Problem-Driven Mechanisms in Project-Based Learning

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Abstract. Problems often launch project-based learning, but the literature is less clear about how they organize later activity. This study examines 82 Chinese journal articles exported from CNKI and indexed from 2003 to June 2026. Descriptive bibliometrics and title-abstract-keyword coding show rapid growth after 2021 and a peak of 23 papers in 2025. Six themes were coded. Driving questions appeared less often than outcomes and assessment, suggesting that the central mechanism is frequently assumed rather than specified. The synthesis proposes a five-stage process: frame authentic uncertainty, decompose it into subquestions, investigate with disciplinary tools, negotiate interpretations, and evaluate solutions through evidence and feedback. Applied to computer experiments, the model requires questions to guide tool use, data interpretation, and revision of technical decisions.

Keywords: Project-based learning, Problem-driven mechanism, Driving question, Thematic analysis, Computer experimental education

1 Introduction

Project-based learning (PBL) links disciplinary knowledge with sustained work on a product, investigation, or practical task. Helle et al. [1] examined PBL in post-secondary education, while Bell [6] emphasized inquiry, collaboration, and purposeful products. Chinese studies increasingly address effects, standards, collaboration, and assessment [2-4]. Yet a project may be labeled "problem driven" even when its opening problem has little influence on later decisions.

For experimental and engineering courses, this distinction matters. Students may follow prescribed operations without defining variables, comparing explanations, or revising a design. A problem becomes a driver only when it shapes information seeking, task division, evidence, and reconsideration of tentative solutions.

Recent studies provide parts of this mechanism. Problem-posing frameworks connect core questions and question chains [5]; international work emphasizes inquiry, collaboration, and purposeful products [6]; studies of deep understanding highlight challenging questions and feedback [7]; and engineering research links ill-structured problems with collaboration and cognitive scaffolds [8, 9].

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This paper asks one question: how does a problem drive the full course of PBL? It maps the supplied CNKI dataset and synthesizes a process mechanism for computer experiments. The analysis examines publication development, recurring problem-related elements, and their sequence.

2 Data and Method

The supplied CNKI export contained 82 journal records with titles, authors, affiliations, journals, years, keywords, abstracts, and links. Records ranged from 2003 to 2026. One online-first article was assigned to 2026 from its CNKI identifier. The search was frozen on June 16, 2026, so 2026 is a partial year.

The analysis had two layers. Descriptive bibliometrics counted annual output, source journals, and author keywords. Because complete cited-reference lists and reliable citation counts were unavailable, no co-citation or coupling claims were made. Titles, abstracts, and keywords were then coded for six overlapping themes: authentic tasks, driving questions, scaffolding, collaboration, assessment, and transfer or higher-order outcomes.

Coding used a predefined vocabulary and record-by-record abstract checking. One paper could receive several codes. International studies cited for conceptual comparison were not included in the 82-record corpus. The counts indicate mechanism visibility rather than exclusive article types and do not replace a full-text systematic review.

3 Results

3.1 Publication Development and Sources

Figure 1 shows a long period of limited output followed by rapid expansion. Only five papers appeared before 2018. Output rose to 14 papers in 2018-2020, 26 in 2021-2023, and 37 in 2024-June 2026. The peak of 23 papers in 2025 is not a minor fluctuation; it marks a shift from occasional discussion toward sustained attention to design, assessment, disciplinary adaptation, and digital support.

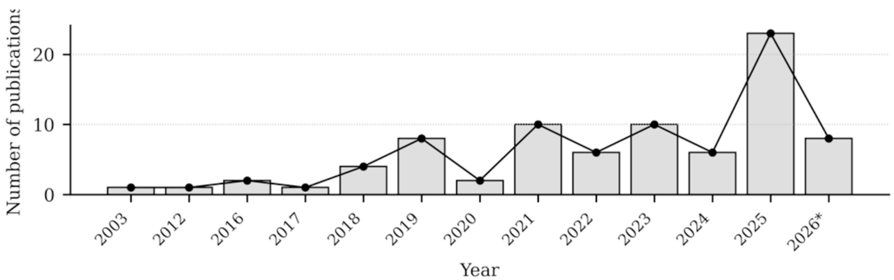

Fig. 1. Annual publication output in the analyzed CNKI dataset. The 2026 value covers records indexed through June 16.

The literature was concentrated but not dominated by one outlet. Chinese Journal of Education published 15 records, followed by e-Education Research (7), Educational Science Research (5), Curriculum, Teaching Material and Method (4), and Research in Higher Education of Engineering (4). These five journals accounted for 42.7% of the dataset, showing that PBL was treated as both general pedagogy and disciplinary practice.

3.2 Thematic Distribution

Table 1 reports the six overlapping themes. Higher-order outcomes and transfer were the most visible theme (44 records), followed by assessment and feedback (36) and authentic contexts or complex tasks (34). Scaffolding and collaboration each appeared in 29 records. By contrast, only 17 records explicitly discussed driving questions, problem posing, or question chains. This imbalance is revealing: the literature often states what PBL should achieve and how it should be assessed, while the mechanism linking the initial problem to students' ongoing decisions receives less direct specification.

Table 1. Visibility of problem-driven themes in 82 records (overlapping codes).

Theme	n	Typical focus
Transfer and higher-order outcomes	44	learning transfer, core competencies, complex problem solving
Assessment and feedback	36	performance evidence, formative feedback, rubrics
Authentic contexts and complex tasks	34	real situations, challenge, ill-structured problems
Scaffolding and teacher guidance	29	supports, monitoring, timely intervention
Collaboration and participation	29	peer interaction, group planning, shared knowledge
Driving questions and question chains	17	core questions, problem posing, subquestions

The explicit problem-focused studies nevertheless show a consistent pattern. A driving problem is most productive when it is authentic enough to create uncertainty, bounded enough to permit progress, and open enough to support alternative routes. Wang et al. [5] placed problem posing across the whole project rather than at the beginning only. Bell [6] linked inquiry with collaborative knowledge construction and purposeful products. Gao et al. [7] argued that a challenging question should connect disciplinary knowledge with a narrative context, while Jin et al. [9] showed that ill-structured engineering problems require contextual interaction, deep collaboration, and external cognitive support.

4 A Five-Stage Problem-Driven Mechanism

The coded themes can be organized as a temporal mechanism rather than a checklist. The first stage is framing. A teacher creates an authentic uncertainty that cannot be answered by recalling one fact. The problem must expose a gap between the present state and a defensible outcome. In engineering education, this gap may involve conflicting constraints, incomplete data, or multiple acceptable solutions [8, 9].

The second stage is decomposition. Students translate the core problem into subquestions about concepts, information, procedures, criteria, and risks. A useful question chain is neither a teacher-provided worksheet nor unrestricted brainstorming. It should preserve ownership while giving the group a navigable structure. Problem decomposition also makes collaboration visible because responsibilities can be assigned to questions rather than to isolated mechanical tasks [5, 10].

The third stage is investigation. Learners seek evidence through reading, experimentation, modeling, or comparison. Teacher guidance is selective: it supplies a scaffold when progress stalls but does not remove the uncertainty that makes inquiry necessary. Studies of teacher guidance and project standards show that sustained monitoring, timely feedback, and explicit learning supports can increase group cohesion and keep disciplinary goals in view [4, 11].

The fourth stage is negotiation. Evidence is interpreted in a social space. Students explain choices, challenge assumptions, coordinate partial findings, and decide whether the original framing should be revised. Peer collaboration is therefore not merely a division of labor. Reviews of PBL implementation identify high-quality group processes, teacher scaffolding, and aligned assessment as conditions for sustained inquiry [12]. Group membership alone does not ensure intellectual participation, so role allocation and timely intervention remain necessary.

The fifth stage is evaluation. Products are judged together with the reasoning and evidence that produced them. Recent assessment approaches make the problem visible again at the end: did the solution address the original uncertainty, and can it transfer to a related case? Recent assessment models combine task, evidence, process data, reflection, and feedback [3]. Evaluation then returns learners to the problem, which is why the mechanism is cyclical rather than linear. Evidence-centered designs make this alignment explicit by connecting learner, evidence, and task models [13].

5 Discussion

The synthesis changes “problem driven” in two ways. The driver is not a single sentence but a sequence linking the problem, evidence, and standards of judgment. Teacher guidance is also compatible with student-centered learning when it protects productive difficulty by withholding answers, adding scaffolds, or demanding stronger evidence.

A design risk appears when assessment rewards only the final artifact. Observable traces - revised questions, experimental records, decision notes, peer explanations, and reflections - make the path from problem representation to solution assessable. Controlled learning-by-teaching studies show that actual teaching can outperform teaching expectancy and that preparation is more effective when followed by teaching [14, 15]. Although not direct tests of PBL, these findings support the explanatory work within the negotiation stage.

In computer experimental education, the mechanism need not turn every laboratory into an open-ended capstone. In performance testing, a core question such as why response time degrades under a workload can be decomposed into workload, monitoring, application, network, and database questions. Students configure tools, collect evidence, compare explanations, and defend a bottleneck diagnosis; merely running a script is insufficient.

The model also clarifies the use of WH questions and cognitive levels. “What happened?” supports observation, whereas “why did this metric change?” and “how would another load pattern alter the result?” move toward analysis and transfer. Questions should follow the project’s changing uncertainties rather than a fixed prompt list.

6 Conclusion

The CNKI literature shows rapid growth in PBL research, but driving questions receive less explicit treatment than outcomes and assessment. The synthesis identifies a five-stage mechanism: frame uncertainty, decompose it, investigate with disciplinary tools, negotiate interpretations, and evaluate solutions through evidence and feedback. For computer experiments, tool use must remain subordinate to evidence, explanation, and revision. The study is limited to one Chinese database and bibliographic records with abstracts; classroom research should test the proposed sequence against interaction and performance data.

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Disclosure of Interests

The author has no competing interests to declare that are relevant to the content of this article.

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