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From Tool Cognition to Literacy Generation: A Study on the PBL Model for AI General Education Courses from the Perspective of Computational Thinking

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Abstract: With the comprehensive advancement of artificial intelligence general education in universities, how to effectively cultivate students' computational thinking under the dual constraints of large-class teaching and limited laboratory resources has become a core issue in current teaching reform. Taking the course "Introduction to Artificial Intelligence" as the research object, this paper proposes a PBL teaching model of "problem-driven-project-supported-literacy-generating" from the perspective of computational thinking. Driven by real problems and supported by lightweight projects, this model achieves project-driven experimental teaching through tiered task design, blended teaching organization, and multi-dimensional process assessment, without relying on high-end experimental equipment. Practice has shown that this model effectively alleviates the pressure on laboratory resources, enhances students' abilities in problem decomposition, algorithm design, and critical thinking, and provides a replicable implementation path for the teaching reform of AI general education courses in universities.

Keywords: Computational Thinking, AI General Education Course, PBL Teaching Model, Project-driven, Large-class Teaching.

1. Introduction

Since 2024, the Ministry of Education and four other departments have successively issued documents such as the "AI+Education" Action Plan[1], explicitly proposing the construction of an AI general education system covering all stages of education. According to incomplete statistics, more than 80% of universities nationwide have offered AI general education courses, and "Introduction to Artificial Intelligence"[2] has become a public compulsory course in many universities. However, the structural contradiction between the large-scale offering of the course and teaching resources has become increasingly prominent: on the one hand, the number of enrolled students is huge, and large-class teaching with hundreds or even thousands of students has become the norm; on the other hand, experimental equipment such as GPU servers and high-performance computing platforms is seriously insufficient, and the traditional experimental teaching model of "lecture+on-computer verification" faces severe challenges.

Against this background, Project-Based Learning (PBL)[3] provides a new approach to addressing the above dilemma. PBL is driven by real problems and centered on students' independent inquiry and collaborative learning, emphasizing the construction of knowledge and ability in the process of "learning by doing". Introducing PBL into AI general education courses can not only replace the dependence on high-end experimental equipment through project carriers, but also realize student-centered deep learning in a large-class environment. More importantly, the implementation process of PBL is naturally consistent with the cultivation path of computational thinking-from problem abstraction and decomposition to algorithm design and evaluation iteration, every project link contains explicit training of computational thinking elements.

However, existing studies mostly focus on the application of PBL in specialized courses, paying insufficient attention to the emerging field of AI general education courses, and especially lacking a systematic discussion of PBL implementation paths under the typical constraint of "large-class teaching+limited experimental conditions". Taking the course "Introduction to Artificial Intelligence"[2] as the research object, and based on the theoretical perspective of computational thinking cultivation, this paper constructs a PBL teaching model adapted to the large-class teaching environment and explores a teaching transformation path from "tool cognition"[4] to "literacy generation"[5], in order to provide theoretical reference and practical solutions for the teaching reform of AI general education courses in universities.

2. Theoretical Basis and Literature Review

2.1. Evolution of the Concept of Computational Thinking

The concept of Computational Thinking[6] was formally proposed by Wing in 2006, who defined it as a set of thinking skills for "solving problems, designing systems, and understanding human behavior by drawing on the concepts fundamental to computer science". Since then, the academic community has continuously deepened the connotation of computational thinking, gradually forming a competency framework centered on abstraction, decomposition, pattern recognition, algorithm design, and evaluation and iteration. In 2024, Zhejiang University released the "Red Book on Artificial Intelligence Literacy of College Students"[7], which incorporated computational thinking into the core literacy system of college students in the era of artificial intelligence, emphasizing its deep integration with AI literacy. In 2026, the Computer and Intelligence Teaching Steering Committee of Higher Education Institutions of the Ministry of Education

further proposed that the teaching of computer fundamentals in higher education in the new era urgently needs to promote the deep coupling of computational thinking and the AI knowledge system.

In the context of AI general education, computational thinking is no longer limited to programming skills or tool operation, but has risen to become a comprehensive literacy oriented toward the intelligent era, covering three levels: first, the tool cognition layer-understanding the basic principles of AI and the use of tools; second, the method application layer-being able to use computational thinking methods to analyze and solve practical problems; third, the literacy generation layer-forming the ability to critically examine AI technology, with innovative awareness and ethical judgment for human-machine collaboration.

2.2. The Theoretical Framework of the PBL Teaching Model

PBL is rooted in constructivist learning theory, emphasizing that learners actively construct knowledge through independent inquiry, collaborative communication, and problem solving in real or simulated problem situations. Compared with traditional lecture-based teaching, PBL has four core characteristics: problem orientation, student centeredness, outcome production, and collaborative learning. In recent years, PBL has been widely applied in computer science and engineering education, and studies have shown that it has significant advantages in improving students' programming ability, problem-solving ability, and innovative thinking.

Table 1. Correspondence between Computational Thinking Elements and PBL Teaching Links

Computational Thinking Element	Core Connotation	Corresponding PBL Link	Example of Teaching Activity
Problem decomposition	Breaking down a complex problem into manageable sub-problems	Problem definition and task decomposition	Decomposing an AI application problem into sub-tasks such as data, model, and evaluation
Pattern recognition	Discovering patterns and features in data or problems	Information collection and analysis	Analyzing the feature distribution of different datasets and identifying data patterns
Abstract modeling	Ignoring irrelevant details and building a formal expression of the problem	Solution design	Abstracting a practical problem into the input and output of a machine learning model
Algorithm design	Designing systematic steps to solve a problem	Solution implementation and iteration	Designing a complete process of data processing, model training, and result evaluation
Evaluation and iteration	Testing the effectiveness of a solution and continuously improving it	Outcome presentation and reflection	Analyzing model performance and proposing improvement strategies

However, the implementation of PBL in a large-class teaching environment faces prominent challenges: an insufficient teacher-student ratio makes personalized guidance difficult, limited experimental resources constrain the depth and complexity of projects, and large differences in students' foundations increase the difficulty of project design. Existing studies pay insufficient attention to how to effectively implement PBL under resource-constrained conditions, and especially lack systematic design for the special scenario of AI general education courses.

There is a deep intrinsic alignment between the cultivation of computational thinking and the implementation process of PBL. Computational thinking emphasizes problem decomposition, pattern recognition, abstract modeling, and algorithm design, while the core links of PBL-problem definition, solution design, iterative implementation, and outcome evaluation-precisely correspond to the training path of the above thinking skills. Designing PBL projects guided by computational thinking theory can make every step of the project an explicit training process of computational thinking elements, achieving the teaching goal of "projects carrying knowledge, process generating literacy".

3. Construction of the PBL Model for AI General Education Courses from the Perspective of Computational Thinking

3.1. Design Principles of the Model

Based on the above theoretical analysis, this paper proposes a three-stage PBL teaching model of "problem-driven-project-supported-literacy-generating", following the design principles below:

First, the principle of low threshold and high ceiling. Project design should ensure that students with no foundation can get started, while providing space for in-depth exploration for those with ability. Through tiered task design, students with different foundations can all grow within their "zone of proximal development".

Second, the principle of light equipment and heavy thinking. In an environment with limited laboratory conditions, project design should weaken the dependence on high-end hardware equipment and strengthen the depth of computational thinking training. Online platforms, lightweight tools, and simulation environments should be used to replace heavy experimental equipment, so that students' attention and energy are focused on problem analysis, solution design, and thinking improvement rather than on equipment operation.

Third, the principle of real situations and interdisciplinary integration. Students in AI general education courses come from different professional backgrounds, so project design should incorporate real situations and interdisciplinary elements, allowing each student to find a connection with their own major and stimulating intrinsic learning motivation.

Fourth, the principle of process visibility and multi-dimensional evaluation. An evaluation system covering the entire project process should be established, focusing not only on the final outcome but also on the externalization and recording of the thinking process. Through learning logs, process reports, and peer assessment, the development process of computational thinking can be made observable and evaluable.

3.2. The Three-Stage Progressive Model Framework

This paper designs the PBL teaching process as three progressive stages, each corresponding to a different level of computational thinking cultivation:

Table 2. Framework of the Three-Stage Progressive PBL Teaching Model

Stage	Teaching Objective	Project Type	Computational Thinking Level	Class Hour Allocation
Stage 1: Cognitive awakening	Establishing basic AI concepts and stimulating learning interest	Experiential micro-project	Tool cognition layer	4-6 class hours
Stage 2: Method construction	Mastering the core methods of computational thinking	Guided medium-sized project	Method application layer	12-16 class hours
Stage 3: Literacy generation	Forming critical thinking and innovative awareness	Open comprehensive project	Literacy generation layer	10-14 class hours

The first stage, "cognitive awakening", focuses on experiential micro-projects, such as having students use existing AI tools (image recognition, voice assistants, etc.) to complete specified tasks. In this process, students are guided to think about three levels of questions: "What does AI do", "How does AI do it", and "Why can AI do it", helping students transition from the "user perspective" to the "thinking perspective". This stage has extremely low requirements for experimental equipment; students can complete it using a personal computer or even a mobile phone.

The second stage, "method construction", introduces guided medium-sized projects, in which teachers provide the project framework and part of the code, and students complete the design and implementation of key links on this basis. For example, in the project "Intelligent Recognition of Campus Waste Classification", teachers provide data collection and basic framework code, and students need to complete data preprocessing scheme design, model selection and parameter tuning, result evaluation, and other links. This stage uses free online platforms such as Google Colab and Baidu AI Studio as the experimental environment, effectively alleviating the computing pressure on local laboratories.

The third stage, "literacy generation", sets up open comprehensive projects, in which students independently choose AI application topics related to their majors and complete the whole process from problem definition to solution design, and from implementation to evaluation, on their own. The teacher's role shifts to that of advisor and reviewer, focusing on evaluating students' thinking performance in dimensions such as problem analysis, solution design, and critical reflection. The project outcomes at this stage take various forms-they can be prototype systems, analysis reports, or solution designs-and coding implementation is not strictly required.

4. Implementation Strategies of PBL in the Large-Class Teaching Environment

4.1. Project Organization Mechanism of Tiered Grouping

The primary challenge of large-class teaching is the insufficient teacher-student ratio. This paper proposes an organizational mechanism of "heterogeneous grouping+ tiered tasks+rotating group leader": project groups of 4-6 people are formed according to the principle of "heterogeneous within a group, homogeneous across groups", ensuring that each group contains students with different professional backgrounds and promoting interdisciplinary collision of ideas; project tasks are set at three levels-basic, advanced, and challenging-and each group chooses the level to complete according to its own ability, ensuring that students at every level can gain a sense of achievement; a rotating group leader system is implemented, with the group leader changed for each project, giving every student the opportunity for organizational management and presentation.

4.2. Construction of a Lightweight Experimental Environment

Limited laboratory conditions are a real dilemma faced by AI general education courses in many universities. This paper proposes a three-layer experimental environment scheme of "cloud platforms as the mainstay, local tools as the supplement, and device-free experience as the fallback".

The core idea of this scheme is to transform "experimental teaching" from "device-dependent" to "thinking-oriented". Students can obtain GPU computing support by using free online platforms, without waiting for the scheduling of university laboratories; by using pre-trained models and transfer learning techniques, meaningful AI experiments can be completed on ordinary laptops; for purely solution-design projects, students can even complete AI tool experience and solution demonstration with only a browser. This layered environment design significantly reduces the pressure on laboratory resources while ensuring the implementation quality of project-driven teaching.

Table 3. Three-Layer Lightweight Experimental Environment Scheme

Layer	Platform/Tool	Applicable Scenario	Computing Power Requirement	Cost
Cloud platform	Google Colab / Baidu AI Studio / Alibaba Tianchi	Model training, data processing, deep learning experiments	Online GPU	Free / very low cost
Local tools	Jupyter Notebook / Scikit-learn / pre-trained models	Data analysis, lightweight machine learning, model invocation	Ordinary PC	Zero cost
Device-free experience	Online AI applications / large model APIs / visualization demonstration tools	AI experience, proof of concept, solution design	Browser	Zero cost

4.3. Design of the Blended Teaching Process

To adapt to the characteristics of large-class teaching, this paper designs a blended teaching process of "online independent learning+offline in-depth discussion+ after-class project practice". The online links complete knowledge transmission through micro-lecture videos, online quizzes, and discussion forums, freeing up offline classroom time for project guidance, group discussion, and outcome presentation.

Specifically, each project cycle includes the following teaching links: (1) Online entry-teachers release project tasks and guiding questions, students learn relevant knowledge modules independently and complete the entry quiz; (2) Offline discussion-groups discuss the solution design, teachers provide itinerant guidance, focusing on guiding students to use computational thinking methods for problem decomposition and solution design; (3) After-class practice-groups collaborate to complete project implementation and record process logs through the learning platform; (4) Offline presentation-groups report project outcomes, conduct peer assessment and teacher comments, focusing on reflecting on the application process of computational thinking methods.

4.4. Process-Oriented Multi-Dimensional Evaluation System

Under the PBL model, the focus of evaluation should shift from result-oriented to process-oriented, and a multi-dimensional evaluation system covering the four dimensions of knowledge, skills, thinking, and attitude should be established.

Table 4. Computational Thinking-Oriented Multi-Dimensional PBL Evaluation System

Evaluaton Dimension	Evaluation Content	Evaluation Method	Weight Proportion
Knowledge understanding	Mastery of basic AI concepts and principles	Online quiz, entry report	20%
Skill application	Practical skills such as tool use, data processing, and model parameter tuning	Project process records, code review	25%
Computational thinking	Abilities in problem decomposition, abstract modeling, algorithm design, and evaluation iteration	Thinking process report, solution defense	35%
Collaboration and attitude	Team collaboration, independent learning, critical reflection	Peer assessment, learning logs	20%

It should be particularly noted that the evaluation of the computational thinking dimension is the core innovation of this system. By requiring students to write a "thinking process report"-that is, a reflective document that records in detail the process of problem analysis, solution selection, failure, and iteration-the originally implicit thinking process is externalized, providing teachers with a direct basis for evaluating the development level of students' computational thinking.

5. Teaching Practice and Effect Analysis

5.1. Practice Background

This study takes the course "Introduction to Artificial Intelligence" of a certain university as the practice object. The course is offered to non-computer-major undergraduates across the university, with about 300-400 students enrolled each semester, and is delivered in a large-class format. The university has a total of 3 computer laboratories equipped with 120 ordinary PCs, with no GPU servers, and the experimental conditions are difficult to meet the needs of traditional on-computer experiments. The course team began implementing the PBL teaching model reform in the fall semester of the 2024-2025 academic year, going through two rounds of teaching iteration.

5.2. Project Implementation Case

Taking a typical project from the second-stage "guided medium-sized project" as an example:

5.2.1. Project: "Campus Parcel Volume Prediction"

Driving question: How can historical data and AI methods be used to predict campus parcel volume and provide a reference for optimizing the operation of parcel stations?

During project implementation, teachers first guide students to decompose the problem: breaking down the complex problem of "parcel volume prediction" into four sub-tasks-data collection and cleaning, feature engineering, model selection and training, and result evaluation and interpretation. Subsequently, students work in groups on the Baidu AI Studio platform to complete data processing and model training, with teachers focusing on guiding students to apply computational thinking methods in each link. The entire project is completed using free online platforms, without occupying the university's laboratory resources.

The tiered task design is as follows: basic level-completing the prediction using the data cleaning code and basic model provided by the teacher, focusing on understanding the data processing flow and model evaluation methods; advanced level-independently designing the feature engineering scheme, comparing the effects of multiple models, and writing an experimental analysis report; challenging level-attempting ensemble learning or time series analysis methods and proposing feasible suggestions in combination with the actual operation of parcel stations.

5.3. Evaluation of Teaching Effectiveness

The teaching effectiveness was evaluated through various methods such as questionnaire surveys, process data analysis, and interviews.

Table 5. Comparison of Teaching Effectiveness before and after the Implementation of the PBL Model

Evaluation Indicator	Traditional Model(Fall 2023)	PBL Model(Fall 2024)	PBL Model(Spring 2025)
Course satisfaction (%)	68.3	84.7	87.2
Project completion rate (%)	45.6	78.4	82.1
Improvement in computational thinking self-assessment (%)	12.4	31.6	35.8
Laboratory occupancy rate (%)	92.0	38.5	35.2
Student active participation rate (%)	52.1	79.3	83.6

The data show that after the implementation of the PBL model, course satisfaction, project completion rate, improvement in computational thinking self-assessment, and student active participation rate all increased significantly, while the laboratory occupancy rate dropped sharply. It is worth noting that the laboratory occupancy rate falls from 92% to about 35%, indicating that the PBL model effectively alleviates the pressure on laboratory resources, and students can complete most project tasks through cloud platforms and personal devices.

In terms of the development of each dimension of computational thinking, students show the most significant improvement in the two dimensions of "problem decomposition" and "evaluation and iteration", which is closely related to the cycle of "decomposing the problem-trying solutions-evaluating and improving" repeatedly experienced in PBL projects. The improvement in the "abstract modeling" dimension is relatively slow, which is related to the mathematical foundation of non-computer-major students; in subsequent teaching, the scaffolding design of this link should be strengthened.

6. Reflection and Suggestions

6.1. Advantages and Applicable Boundaries of the PBL Model

The practice of this study proves that the PBL model has three outstanding advantages in AI general education courses: first, it effectively reduces the dependence of experimental teaching on high-end equipment and realizes project-driven teaching through lightweight environment design; second, through tiered tasks and grouping mechanisms, it realizes differentiated teaching in a large-class environment; third, it integrates the cultivation of computational thinking into the whole project process, realizing the teaching transformation from "tool cognition" to "literacy generation".

At the same time, the PBL model also has applicable boundaries. For student groups with weak theoretical foundations and insufficient independent learning ability, directly entering PBL may lead to a situation of "lively in form, idle in substance". It is suggested to set up a prerequisite knowledge module before implementation, fully awaken students' cognitive foundation in the first stage, and gradually transition to the independent project stage.

6.2. Transformation of the Teacher's Role and Support

The PBL model puts forward new requirements for teachers. Teachers need to transform from knowledge transmitters to project designers, process guides, and thinking coaches. In a large-class environment, it is suggested to equip teaching assistants or a graduate teaching assistant team responsible for daily project guidance and data collection for process evaluation. At the same time, it is suggested that universities establish a PBL teaching support system, including a project case library, an evaluation toolkit, and a teacher training mechanism, to reduce the cognitive load of teachers implementing PBL.

6.3. Empowering PBL Teaching with AI Tools

The development of AI tools such as large language models provides new empowering means for PBL teaching. Teachers can use AI tools to assist in generating project cases, designing tiered tasks, and providing instant feedback; students can use AI tools to assist in code debugging, solution demonstration, and report writing. However, it should be emphasized that AI tools should be positioned as "thinking scaffolds" rather than "substitute execution", and teachers should guide students to maintain critical thinking while using AI tools, avoiding "thinking outsourcing".

7. Conclusion

The core goal of AI general education is not to cultivate AI technicians, but to cultivate future talents who possess computational thinking literacy and are able to collaborate and coexist with AI. Under the dual constraints of large-class teaching and limited laboratory resources, the PBL model, with its characteristics of being problem-driven, project-supported, and process-oriented, provides a practical and feasible path for the teaching reform of AI general education courses. The three-stage progressive PBL model of "problem-driven—project-supported—literacy-generat -ing" constructed in this paper, through tiered task design, a lightweight experimental environment, and multi-dimensional process evaluation, achieves high-quality project-driven teaching under limited resource conditions and effectively promotes the leap of students' computational thinking from tool cognition to literacy generation.

Future research will continue to deepen in the following directions: first, expanding the practice sample and verifying the applicability and transferability of the model in different types of courses in multiple universities; second, developing AI-based intelligent evaluation tools to realize automated diagnosis and feedback of the development process of students' computational thinking; third, building an open-source project case library to provide more university teachers with directly reusable PBL teaching resources.

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