Research on the Practical Path of Integrating Artificial Intelligence into Project-Based Mathematics Teaching in the Upper Grades of Primary School

Rui Li*

College of Education, Yangzhou University, Yangzhou, Jiangsu 225000, China

*Corresponding author: Rui Li
(E-mail: lirui011229@163.com)

Abstract. Artificial intelligence is entering education at an unprecedented pace and is reshaping teaching and learning. As a foundational subject for cultivating logical thinking and practical application, primary school mathematics needs to be deeply integrated with artificial intelligence in order to respond to new requirements for talent development. In current project-based mathematics teaching in the upper grades of primary school, several problems remain prominent, including unclear instructional objectives, insufficient innovation in teaching content, inadequate student agency in the learning process, and evaluation practices that overemphasize final products while relying on a single evaluator. Guided by the concept of project-based learning, this study takes the integration of artificial intelligence into upper-grade primary mathematics teaching as its point of departure. Focusing on four dimensions namely objectives, content, process, and evaluation, it proposes a practical pathway for improving the quality of project-based mathematics teaching with the support of artificial intelligence.

Keywords: Artificial intelligence; upper-grade primary mathematics; project-based teaching; practical pathway

1 Introduction

The rapid development of artificial intelligence is providing a powerful driving force for reform and innovation in education. The deep integration of artificial intelligence with teaching and learning has become an inevitable choice for promoting high-quality educational development. In November 2024, the General Office of the Ministry of Education issued the Notice on Strengthening Artificial Intelligence Education in Primary and Secondary Schools, which explicitly called for promoting the deep integration of artificial intelligence with education and teaching, and encouraged the exploration of innovative approaches such as project-based learning. In May 2025, the Basic Education Teaching Guidance Committee of the Ministry of Education released the Guidelines for General Artificial Intelligence Education in Primary and Secondary Schools (2025 Edition). The document further clarified that literacy development

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should be taken as the core, and that a layered, progressive, and spiraling curriculum design should support students' development from cognitive enlightenment to innovative practice. It positions the primary school stage as one of experience and interest cultivation, emphasizing that students should be guided to perceive the value of technology through project-based learning and other practical approaches. The Guidelines for the Use of Generative Artificial Intelligence by Primary and Secondary School Students (2025 Edition), released in the same period, focuses on the norms governing the use of generative artificial intelligence in schools. It specifies that primary school students should not independently use open-ended content generation functions, while teachers may appropriately use such tools for instructional support in class.

The shared orientation of these policy documents can be summarized in three points. First, artificial intelligence education must be deeply integrated with subject teaching rather than established as an isolated track. Second, project-based learning is an effective carrier for such integration. Third, the upper grades of primary school constitute a critical stage in guiding students from perceptual experience toward understanding and application. These policy orientations provide a solid basis for this study. Exploring the practical path for integrating artificial intelligence into project-based mathematics teaching in the upper grades of primary school is a concrete response to policy requirements such as promoting the deep integration of artificial intelligence with education and teaching, exploring project-based learning, and emphasizing understanding and application in the upper primary stage. At the national level, a series of intensive policy documents has systematically constructed the top-level design for artificial intelligence education in primary and secondary schools and has provided clear guidance for integrating artificial intelligence into subject teaching.

Upper-grade primary mathematics refers to the mathematics curriculum and learning activities designed for students in Grades 5 and 6. Students at this stage are in a critical period of transition from concrete visual thinking to abstract logical thinking. Their mathematical learning gradually expands from number and calculation to more abstract areas such as geometry, graphics, statistics, and probability, placing higher demands on their problem-solving abilities and integrative thinking. Project-based mathematics teaching in the upper grades of primary school is grounded in these developmental characteristics. It takes core mathematical knowledge as the carrier and guides students to conduct sustained inquiry around complex problems in authentic contexts. Through task completion and the production of learning outcomes, students deepen their mathematical understanding and develop comprehensive competencies.

However, in current upper-grade primary mathematics classrooms, project-based teaching commonly faces problems such as unclear instructional objectives, lack of innovation in teaching content, insufficient student agency in the teaching process, and evaluation that focuses heavily on outcomes while involving a single evaluation subject. As a result, the core value of applying mathematics to solve problems in practice has not been fully realized. Against the background of digital and intelligent transformation in education, it is therefore of practical significance to explore how artificial intelligence can be deeply integrated with project-based mathematics teaching in the upper grades of primary school and to construct a feasible pathway for such integration.

2 Problems in Project-Based Mathematics Teaching in the Upper Grades of Primary School

2.1 Unclear Positioning of Instructional Objectives

Unclear instructional objectives often remain at the level of completing tasks or displaying products, such as “completing a statistical chart” or “presenting a report”, without specifying the mathematical processes students must experience. Key processes like posing questions, selecting calculation methods, converting units, and explaining conclusions may be compressed or omitted. When these processes are not included in the objectives, corresponding checkpoints are absent from classroom instruction. Consequently, although the project appears completed, students' mathematical thinking remains unclear, and learning outcomes become difficult to judge.

2.2 Insufficient Innovation in Teaching Content

Some teachers rely heavily on textbooks and rarely reorganize teaching content, resulting in insufficient innovation. This path dependence is also reflected in patterned instructional design that mechanically applies templates. For example, in a project on measuring school grounds, if the teacher simply copies the textbook context for calculating the area of a rectangle, the project loses opportunities to guide students to think about why measurement is needed or how to handle irregular figures. Mathematics learning then remains at the level of surface operation.

2.3 Neglect of Student Agency in the Teaching Process

Students are often placed in a passive position, lacking clear understanding of learning objectives and having little room for independent thinking or exploration. To ensure efficient completion, teachers simplify inquiry into fixed steps. Students have few opportunities to raise questions, choose methods, or adjust their thinking. In integrated activities, teachers usually design measurement content and presentation forms in advance; students only need to follow instructions. This over-guided approach weakens the inquiry value of project-based teaching and hinders the development of learning motivation.

2.4 Outcome-Oriented Evaluation and a Single Evaluation Subject

Two prominent problems are reflected. First, evaluation overemphasizes outcomes, focusing only on final products while ignoring mathematical thinking generated during the process. Second, the evaluation subject is singular, completed by the teacher alone, while student self-evaluation and peer evaluation lack clear criteria. Consequently, evaluation fails to play its facilitative role in project-based teaching and cannot truly support the development of students' mathematical thinking and problem-solving abilities.

3 Practical Pathways for Integrating Artificial Intelligence into Project-Based Mathematics Teaching in the Upper Grades of Primary School

3.1 Objective Level: Clarifying Teaching Objectives and Cultivating AI Literacy

In primary school mathematics teaching, teachers can use artificial intelligence to reconstruct the design logic of project-based teaching and to achieve a deeper alignment between project themes and educational objectives [1]. Specifically, teachers may use artificial intelligence tools to analyze a designated mathematics unit. These tools include but are not limited to ChatGPT and Wenxin Yiyan, which can assist in generating clear and specific project objectives. Taking the unit Understanding Circles in the Grade 6 first-volume textbook published by People's Education Press as an example, teachers can first use artificial intelligence to analyze the textbook content and curriculum standards, thereby accurately identifying core competencies such as spatial awareness and application awareness that should be cultivated in this unit. Second, artificial intelligence tools can help diagnose students' prior knowledge, such as their understanding of the concept of perimeter, so as to determine the starting point of instruction. On this basis, artificial intelligence can further assist teachers in combining core competencies with learning-condition analysis to generate clear and specific project objectives.

For example, when designing a project entitled “Renovating a Circular Flowerbed on Campus”, the teacher can use ChatGPT or Wenxin Yiyan to generate the following specific objective: students should be able to accurately explain the roles of the center and radius in the layout design of a circular flowerbed, and calculate the circumference and area of the proposed flowerbed in order to plan the required materials (e.g., determine the length of the fence and the area of turf needed). In this way, through the sequence of analysis, diagnosis, and transformation, artificial intelligence helps transform the vague statement of “understanding knowledge about circles” into the ability to use knowledge of circles to solve a specific practical problem. This ensures that teaching objectives are directional and operational.

3.2 Content Level: Constructing Innovative Teaching Content

At the level of teaching content, traditional instructional design is often constrained by the fixed presentation of textbook examples and therefore struggles to meet the cognitive needs of upper-grade primary students as they move from concrete thinking toward abstract thinking [2]. The intervention of artificial intelligence provides an innovative pathway for addressing this difficulty. It can help teachers transform static mathematical knowledge into a series of visual inquiry tasks that conform to students' cognitive development and progress step by step [3].

Taking the unit on circles as an example, students usually learn about pi by measuring the circumference and diameter of several circular objects according to the textbook arrangement. Although this operation is concrete, the data are limited, which may lead students to memorize the value of pi mechanically. With the simulation and generation capabilities of artificial intelligence, teachers can design more innovative teaching content [4]. For instance, in the learning activity "Exploring Pi" , teachers can use artificial intelligence to design an interactive program. The program can be built using tools such as GeoGebra with an AI plugin or Python with AI-assisted code generation. In this interactive interface, students can freely create circles of different sizes by dragging the radius slider or inputting radius values. Each time a circle is generated, the system dynamically calculates and displays its circumference, diameter, and the circumference-to-diameter ratio. After students create dozens of different circles, the AI automatically summarizes all the data and generates clear visual charts (e.g., a scatter plot showing the ratio approaching a constant). With the charts generated by artificial intelligence, students can intuitively observe that the ratio of circumference to diameter tends to remain constant for circles of different sizes. They can thus naturally understand pi as a fixed proportional relationship, effectively completing the cognitive transition from concrete operation to abstract thinking.

3.3 Process Level: Constructing a Student-Centered Dynamic Learning Process

At the process level, a common problem in traditional project-based teaching is that students participate in activities but do not truly gain initiative. Projects are often defined by teachers in terms of topic, steps, and conclusions, while students mainly complete tasks according to assigned roles and have limited opportunities to raise questions, choose methods, or revise their thinking. After artificial intelligence is introduced, students' initiative can be activated across the three stages of before class, during class, and after class [5].

Specifically, the three-stage student-centered process is designed as follows. Before class, teachers use artificial intelligence to push project scenarios (e.g., a short video introducing the campus circular flowerbed renovation project) and pre-tasks (e.g., "draw three circles of different sizes, record their radii and circumferences, and think about what you observe"). Students conduct observation and preliminary attempts in advance. In a project on circles, for example, students can first draw circles of different sizes in an interactive interface, record data such as radius, diameter, and circumference, and bring their discovered patterns or questions to class. In this way, students enter the classroom not as passive listeners waiting for the teacher's explanation, but as learners with questions. During class, artificial intelligence provides immediate support for inquiry. When students measure, calculate, and compare in groups, artificial intelligence can help rapidly organize data [6], remind students of missing elements, and identify obvious errors, enabling students to return promptly to mathematical thinking itself. For example, the AI may generate prompts such as: "you haven't recorded the diameter for circle No. 3" or "the ratio you calculated for circle No. 2 is outside the normal range, please check your measurement". Teachers can then devote more time to asking why students calculated in a particular way, why they chose a certain method, and whether their results are reasonable [7]. Such questioning encourages students to justify their reasoning and adjust their plans according to feedback, allowing student participation to occur at key points of learning.

After class, artificial intelligence turns project-based teaching into a process that can be reviewed. The AI saves detailed operation records including revision history (e.g., each revision of data), chart adjustments (e.g., each adjustment of a chart's scale or type), and calculation method changes (e.g., switching from one formula to another). Students can organize conclusions, improve expression, and reflect on their methods on the basis of data, charts, and operation records saved by the system. Teachers can also use these records to observe students' participation and changes in thinking during the project and provide more targeted feedback. Through the support of artificial intelligence before, during, and after class, the project-based teaching process gradually shifts from teacher dominance to active student participation. Artificial intelligence does not replace students' thinking; rather, it provides support and feedback at key moments, giving students more opportunities to pose questions, try methods, and express understanding, thereby better enabling them to exercise their agency.

3.4 Evaluation Level: Improving Evaluation Methods and Diversifying Evaluation Subjects

At the level of evaluation, traditional project-based mathematics teaching in primary schools often focuses on final products, and evaluation is generally completed by teachers alone. Student self-evaluation and peer evaluation tend to become formalities, making it difficult for evaluation results to reflect students' learning comprehensively. The application of big data and artificial intelligence technologies to unit-based project learning can effectively optimize the evaluation system. By enriching evaluation subjects, these technologies guide students to think deeply and reflect on their learning, while also providing teachers with directions for future instructional strategies [8].

During project implementation, artificial intelligence can record students' operation trajectories and thinking traces. Specifically, AI-recorded evaluation data include detailed process evidence such as: the number of times a student revises input data (e.g., changing the measured circumference from 15.7 cm to 15.85 cm), the adjustment history of charts (e.g., modifying the scale or type of a chart), changes in calculation methods (e.g., switching from the formula $\pi \times$ diameter to $\pi \times 2 \times$ radius and then to the correct area formula $\pi \times \text{radius}^2$), the timing and content of AI error prompts and student responses (e.g., when an AI prompt appeared and how the student responded), and the version differences of final submitted results. Students' mathematical thinking is therefore no longer presented only through final results but preserved as process evidence. Such information provides a basis for evaluating students' reasoning processes, calculation strategies, and problem-solving abilities. On this basis, evaluation subjects can also move from singularity toward plurality. Students can use evaluation prompts provided by artificial intelligence to conduct self-checks against learning objectives. Peers can also evaluate one another on the basis of system-generated process records, focusing on differences in thinking methods and expression. Teachers then make comprehensive judgments by considering both final products and process performance, guiding students to reflect on the reasonableness of mathematical methods and the credibility of conclusions. With the support of artificial intelligence, evaluation is no longer merely a judgment of report quality [9]; it becomes an important link in promoting the development of students' mathematical thinking.

It should be noted that, according to the Student Generative AI Guidelines (2025), primary school students are not permitted to independently use open-ended content generation functions. The practical pathway proposed in this study strictly adheres to this limitation by ensuring that students only interact with structured AI tools. Specifically, students use pre-designed interactive programs (e.g., the “Exploring Pi” program built with GeoGebra or Python) where they explore mathematical concepts by manipulating parameters and observing outputs, and they receive AI-supported error prompts (e.g., “you haven't recorded the diameter for circle No. 3”, “the ratio you calculated is outside normal range, please check your measurement”) that provide structured feedback without open-ended generation. All generative AI functions (e.g., using ChatGPT or Wenxin Yiyan to generate project objectives) are performed exclusively by teachers during the instructional design phase, not by students. Thus, the proposed pathway fully complies with policy requirements while still leveraging AI's pedagogical benefits.

These evaluation practices, together with the objective, content, and process designs in Sections 3.1–3.3, collectively respond to three 2024–2025 Ministry of Education documents: the Notice on Strengthening AI Education (operationalizing AI-subject integration), the General AI Education Guidelines (using project-based learning to cultivate AI literacy), and the Student Generative AI Guidelines (ensuring primary students use only structured AI interactions without open-ended generation).

4 Conclusions

In project-based mathematics teaching in the upper grades of primary school, the introduction of artificial intelligence is not intended to replace teacher instruction or student thinking. Rather, it provides new tools and pathways for addressing long-standing practical problems, including unclear objectives, monotonous content, passive student participation, and imbalanced evaluation. By strengthening directionality at the objective level, expanding learning experiences at the content level, enhancing student participation at the process level, and focusing on mathematical thinking and learning processes at the evaluation level, artificial intelligence can improve the implementation quality of project-based teaching to a certain extent. Moreover, the value of artificial intelligence depends on teachers' reasonable design and guidance; its role should always serve mathematics learning itself and students' development. Future practice still needs to be continuously tested and adjusted in authentic classroom contexts so that artificial intelligence can truly become a supportive force for the effective implementation of project-based mathematics teaching in primary schools.

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