post-class: Human-Machine Integration Consolidation and Enhancement

The post-class phase is an important stage for consolidating, expanding, reflecting, and optimizing PBL. Teachers and students generate detailed project data reports, slides, charts, design plans, and other results using GAI tools based on project outcome requirements. In this stage, teachers use intelligent tools to conduct multi-dimensional and diverse evaluations of students' project works, including summarizing and analyzing students' learning processes, and generating personalized post-class extension projects for each student based on learning situation analysis, guiding students to transfer and apply their knowledge. GAI, relying on its powerful data screening and analysis capabilities, analyzes project-related data and generates detailed evaluation reports, helping teachers comprehensively grasp students' performance during project implementation, thereby conducting iterative evaluations of students. Students, based on the extended projects supplemented by teachers, collaborate with GAI to complete project tasks. During the process of discussing and solving problems with GAI, students can receive real-time personalized feedback and suggestions, consolidating and deepening their knowledge, enhancing learning effectiveness, and ultimately achieving the effect of "smarter machines, wiser students."[13]

In summary, GAI tools run through the entire project activity, collecting and obtaining data information from students, teachers, the internet, industry experts, and external feedback, integrating and optimizing the retrieved results, providing comprehensive evaluation results, reflecting the integrity of the entire project learning activity, and ensuring the comprehensiveness and diversity of evaluations. Finally, based on self-evaluation results and suggestions, understanding each student's personalized performance helps students continuously improve in future PBL.

4. Research Results

4.1 Project Implementation Results Analysis

Through the implementation of PBL activities in the pre-class, in-class, and post-class stages in the experimental class, students not only completed project works but also mastered GAI-related technologies and subject knowledge during the process, achieving good learning outcomes. The computational thinking and project implementation effectiveness of the six groups in the class were re-tested, and the learning situation of each group was statistically analyzed. The results are shown in Table 3:

Table 3.Post-test of PBL Evaluation

Group	Challenging Problems	Continuous Inquiry	Product Creation	Learning Support	Reflective Improvement	Total Level
①	13	11	11	12	13	High
②	10	10	12	9	10	Relatively High
③	11	10	10	11	11	Relatively High
④	14	12	12	10	14	High
⑤	15	11	12	10	13	High
⑥	14	12	9	11	12	High

The post-test results show that the project level assessment and students' computational thinking of each group are at a relatively high to high level. Compared with the pre-test conducted at the beginning of the project activities, each group's five-dimensional indicators have significantly improved, indicating that the implementation effect of GAI-empowered PBL activities is good, with high project completion, effectively cultivating students' thinking and enhancing multi-dimensional abilities. At the same time, students' scores in challenging problems, product creation, and learning support have significantly improved, indicating that students have good external performance in knowledge construction, tool application, and work innovation, with good peer collaboration and human-machine collaboration abilities.

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The project works of each group were also displayed and scored, and the scoring situation of each group is shown in Table 4:

Table 4.Total Scores of Each Group

Group	Total Score
①	8+8+7+8+9+9=49
②	7+8+6+7+8+8=44
③	7+8+6+9+7+9=46
④	8+9+6+7+8+7=45
⑤	7+7+8+7+8+8=45
⑥	8+7+7+8+8+9=47
Note：Evaluation dimensions include: design, functional practicality, aesthetic innovation, model completeness, teamwork, and technical support. The evaluation range is 0-10, with a total score of 60.	

From the table analysis, it can be seen that students' works in GAI-empowered PBL have a high completion rate and meet the standards. Especially in the fifth dimension of technical support, each group generally scores high, indicating that in the process of completing the works, intelligent technology can be fully applied to improve and optimize work details, mastering the correct usage methods.

4.2 Teacher and Student Interview Results Analysis

After class, random interviews were conducted with the teacher and participating students. The teacher indicated that using GAI in the teaching process for instructional design, helping to construct intelligent teaching contexts, improving student enthusiasm, and providing targeted teaching strategies have shown significant advantages; students expressed that using GAI can provide innovative ideas and suggestions, enrich their knowledge reserves, and provide personalized recommendations, effectively improving learning effectiveness and efficiency.

Based on the above results analysis, this study proves through the pre- and post-test implementation of project activity design and teacher-student interview summaries that, on one hand, this design can effectively enhance students' ability to use intelligent thinking to solve problems and achieve human-machine collaboration; on the other hand, the application of GAI can make the project teaching process more intelligent and rich, providing strong technical support and guidance for teachers and students.

5. Conclusion

The accelerated development of educational digital transformation promotes the empowerment of GAI technology in primary and secondary school PBL practices, providing new paths for cultivating future talents with intelligent literacy, innovative thinking, and high-order abilities. Using GAI for PBL instructional design, implementation, and evaluation, as an intelligent assistant providing intelligent support and technical support, can not only make teaching links more intelligent, systematic, and rich but also provide teachers with implementation strategies and suggestions for teaching projects and provide students with targeted measures and personalized learning paths.

In the future, with the continuous development of intelligent technology and the continuous updating of educational concepts, the application prospects of GAI in education and teaching will be broader and deeper, expected to promote multi-disciplinary integrated teaching and promote teaching model innovation and education quality improvement.

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