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# Implementation Challenges of Artificial Intelligence-Empowered Project-Based Learning in Compulsory Education

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## Abstract

With the rapid development of generative artificial intelligence, new possibilities have emerged for addressing problems in project-based learning at the compulsory education stage, such as insufficient teacher guidance resources and inadequate personalized support for students. Based on literature research, this paper analyzes the implementation challenges faced by artificial intelligence-empowered project-based learning from the dual perspectives of teachers and students. The study finds that, at the teacher level, there are three types of problems: superficial AI application, generalized technology embedding, and fragmented instructional design. At the student level, there are difficulties such as the substitution of the inquiry process, interference with learning engagement, and compression of the space for collaborative construction. In response to these problems, this paper proposes optimization strategies, including promoting subject-differentiated technical support, designing structured collaborative learning sheets, improving the formative evaluation system, and enhancing teachers' AI literacy, with a view to providing references for the deep integration of artificial intelligence and project-based learning in compulsory education.

## Keywords

project-based learning, artificial intelligence, compulsory education, implementation challenges

## 1. Introduction

### 1.1 Research Background

With the full implementation of the Compulsory Education Curriculum Plan and Curriculum Standards (2022 Edition), project-based learning has become an important means of carrying out interdisciplinary thematic learning and cultivating students' core competencies, and its key position has become increasingly prominent. However, in the process of normalized implementation, project-based learning still faces practical difficulties, including insufficient teacher guidance and a lack of personalized learning scaffolds for students. Against this background, the development of generative artificial intelligence represented by ChatGPT provides an important opportunity to address the above bottlenecks [1]. Relying on its advantages in intelligence and personalization, artificial intelligence creates new possibilities for optimizing project-based learning. However, the deep integration of emerging technologies and complex teaching fields cannot be achieved overnight. How AI can help teachers carry out project design, how it can support students in deep



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inquiry, and how it can truly become teachers' thinking partner and students' intelligent learning companion remain important issues that urgently need clarification.

### 1.2 Literature Review

Project-based learning is a teaching model that starts from authentic driving questions and guides students to master core knowledge and develop higher-order thinking and disciplinary literacy through sustained inquiry, collaborative construction, and revision of outcomes. Its theoretical foundation is rooted in Dewey's educational idea of learning by doing, constructivist learning theory, and situated cognition theory.

At present, the academic community is actively exploring the integration path of artificial intelligence and project-based learning. At the level of general theoretical mechanisms, existing studies have explored the possibility of embedding educational agents into key links of project-based learning [2] and have constructed a general model of interdisciplinary project-based learning [3], providing theoretical support for demonstrating the rationality of technology empowerment. At the level of units and subject practice, some scholars have clarified the logical mechanism by which generative artificial intelligence precisely empowers unit-based project-based learning [4], and other researchers have taken science project-based learning as an example to demonstrate the practical value of technology in optimizing subject inquiry teaching [5]. At the same time, the construction of project-based learning teaching models for specific subjects such as mathematics [6], as well as the actual effects of promoting classroom change and improving competencies through specific practice scenarios [7], have also been preliminarily verified. These multi-dimensional explorations fully confirm the practical feasibility of integrating intelligent technology into project-based learning. However, a review of existing literature shows that current research mostly remains at the level of idealized logical deduction of technology empowerment or summary of local successful experiences. When artificial intelligence is fully connected with daily teaching at the compulsory education stage, the practical resistance and implementation difficulties it faces in a real and complex teaching ecology have not yet been systematically and deeply analyzed in the existing literature.

### 1.3 Research Issues

Based on the practical problems that urgently need to be solved, this study proceeds from the dual dimensions of teachers and students, focuses on the implementation problems faced by artificial intelligence-empowered project-based learning in real teaching fields, and constructs optimization strategies on this basis. It aims to provide theoretical basis and action guidance for frontline primary and secondary school teachers to apply artificial intelligence rationally and deeply in project-based learning.

## 2. Main Problems in the Integration of Artificial Intelligence into Project-Based Learning Design

### 2.1 Superficial AI Application

The essence of project-based learning is to guide students to experience a complete process of sustained inquiry, problem solving, and outcome construction in authentic problem situations, and ultimately to cultivate critical thinking, collaboration ability, and disciplinary core competencies. It is not a simple superposition of single activities, but a long-cycle deep learning process that covers multiple links, including project initiation, inquiry implementation, outcome production, presentation, and reflection. It requires teachers to comprehensively use strategies such as scaffold building, process monitoring, and collaborative organization to guide students to inquire gradually and deeply along a chain of questions.

However, when teachers currently introduce artificial intelligence, most of them stop at the stage of situational introduction, deviating from the core essence of sustained inquiry in project-based learning. Teachers often take technical functions as the logical starting point and are more inclined to use AI to complete peripheral auxiliary tasks such as instructional design and generation of situational materials, while neglecting attention to the disciplinary essence of project-based learning [5]. Most teachers have not deeply considered how to use AI to support students' disciplinary thinking training and evidence-based reasoning ability in project inquiry, such as how to use AI to simulate experimental variables and analyze experimental data in science project-based learning. Most teachers only allow AI to remain in the project initiation stage,



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responsible for generating interesting contexts and introducing inquiry themes. In later core links, such as the advancement of sustained inquiry and the iteration of problem solving, they rarely further use AI to build personalized thinking scaffolds or decompose complex inquiry tasks. Even when some teachers attempt to introduce AI into the inquiry process, they often directly use general-purpose large language models, regarding them as standardized tools that can be grafted onto any subject and any link. They apply the fixed procedure of "AI generates a plan - students screen and revise it - outcomes are presented" without targeted adaptation to the thinking paths of project inquiry in different disciplines. This superficial mode of AI application appears to inject artificial intelligence elements into project-based learning, but in fact it does not truly exert AI's supporting role in deep inquiry and deviates from the essential requirement of project-based learning to cultivate core competencies through complete problem solving.

## 2.2 Generalized Technology Embedding

The current feature of "technology generalization" in artificial intelligence-empowered project-based learning stems not only from teachers' simplified tendency in tool selection, but also from the generation logic of current general-purpose large language models. Generative artificial intelligence represented by ChatGPT mainly relies on large-scale corpora for pre-training and generates language content with a high probability by analyzing the input context, thereby forming strong cross-task and cross-domain transfer abilities [8]. This general generation mechanism allows the model to respond to questions in different subjects, such as science, Chinese, and mathematics, through similar interaction modes. However, its "generality" does not mean that it truly understands the knowledge structures, inquiry paradigms, and cognitive goals of different disciplines.

In project-based learning, different disciplines have obviously differentiated thinking paths. However, general-purpose large language models often tend to directly generate relatively complete answers, plans, or texts according to natural language instructions, and they easily transform project tasks in different disciplines into similar "questioning - generation - revision" processes. When teachers use general-purpose large language models as unified project inquiry tools, AI may cover the cognitive processes of different disciplines with the same generation logic, causing inquiry activities that should reflect disciplinary specificity to be homogenized by the technological framework.

A deeper problem lies in the obvious insufficiency in the development of specialized large language models for project-based learning in compulsory education. The training goal of general-purpose models is to form broad language understanding and generation abilities, and they have not been deeply optimized for the curriculum standards, textbook systems, core competencies, and student cognitive characteristics of specific disciplines. Existing studies have pointed out that, after general-purpose large language models enter professional fields, they need to be further adapted to domain knowledge, data, task objectives, and specific application norms. Relying solely on general-purpose models makes it difficult to fully meet the needs of specialized applications [9].

Therefore, the essence of generalized technology embedding is not simply "one tool applied to multiple disciplines", but the mismatch between the generation logic of general-purpose large language models and the logic of project-based learning that respects disciplinary differences. Models pursue the rapid generation of complete content, while project-based learning emphasizes that students should experience the complete cognitive process of question posing, evidence collection, reasoning and argumentation, trial-and-error revision, and outcome iteration. If models and tool designs that fit disciplinary characteristics are lacking, the standard answers, experimental plans, or textual paradigms generated by AI may prematurely cover the thinking process that students should independently experience. This eventually causes project inquiry in different disciplines to become homogeneous and weakens the value of disciplinary thinking cultivation that project-based learning should possess.

## 2.3 Fragmented Instructional Design

In project-based learning, students' originally coherent inquiry process is divided into isolated technical nodes. Project-based learning requires long-cycle and coherent design of inquiry activities, but teachers' application of AI shows a fragmented feature. AI is used only in isolated ways in different links, such as generating videos, conducting instant question answering, and producing presentation materials. AI is scattered into multiple independent nodes of the project. For example, AI may be used to generate a question wall at the



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beginning of the course, to complete one information summary in the data collection link, and then to polish the outcome report at the conclusion stage. Such use lacks an integrated architecture that runs through the whole process of "initiation - inquiry - evaluation - improvement" [2]. The consequence of this application mode is that the project inquiry process, which originally requires students to gradually construct and repeatedly iterate, is cut into several disconnected "technical highlight" fragments, making it difficult for students to form a coherent learning experience. If teachers cannot plan AI intervention points in an orderly way along the complete chain of driving-question decomposition, inquiry milestone evaluation, and outcome iteration and upgrading, technology empowerment can only play a partial role in isolated links and cannot support the complete context of deep learning.

## 3. Problems in Artificial Intelligence-Assisted Student Participation in Project-Based Learning

### 3.1 The Inquiry Process is Substituted

In links such as data collection, phenomenon analysis, and viewpoint refinement in project-based learning, students are very likely to form cognitive dependence. When facing complex driving questions, they skip cognitive labor such as information retrieval, cross-verification, and inductive reasoning, and directly ask AI for conclusions or even complete project reports, while tending to accept them wholesale. Understanding that should gradually grow through field observation, experimental records, and group reflection is simplified into thin question-and-answer interaction. In this process, students lack awareness of distinguishing truth from falsehood, examining logic, and judging value positions in the information provided by AI, and the subjectivity of inquiry gives way to algorithmic recommendation. At the same time, frequent question-and-answer interaction with AI fragments the block time in which students could have been immersed in plan iteration. As a result, the final project outcome appears complete but lacks solid thinking traces and cognitive progression. This "thinking sprint" causes students' deep problem-solving ability to stagnate. Once separated from the direct answer output of AI, students find it difficult to independently conduct reasoning, argumentation, and viewpoint creation in project advancement, which completely deviates from the original intention of project-based learning to cultivate critical thinking and discernment [10].

### 3.2 Sustained Engagement is Interfered With

Project-based learning requires students to maintain coherent cognitive engagement for several weeks or even longer, but the multi-source information and dialogic interaction forms in AI learning environments can create strong interference. When students use tablets, computers, and other devices to conduct project research or plan design, applications such as short videos, online games, and social media easily form strong temptations, pulling students' attention away from rigorous inquiry processes. Frequent task switching cuts the block time that could originally be used for deep thinking into scattered fragments. Students often stop at a superficial level at key inquiry nodes and find it difficult to enter a sustained state of "deep work".

At the same time, the interaction mode of instant AI question answering may also reinforce the learning habit of rapidly obtaining information. Traditional project inquiry requires students to experience a continuous process of "retrieval - screening - comparison - judgment - integration", while generative AI can directly provide organized answers. This makes it easier for students to ask questions frequently, obtain information quickly, and ask again, thereby weakening sustained thinking on a single problem. Studies on secondary school students have found that students may experience relatively high cognitive load when using ChatGPT to complete learning tasks. Researchers therefore emphasize the need to control cognitive burden in the process of AI use through reasonable instructional design and scaffolding [11]. The attention shift and cognitive burden jointly caused by the multi-task learning environment and interaction forms ultimately lead to project outcomes that lack solid thinking traces and cognitive progression.

### 3.3 Collaborative Construction is Compressed

The core social construction mechanism of project-based learning lies in the collision of ideas, negotiated argumentation, and collective reflection among teachers and students and among students themselves. However, when students rely excessively on individual dialogue with AI, social interaction within project



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groups sharply decreases [12]. Members face screens separately to ask AI for answers or revision suggestions, instead of jointly sorting out solution paths. Isolated individualized operations lead to the loss of the core of collaborative learning, including the generation of shared knowledge, the exposure of misunderstandings, and the integration of viewpoints in the project. At the same time, teacher-student interaction is weakened to the same degree. As inquiry guides, teachers originally need to capture cognitive conflicts in group discussions and provide timely guidance. However, in the human-machine dialogue mode, students' confusion and thinking are retained in individual interaction with AI, causing teachers to lose key opportunities for diagnosis and intervention, and making their guiding role hollowed out. In the long run, the social construction and interactive learning on which project-based learning relies will lose their foundation, and educators' role positioning in this technological wave will also be marginalized [13].

## 4. Optimization Strategies for Artificial Intelligence-Empowered Project-Based Learning

### 4.1 Explore Subject-Differentiated Technical Means for AI-Supported Project-Based Learning

To resolve the difficulties of superficial application and technology generalization, project-based learning must return to its disciplinary foundation. This requires that AI intervention should not pursue a grand technical solution with complete functions and full-process coverage. Instead, it should start from the most critical and subtle cognitive nodes in disciplinary inquiry, replacing complex stacked functions with concise and appropriate technical support. In this way, seemingly small tool designs can gradually accumulate and amplify their teaching value in sustained inquiry, thereby supporting the deep thinking process required by long-cycle and complex disciplinary practice [5]. Starting from subject attributes, AI intervention plans should be customized for projects in different disciplines. Science projects can embed AI assistants for simulated experiments and abnormal data analysis, allowing students to interact and iterate with AI in hypothesis testing. Humanities projects can design AI text comparison and multi-role argumentation scaffolds, prompting students to deepen understanding through exchanges of viewpoints. Technical functions must be simplified and closely connected with the core cognitive nodes of disciplinary inquiry, rather than attempting to take over everything, so that AI can truly become an internal element that supports the thinking flow of long-cycle and complex disciplinary practice.

### 4.2 Design Structured Collaborative Learning Sheets to Guide AI-Collaborative Thinking

To reverse students' cognitive dependence and strengthen collaborative interaction, teachers should design structured collaborative learning sheets around key nodes of project inquiry, with teachers building frameworks in advance and dynamically adjusting them according to students' actual inquiry situations. Learning sheets should not be merely task lists. Instead, they should transform "independent thinking - group discussion - AI intervention - verification and revision - reflection and summary" into a clear process and define the boundaries of AI use at different stages. In the initiation stage, columns such as "existing understanding - question posing - preliminary hypothesis" can be set, requiring students to think independently and discuss collaboratively before using AI to expand their ideas. In the inquiry stage, "information sources - AI suggestions - group judgment - verification results" can be recorded, requiring students to cross-verify AI information. In the outcome stage, content such as "original plan - AI suggestions - group discussion - final revision" can clarify that AI mainly undertakes the functions of suggestion and feedback rather than directly generating final outcomes [10].

At the same time, learning sheets should be completed mainly by groups, and reflective questions such as "whether to accept AI suggestions" and "what the basis is" should be set so that AI output returns to group negotiation. Through cognitive steps preset by teachers, students can be prevented from directly asking for answers while the advantages of AI in providing multiple viewpoints and immediate feedback can be retained. In this way, technology use is re-embedded in student-student interaction and collective construction.



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### 4.3 Construct a Formative Evaluation Mechanism to Ensure the Coherence of Project-Based Learning

In view of fragmented instructional design and students' cognitive dependence, it is necessary to construct a formative evaluation system based on key nodes of project inquiry and to run AI intervention through the whole project process. Teachers can use AI to record process evidence, such as students' question decomposition, draft generation, peer feedback, and plan iteration around links including question posing, data collection, plan design, and outcome revision, forming a continuous learning trajectory. AI is responsible for collecting and organizing process data, while teachers make professional judgments, forming a collaborative model of "AI collection - teacher evaluation - student reflection" [2]. When the system finds that students frequently rely on AI to generate answers or remain stagnant in a certain link for a long time, teachers can intervene promptly and provide targeted scaffolding.

This formative evaluation can prevent final outcomes from concealing students' insufficient real inquiry and can prompt students to realize that AI output needs to be judged, verified, and revised, thereby reducing cognitive dependence. At the same time, incorporating group discussion, peer feedback, and plan iteration into the evaluation process helps maintain students' sustained engagement with core problems. Therefore, AI is no longer only a tool for improving task completion efficiency, but becomes an auxiliary mechanism for teachers to diagnose the learning process and for students to carry out self-monitoring. While controlling the negative impact of technology, it promotes the development of students' critical thinking, self-regulation, and cooperation abilities.

### 4.4 Enhance Teachers' AI Literacy and Build a New Classroom Order of Human-Machine Collaboration

Problems such as attention distraction and weakened collaboration cannot be addressed solely through technical restrictions. They require active construction at the levels of teacher literacy and classroom order. AI application competence should be incorporated into special training for project-based teaching, guiding teachers to select appropriate AI tools according to project types and subject characteristics [14]. This can help teachers learn to judge which inquiry links require "AI withdrawal" to preserve necessary cognitive friction and which links are suitable for introducing AI as a thinking accelerator. At the same time, teachers and students should be guided to jointly formulate conventions for AI use, clarify the boundaries and degree of AI use in each project link, and cultivate students' technical self-discipline and awareness of information ethics [12]. At the classroom level, norms for time-divided and task-divided AI intervention and rules for group shared-screen collaboration should be established, promoting the transformation of technology use from individual arbitrary behavior into bounded, supervised, and collaborative learning activities. Ultimately, a new order of project inquiry with benign human-machine interaction can be formed throughout the class.

## 5. Conclusion

This paper focuses on artificial intelligence-empowered project-based learning and analyzes three dimensions: teachers' instructional design, students' learning participation, and optimization of implementation mechanisms. The study finds that the actual educational value of AI integration into project-based learning depends on whether the technology generation logic, disciplinary inquiry, and project learning process can form an effective coupling.

At the level of project-based learning design, teachers' application of AI involves three problems: superficial use, generalized technology embedding, and fragmented instructional design. AI is mainly used for surface tasks such as context generation and content production. The generation logic of general-purpose large language models is mismatched with the inquiry logic of different disciplines, and AI intervention lacks integrated design throughout the whole project process.

At the level of student participation, AI mainly brings three problems: the inquiry process is substituted, sustained engagement is interfered with, and collaborative construction is compressed. Students may rely excessively on AI to obtain answers, reducing necessary cognitive labor and sustained thinking. Collaboration among students and between teachers and students is also weakened by individualized human-machine interaction.



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At the level of optimization paths, this paper proposes subject-differentiated technical support, structured collaborative learning sheets, formative evaluation mechanisms, and improvement of teachers' AI literacy. These measures clarify the functional positioning and boundaries of AI intervention in project-based learning, turning AI from a content generation tool into a learning scaffold guided by teachers.

The main significance of this paper lies in breaking the simple idea that artificial intelligence empowerment of project-based learning merely means "adding technical tools". Starting from the relationship among the generation logic of general-purpose large language models, the logic of disciplinary inquiry, and the implementation process of project-based learning, this paper reveals the problem of AI generalization in project-based learning across different disciplines and provides practical evidence for the deep integration of AI and project-based learning at the compulsory education stage.

This paper is mainly based on existing research and theoretical analysis. It lacks long-term empirical observation and intervention experiments in real classrooms across different disciplines and school stages. Therefore, some problems and optimization strategies still need to be further verified through large-scale classroom practice.

Future research can further focus on "specialized large language models + project-based learning" and carry out empirical studies. Specialized AI models with disciplinary knowledge, cognitive scaffolding, and project process control capabilities can be developed for different disciplines. Real classroom experiments can then be used to compare general-purpose large language models and specialized models in terms of students' inquiry quality, disciplinary thinking development, cooperative learning, and learning engagement. In this way, a more specific and verifiable implementation model of artificial intelligence-empowered project-based learning in compulsory education can be formed.

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