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The Urgency of Using Project-Based Learning-Oriented Science Learning Modules to Enhance Students' Interest and Learning Outcomes

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Abstract
Science learning in many school contexts continues to face two intertwined challenges: students' declining interest in learning science and persistently uneven learning outcomes. Beyond pedagogy, the quality of learning materials matters because it shapes what students do, how long they persist, and what evidence of learning is produced. This article synthesizes research evidence (up to 2024) on the urgency of using science learning modules designed around Project-Based Learning (PjBL) to improve students' interest and achievement. Using a targeted narrative review approach, we prioritized peer-reviewed meta-analyses, systematic reviews, and representative quasi-experimental and development studies that examined PjBL in science/IPA settings and reported outcomes related to interest, motivation, engagement, or academic achievement. Across the literature, PjBL shows a consistent positive association with achievement (e.g., medium-to-large effects in meta-analytic comparisons with traditional instruction) and small-to-moderate positive effects on motivation constructs, including interest and task value. Evidence from recent elementary and secondary school studies further indicates that well-structured PjBL can improve learning outcomes and student motivation when projects are anchored in clear driving questions, sustained inquiry, collaboration, formative assessment checkpoints, and explicit reflection. Based on this synthesis, we propose a practical module design framework that links PjBL module features to motivational mechanisms (autonomy, competence, relatedness, and task value) and to measurable learning outcomes. Implications are discussed for teachers, curriculum leaders, and module developers, emphasizing feasibility, assessment alignment, and equity of access.

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1. Introduction

Improving science learning is a continuing priority because scientific literacy and evidence-based reasoning are foundational for participation in modern societies. Yet, in many classrooms science is still taught as a sequence of concepts to be memorized rather than as a way of investigating phenomena and building explanations. When science is experienced as abstract, text-heavy, and disconnected from students' lives, learners may disengage, participate only minimally, and show limited conceptual growth. International assessments repeatedly indicate that gaps in science achievement persist across and within countries. These outcomes often co-occur with motivational challenges such as low interest, low perceived value, and low confidence (OECD, 2019, 2023) [18, 19].

Two consequences follow from this situation. First, instructional quality cannot be reduced to teaching strategies alone; learning materials influence how strategies are enacted. Second, efforts to improve science learning should explicitly target both achievement and motivation, because motivation supports the sustained attention and persistence needed for complex learning. In other words, achievement and interest are not competing priorities; they are mutually reinforcing.

Learning interest is not merely an affective 'add-on'; it is a motivational resource that influences attention, persistence, and depth of processing. Interest can be triggered situationally—by novelty, relevance, or challenge—and, under supportive conditions, can develop into more stable individual interest that sustains learning over time (Hidi & Renninger, 2006) [10]. In science classrooms, interest is closely linked to perceived relevance and the opportunity to engage in authentic practices rather than only receiving information. Students are more likely to value science when they see it as a tool for making sense of everyday problems and when they have agency in asking questions and testing ideas.

Project-Based Learning (PjBL) offers a promising response because it organizes learning around meaningful problems and the creation of shareable products. PjBL aligns with constructivist perspectives that view learning as active knowledge construction through inquiry, collaboration, and reflection. Foundational work emphasized that PjBL must sustain 'the doing' (engagement and persistence) while supporting 'the learning' (conceptual understanding) through scaffolding and feedback (Blumenfeld *et al.*, 1991) [3]. In science education, PjBL is often positioned as a way to engage students in processes similar to those of scientists—observing, modeling, testing explanations, and communicating evidence-based claims (Krajcik & Blumenfeld, 2006; National Research Council, 2012) [13, 16].

Meta-analytic evidence supports the effectiveness of PjBL. Chen and Yang (2019) [4] synthesized research comparing PjBL with traditional instruction and reported a medium-to-large positive effect on academic achievement. A 2024 meta-analysis focusing on motivation found that problem-driven learning methods including PjBL have a small-to-moderate positive effect on motivation constructs such as interest and task value (Wijnia *et al.*, 2024) [24]. However, PjBL is not a 'plug-and-play' method. Its success depends on the quality of project design, the clarity of learning goals, the scaffolding of inquiry, and the alignment of assessment with intended outcomes (Kokotsaki *et al.*, 2016; Markula & Aksela, 2022) [12, 15].

This is where learning modules become crucial. A module is a structured package of learning goals, resources, learning tasks, and assessment tools that supports coherent learning experiences. For PjBL, modules are particularly important because teachers must orchestrate inquiry phases, allocate roles, manage collaboration, and collect evidence of learning beyond paper-and-pencil tests. Without a well-designed module, PjBL implementation may become 'activity-based' rather than learning-goal-driven, which can dilute conceptual gains and widen inequities.

In the Indonesian context, science learning increasingly emphasizes integrated competencies and real-world application, particularly under curriculum reforms that highlight essential content and student agency. This places pressure on teachers to create meaningful learning experiences while also ensuring assessment readiness. In such settings, high-quality PjBL-based modules can reduce teacher workload, increase instructional consistency, and provide a practical bridge between curriculum intentions and classroom realities.

Accordingly, this article aims to (a) clarify why PjBL-oriented science modules are urgently needed to improve students' interest and learning outcomes; (b) synthesize empirical evidence (up to 2024) on the effects of PjBL in science/IPA learning for motivation/interest and achievement; and (c) propose an implementable module design framework, including design principles and assessment alignment that can be adopted by teachers and developers.

2. Literature Review

2.1. Project-Based Learning in Science/IPA Education

Project-Based Learning is an instructional approach in which students engage in sustained inquiry to respond to a complex question, problem, or challenge and produce a concrete product or performance that can be shared publicly. Unlike short "hands-on" activities, PjBL typically involves extended time, iterative refinement, and an emphasis on explanation and communication. In science, this may involve building models, designing investigations, analyzing data, and presenting evidence-based conclusions. The intent is to move beyond procedural activity toward knowledge-building that is connected to disciplinary ideas (Krajcik & Blumenfeld, 2006) [13].

The early PjBL literature highlighted a central tension: projects can be highly engaging but may fail to produce deep learning unless they are designed to promote conceptual understanding. Blumenfeld *et al.* (1991) [3] described this as sustaining the doing while supporting the learning. Sustaining the doing requires meaningful problems, social support, and visible progress; supporting the learning requires scaffolding, feedback, and opportunities for reflection and explanation. Subsequent reviews confirm that poorly structured projects can drift away from learning goals, resulting in superficial products or fragmented understanding (Kokotsaki *et al.*, 2016) [12].

Science education adds specific requirements because scientific understanding develops through linking ideas to evidence and reasoning. A PjBL design that emphasizes only product aesthetics or presentation skills, without requiring evidence-based explanations, may improve engagement but not necessarily scientific understanding. Thus, the quality of PjBL depends on how inquiry and explanation are embedded as non-negotiable components. This aligns with science learning frameworks emphasizing scientific practices and crosscutting concepts (National Research Council, 2012) [16].

PjBL is sometimes confused with "doing projects" as an end-of-unit activity. In a strong PjBL design, the project is not a decoration at the end; it is the vehicle through which core ideas are learned. This difference matters for interest and outcomes. When the project is central, students repeatedly return to the driving question, gather evidence, revise explanations, and see how concepts help them progress. When the project is peripheral, students may enjoy making something but fail to connect it to scientific reasoning, resulting in weak learning gains.

2.2. Why 'Modules' Matter: From Pedagogical Ideas to Classroom Feasibility

A learning module can be understood as a coherent instructional script: it specifies the learning goals, sequence, resources, and assessments needed to enact a teaching approach. In contexts where teachers face limited time for planning and high administrative demands, modules provide a way to standardize quality without standardizing pedagogy. That is, a good module preserves teacher flexibility while preventing common design errors such as unclear success criteria, misalignment between activities and assessment, or insufficient scaffolding for student inquiry.

For PjBL, modules matter because the approach increases the number of moving parts in a lesson cycle. Teachers must manage group work, coordinate materials, plan checkpoints, provide feedback, and integrate mini-lessons when conceptual gaps emerge. Modules can lighten this burden by providing reusable templates: driving question prompts, planning sheets, investigation guides, data tables, reflection logs, and rubrics. They can also ensure that projects remain academically rigorous by linking each phase to explicit learning objectives and assessment evidence.

Development studies of PjBL modules and e-modules show the practical value of this structure. Delimanugari (2024) [6], for example, reported that a project-based e-module with local wisdom content for Grade IV IPAS was validated by experts and trialed with users, with positive responses suggesting improved attention and self-directed learning. Importantly, the study also recommended revision, reminding developers that "module quality" is not automatic. Validation, iteration, and usability testing are essential to avoid producing attractive but instructionally weak materials.

Modules can also support continuity across classrooms and grade levels. When schools adopt a shared module structure—while allowing contextual adaptation—teachers can collaborate more efficiently. For instance, a science teacher team can co-develop driving questions and rubrics, then each teacher adapts examples and resources to match their students' needs. This collaborative approach reduces burnout and increases the likelihood that PjBL becomes a stable practice rather than a one-time innovation.

2.3. Theoretical Links: PjBL Modules, Interest, and Learning Outcomes

Why should modules influence interest and learning outcomes? The theoretical answer is that modules shape the learning environment through task design and support structures. Self-determination theory suggests that motivation increases when environments support autonomy, competence, and relatedness (Deci & Ryan, 2000) [5]. A PjBL module can support autonomy by offering bounded choices (topic, product format, roles), competence by providing scaffolds and feedback cycles, and relatedness through collaboration norms and peer feedback routines.

Expectancy-value theory emphasizes that students engage more when they expect success and value the task (Eccles & Wigfield, 2002) [8]. Modules can increase expectancies by clarifying success criteria early, providing exemplars, and sequencing tasks from simpler to more complex. Modules can increase task value by connecting projects to real-life issues (health, environment, technology, local community) and making the usefulness of science visible.

Interest development theory adds a time dimension. Interest is triggered and maintained through repeated experiences that feel meaningful and manageable (Hidi & Renninger, 2006) [10]. A PjBL module can help maintain interest by building momentum: students see progress across phases, receive feedback, revise products, and ultimately share outcomes publicly. In contrast, loosely organized projects may trigger interest briefly but fail to maintain it when students feel confused or overwhelmed.

These theories converge on one practical insight: motivation is supported when learners can make sense of what they are doing and why it matters. Modules provide the "why" through relevant driving questions and the "how" through structured supports. This is also why teacher facilitation is crucial—teachers help students interpret progress, resolve confusion, and connect evidence to concepts.

2.4. Evidence Trends up to 2024

Evidence up to 2024 provides converging support for the PjBL-module rationale. With respect to achievement, Chen and Yang (2019) [4] reported an overall mean effect size of d = 0.71 in favor of PjBL compared with traditional instruction. This magnitude is consistent with the view that sustained inquiry and application-oriented learning can deepen understanding when well supported.

Science-specific syntheses reinforce this conclusion. Nurhasnah *et al.* (2022) [17] reviewed 25 studies and reported a high overall influence of PjBL in science learning (reported effect size = 1.67). Although effect size metrics vary across studies and therefore should not be compared mechanically, the direction of evidence is robust: PjBL is typically beneficial for science learning outcomes.

Regarding motivation and interest, Wijnia *et al.* (2024) [24] synthesized 132 reports (139 subsamples) and concluded that problem-driven methods (including PjBL) had a small-to-moderate positive effect on motivation (d = 0.498). Stronger effects were found for motivation components such as beliefs, values, and attitudes than for reasons for studying, suggesting that PjBL is particularly useful for building students' sense that learning is meaningful and worthwhile.

Classroom-level evidence in Indonesia provides concrete illustrations. Pangestu *et al.* (2024) [20] found that PjBL significantly improved elementary students' learning outcomes and motivation in science learning compared with conventional instruction. Hindun *et al.* (2024) [11] reported higher science literacy and collaboration in PjBL groups. Sutaryani *et al.* (2024) [21] documented improved science process skills and learning outcomes in a PjBL intervention in high school physics.

Studies in broader STEM contexts also highlight the relevance of attitudes and interest. For instance, research on STEM-oriented PjBL environments has reported positive student experiences and increased enthusiasm for learning (Afriana *et al*., 2016; Tseng *et al*., 2013) [1, 23]. These findings are consistent with the idea that interest is strengthened when learning is contextualized, collaborative, and product-oriented.

2.5. A Practical Definition of 'Urgency' for Schools

In school decision-making, "urgency" should be interpreted as a convergence of need, feasibility, and expected impact. Need is visible when students show low interest, passive participation, and weak achievement. Feasibility concerns whether teachers can realistically implement an approach within curricular time and assessment systems. Expected impact concerns whether the approach has credible evidence for improving priority outcomes. PjBL-oriented modules score strongly on these criteria because they address motivational and cognitive needs and improve feasibility by packaging design, scaffolds, and assessments in a reusable form.

Urgency also reflects opportunity cost. When science learning remains dominated by transmission and worksheet completion, students lose the opportunity to experience science as inquiry and problem solving. This can produce long-term motivational costs: students may avoid science pathways and underestimate their ability to do science. PjBL modules offer a structured alternative that can be implemented even in constrained contexts, especially when modules are designed with resource-light options, clear classroom routines, and assessment alignment.

Finally, urgency is not only about raising average scores; it is also about reducing dispersion. Classrooms often show high variability: a few students thrive, many are compliant, and some disengage. A well-designed module supports more students by making expectations explicit and by providing multiple entry points (visuals, hands-on investigation, discussion, writing). This aligns with equity-oriented teaching: scaffolding is not a sign of low standards but a way to give more learners access to high standards.

2.6. Common Implementation Pitfalls and How Modules Mitigate Them

Several common pitfalls explain why PjBL sometimes fails to improve outcomes. First, projects may be 'fun' but weakly connected to learning objectives. Students may spend time decorating products or collecting information without building conceptual understanding. A module can prevent this by requiring evidence-based explanations in every phase (e.g., claim-evidence-reasoning prompts), and by integrating short conceptual mini-lessons when students need new tools to progress.

Second, group work can hide unequal participation. Some students may carry the project while others disengage, which undermines both learning and motivation. Module design can address this by assigning rotating roles (data manager, materials manager, reporter), requiring individual accountability artifacts (individual reflection logs, individual concept checks), and using simple peer assessment tools.

Third, assessment can unintentionally communicate that the project is "extra" rather than central. If the final test ignores project learning, students may not take inquiry seriously. Conversely, if grading focuses only on product appearance, students may not invest in scientific reasoning. Module-based assessment alignment—rubrics for reasoning plus tests for concepts—helps avoid this split.

Fourth, time management is a major barrier. Teachers may avoid PjBL because it feels unpredictable. Modules can provide a clear pacing guide and "minimum viable" versions of project phases. For example, a project can be planned as two lesson cycles (planning/inquiry; revision/showcase) with optional extensions for enrichment.

2.7. Quality Criteria for PjBL Science Modules

Module quality can be evaluated using three criteria: coherence, usability, and robustness. Coherence means alignment between objectives, activities, and assessment. Usability means that students and teachers can follow the module with minimal confusion. Robustness means that the module works across typical classroom constraints (limited time, mixed readiness, varying resources). Development studies commonly operationalize these criteria through expert validation and field trials (Delimanugari, 2024) [6].

From a developer perspective, a high-quality PjBL module typically includes: (a) clear learning targets and success criteria stated in student-friendly language, (b) a driving question and context that matter to students, (c) step-by-step inquiry prompts that require evidence, (d) checkpoints for formative feedback, (e) rubrics that prioritize scientific reasoning, and (f) reflection prompts that help students articulate what they learned and how they learned it.

An overlooked but essential criterion is 'instructional resilience': the module should be usable even when the teacher cannot provide constant one-on-one support. This requires well-designed student-facing guidance (checklists, exemplars, common error warnings) and simple self-monitoring tools (progress trackers, milestone logs).

3. Method

This article used a targeted narrative review to synthesize research evidence on Project-Based Learning (PjBL) and PjBL-oriented science learning modules in relation to students' interest/motivation and learning outcomes. A targeted narrative approach is appropriate when the goal is to integrate different kinds of evidence—meta-analyses, classroom experiments, and module development studies—into actionable design guidance. Unlike a narrow systematic review that focuses on a single outcome metric, this review aimed to connect evidence on outcomes with evidence on implementable design features.

Search and selection were conducted by consulting peer-reviewed sources indexed in major databases and publishers (e.g., SpringerLink, ScienceDirect, OECD reports, and institutional journal platforms) and by cross-checking references within key reviews. The search focused on publications up to 2024 using combinations of terms such as "project-based learning", "science education", "IPA", "module", "e-module", "interest", "motivation", "engagement", and "learning outcomes". We prioritized: (a) meta-analyses and systematic reviews that reported effect sizes; (b) quasi-experimental studies in school science/IPA settings; and (c) development studies reporting validation/practicality of modules or e-modules.

For synthesis, we extracted: (1) outcome focus (interest/motivation, engagement, achievement, science literacy, process skills), (2) reported direction and magnitude of effects (where available), and (3) implementation features (driving question, inquiry duration, collaboration structures, formative assessment, reflection and public sharing). Findings were integrated using qualitative thematic synthesis. The discussion then translates themes into a design framework and a set of module design principles, including assessment alignment, that can guide development and adoption in school contexts.

To maintain transparency, we do not claim exhaustive coverage of all PjBL studies. Instead, the review emphasizes high-leverage sources (meta-analyses and recent classroom studies) and uses them to identify design principles that recur across contexts. This approach is aligned with the practical goal of supporting teachers and developers who need actionable guidance rather than a purely descriptive catalog.

4. Results and Discussion

4.1. What the Evidence Says About Achievement Gains

Across quantitative syntheses, academic achievement outcomes show consistent advantages for PjBL compared with traditional instruction. In the meta-analysis by Chen and Yang (2019) [4], the overall mean weighted effect size was d = 0.71 in favor of PjBL. This implies that, on average, students in PjBL conditions outperform those in traditional conditions by a meaningful margin. Moderator findings in the same meta-analysis also highlight a practical point: PjBL benefits are not automatic. Study features such as instructional time, technological support, and group size may influence the magnitude of effects, suggesting that implementation quality is a key driver of outcomes.

Science-specific syntheses provide complementary evidence. Nurhasnah *et al*. (2022) [17] reviewed science learning studies across education levels and reported a high overall influence of PjBL (reported effect size = 1.67). Although the reported metric differs from the standardized mean difference d used in other meta-analyses, the implication is consistent: PjBL tends to benefit learning outcomes in science-related domains.

A practical interpretation is that PjBL is especially powerful when it creates repeated opportunities to connect ideas to evidence. Projects typically require students to make decisions, test alternatives, and justify choices. Each of these demands can surface misconceptions and create a need for conceptual tools, which can be supplied through mini-lessons and feedback. This mechanism is less available in purely lecture-based contexts.

Recent classroom studies in Indonesia illustrate how achievement gains can be realized. Pangestu *et al*. (2024) [20] found that PjBL significantly improved elementary students' learning outcomes in science learning. Sutaryani *et al*. (2024) [21] reported improvements in science process skills and learning outcomes in high school physics. Hindun *et al*. (2024) [11] found higher science literacy and collaboration in PjBL groups compared with conventional learning. Collectively, these studies support two conclusions: first, PjBL can improve achievement; second, projects that emphasize inquiry and evidence (process skills, literacy) are particularly aligned with science learning goals.

4.2. Why PjBL Modules Strengthen Interest and Motivation

Motivation and interest outcomes are central to urgency arguments because they are preconditions for sustained learning. The 2024 meta-analysis by Wijnia *et al*. reported that problem-driven learning methods, including PjBL, have a positive overall effect on motivation (d = 0.498). The authors conceptualized motivation as a multifaceted construct consisting of beliefs (competence/control), perceptions of task value (interest/importance), reasons for engaging (intrinsic/extrinsic), and attitudes toward subjects. Their moderator analysis suggested that effects were larger for beliefs, values, and attitudes than for reasons for studying, implying that PjBL can help students feel that learning is meaningful and that they can succeed.

Why might PjBL influence interest? One explanation is the nature of tasks. Compared with conventional instruction, PjBL tasks are often more authentic, open to multiple solutions, and connected to real-life issues. Authentic contexts can trigger situational interest, while sustained inquiry, collaboration, and product revision can help maintain interest (Hidi & Renninger, 2006) [10]. Another explanation is agency: PjBL often gives students a sense of ownership, which increases autonomy and perceived control—key predictors of motivation (Deci & Ryan, 2000) [5].

However, interest is fragile in poorly designed projects. If learners do not understand what to do next, or if projects feel too difficult, interest can quickly drop. This is why modules matter: they embed motivational supports into the learning flow. Autonomy can be supported through bounded choices, competence through scaffolds and frequent feedback, and relatedness through collaboration routines. A module can also reduce uncertainty by making success criteria visible and by providing exemplars and checklists that help students self-monitor progress.

In practical terms, modules should aim to trigger interest early (first session) and then protect it during the "messy middle" of inquiry. The messy middle is when students collect data, face unexpected results, and struggle with coordination. Checkpoints and teacher conferences are essential here. Without them, students may experience repeated failure and interpret it as lack of ability, which reduces both motivation and achievement.

4.3. Design Principles for a PjBL-Based Science Module

A recurring theme in the literature is that effective PjBL requires careful balance between openness and guidance. Projects that are too open-ended may overwhelm students with low prior knowledge; projects that are overly scripted may reduce autonomy and interest. High-quality modules manage this balance by providing structured freedom: choice within clear boundaries, and inquiry within explicit learning goals.

Based on the synthesis, we propose five non-negotiable module elements: (1) a driving question grounded in local or societal relevance, (2) sustained inquiry supported by curated resources and data routines, (3) structured collaboration and role clarity, (4) formative assessment checkpoints with feedback and revision, and (5) public product sharing and reflection (Kokotsaki *et al*., 2016; Markula & Aksela, 2022) [12, 15]. Figure 2 summarizes a pragmatic phase sequence that can be adapted to different IPA topics and grade levels.

Each element can be translated into concrete module components. A driving question needs a short scenario, key constraints, and explicit deliverables. Inquiry needs worksheets with prompts that guide students to generate evidence, not only to search the internet. Collaboration needs roles, norms, and simple tools to manage accountability (e.g., team contracts, peer feedback forms). Formative assessment needs checkpoints and criteria that are shared early, so students can improve during the project rather than after it. Finally, showcase and reflection turn the project into an experience of accomplishment, which supports interest consolidation and future engagement.

Design features should be linked to learning goals, not treated as generic "PjBL steps." For example, if the goal is understanding ecosystems, the module should require students to collect and interpret local data (e.g., schoolyard biodiversity), not merely to create posters. If the goal is understanding energy transfer, the module could require building and testing simple devices and explaining performance differences using scientific concepts. This alignment ensures that student effort is invested in activities that produce learning evidence.

4.4. Practical Assessment Alignment: Measuring Interest and Learning Outcomes

Assessment is where many PjBL implementations succeed or fail. If assessment focuses only on the final product, students may optimize for appearance rather than scientific reasoning. If assessment focuses only on a final test, students may not see the connection between the project and learning. Thus, modules should embed a multi-layer assessment system that captures both process and outcome.

A practical approach is to embed three layers of assessment: (a) checkpoint assessments during inquiry (concept checks, notebook entries, teacher conferences, peer feedback), (b) product/performance assessment using rubrics, and (c) summative achievement assessment aligned with learning objectives. This layered approach supports feedback cycles and increases the likelihood that motivational gains translate into achievement gains.

Measuring motivation and interest can be done with validated instruments and short context-specific measures. For example, the Science Motivation Questionnaire II (SMQ-II) has been validated for measuring dimensions such as intrinsic motivation and self-efficacy (Glynn *et al*., 2011) [9]. At school level, shorter instruments may be used to measure situational interest and perceived relevance, but should be piloted for clarity and reliability if the study is intended for publication.

Importantly, assessment in PjBL should be used to guide learning, not only to judge. Feedback should be timely and specific, ideally linked to rubrics that are shared from the start. When students can see what quality looks like and receive feedback while they still have time to improve, they are more likely to persist and more likely to produce better learning outcomes.

4.5. Implementation Roadmap and Equity Considerations

Implementation feasibility is decisive for module adoption. Teachers may hesitate to use PjBL because of time constraints, classroom management concerns, and uncertainty about assessment. Modules can reduce this barrier by providing a clear timeline, ready-to-use worksheets, and explicit management routines. For example, a module may include a one-page facilitation map for each session: objectives, expected student actions, teacher prompts, materials, and checkpoint evidence.

Teacher roles in PjBL shift from delivering content to facilitating inquiry. This does not mean teachers do less; it means they do different work: circulating, asking probing questions, monitoring misconceptions, and orchestrating productive talk. Modules can support this by including suggested "teacher moves" such as prompts for eliciting explanations, questions for challenging unsupported claims, and ways to redirect groups that are stuck. These supports are especially valuable for teachers who are new to PjBL.

Digital and blended modules can further increase feasibility when they reduce printing needs and provide multimedia resources. However, digitalization is not automatically an improvement; it must be designed for accessibility. Low-bandwidth options (offline PDFs, printable backups) help avoid excluding students with limited devices or connectivity. Hybrid modules—print worksheets supported by optional digital resources—often offer the most equitable path.

Equity is also influenced by project topic selection. Projects that assume expensive materials or out-of-school access may widen gaps. Modules should therefore include resource-light alternatives and encourage project topics grounded in the local environment. In science/IPA, local issues such as waste management, water quality, school biodiversity, energy use, or food systems can provide authentic contexts without requiring costly materials.

Scaling and sustainability depend on building a school-level routine: module review meetings, shared repositories, and short reflection cycles after implementation. Rather than seeking a perfect module on the first attempt, schools can adopt an improvement cycle: implement, collect evidence (student work, engagement indicators), refine module components, and share revisions. This mirrors the iterative nature of projects themselves and increases the likelihood that PjBL becomes embedded in school culture.

4.6. A Worked Module Example to Illustrate Feasibility

To make the design framework concrete, consider an example module for the topic "Ecosystems and Human Impact" in middle school IPA. A driving question could be: "How healthy is our school ecosystem, and what changes would improve it?" The project product might be a school biodiversity report and an improvement proposal. This context is authentic, resource-light, and inherently connected to science practices: students can observe, classify, quantify, and infer relationships.

In Phase 1 (Driving Question & Context), the module presents a short scenario (e.g., increasing litter, declining green space) and shows an example of a simple biodiversity survey. The module asks students to generate initial hypotheses and to set success criteria: what counts as evidence, what counts as a good proposal. To trigger interest, the module can include a brief photo prompt or a short schoolyard walk to notice phenomena.

In Phase 2 (Plan & Roles), students form teams and assign roles (data manager, photographer, map maker, reporter). The module includes a team contract template and a timeline. To support competence, the module provides a checklist of tools and a brief mini-lesson on sampling methods (e.g., transects or quadrats) appropriate for the grade level.

In Phase 3 (Inquiry & Creation), students collect data (species counts, habitat notes, litter density, microclimate). The module provides data tables and prompts that require interpretation, not only recording. For example: "What patterns do you see across locations? What might explain differences?" This is where formative checkpoints matter. The module schedules a teacher conference after the first data collection session so teams can correct methods and refine questions.

In Phase 4 (Feedback & Revision), students draft their report and proposal. The module includes a rubric emphasizing scientific reasoning: claims must be supported by evidence and linked to ecosystem concepts. Peer feedback is structured through a simple protocol: one strength, one question, one suggestion. Students then revise their work based on feedback. This phase supports motivation by making improvement visible; students see that quality is achieved through iteration, not perfection on the first try.

In Phase 5 (Showcase & Reflection), teams present their findings to a real audience (school leadership, other classes). The module provides reflection prompts: What did we learn about ecosystems? What evidence changed our thinking? What was challenging, and how did we handle it? Reflection consolidates learning and supports interest maintenance because students connect effort to outcomes and recognize their own growth.

Assessment is layered. Achievement is measured through a short concept test aligned with ecosystem ideas and through the rubric-scored report. Interest can be measured with a short situational interest scale at the beginning and end, plus reflection data. This worked example illustrates how a module translates PjBL principles into a feasible sequence that supports both learning and motivation.

4.7. Limitations and Research Agenda

Limitations of the evidence base should be acknowledged. First, definitions of PjBL vary across studies, and many interventions combine PjBL with other approaches (e.g., STEM integration, digital media), making it difficult to isolate the contribution of PjBL alone. Second, studies use different instruments for motivation and interest, and some use researcher-developed measures without extensive validation. Third, implementation quality varies widely, and many papers provide limited details about scaffolding and assessment alignment.

Nevertheless, the convergence of meta-analytic evidence with classroom studies suggests that the overall direction of impact is positive. When PjBL is implemented with strong design and support, both motivation and learning outcomes tend to improve. For practitioners, the implication is pragmatic: invest in module quality and facilitation routines rather than adopting PjBL as a label.

Future research should focus on design-to-outcome links: which module features most strongly predict motivational maintenance and conceptual gains? Studies could compare modules with and without specific scaffolds (reflection prompts, formative checkpoints, collaboration structures) to identify high-leverage components. Research is also needed on sustainable teacher support, because module adoption often depends on professional development and leadership support.

Finally, there is a need for more studies that examine long-term interest development. Many interventions measure motivation immediately after a project. Interest development theory suggests that stable individual interest requires repeated experiences over time (Hidi & Renninger, 2006) [10]. Longitudinal studies that track whether PjBL modules influence course selection, persistence, and science identity would strengthen the urgency case further.

Table 1: Core design features of a PjBL-oriented science module and their intended motivational/learning functions.

Module feature	Operationalization in the module	Motivational mechanism (examples)	Expected learning evidence
Driving question & context	A real-world problem/scenario linked to the topic; constraints and product requirements.	Task value, situational interest (relevance, novelty).	Problem statement, initial ideas, success criteria checklist.
Sustained inquiry resources	Curated readings/videos/experiments; inquiry prompts and data tables.	Competence support; reduced cognitive overload.	Investigation notes, data records, interim explanations.
Collaboration structure	Roles, norms, timelines, collaboration rubrics; peer feedback routines.	Relatedness, accountability, social engagement.	Peer feedback logs, teamwork rubric scores, discussion artifacts.
Formative checkpoints	Mini-lessons, concept checks, teacher prompts, revision cycles.	Competence, expectancy for success; maintenance of interest.	Draft iterations, checkpoint quizzes, teacher feedback notes.
Showcase & reflection	Public product sharing; reflection prompts about learning and process.	Autonomy, identity, internalization of value; interest consolidation.	Final product rubric, reflection journal, self-assessment.

Table 2: Selected evidence sources linking PjBL to motivation/interest and learning outcomes in science/IPA contexts.

Source	Design/type	Population/context	Main relevant findings
Chen & Yang (2019) [4]	Meta-analysis (30 studies; 46 effect sizes)	Multiple domains/levels	PjBL showed a medium-to-large positive effect on academic achievement versus traditional instruction (d = 0.71).
Wijnia *et al*. (2024) [24]	Meta-analysis (132 reports; 139 subsamples)	Multiple domains incl. STEM	Problem-driven learning (incl. PjBL) had a small-to-moderate positive effect on motivation (d = 0.498), with larger effects for beliefs/values/attitudes.
Nurhasnah *et al*. (2022) [17]	Meta-analysis (25 articles)	Science subjects across levels	Reported a high overall influence of PjBL on science learning (effect size = 1.67).
Pangestu *et al*. (2024) [20]	Experimental/quasi-experimental	Elementary science (Indonesia)	PjBL significantly influenced learning outcomes and student motivation in science learning.
Sutaryani *et al*. (2024) [21]	Quasi-experimental	High school physics (Indonesia)	PjBL improved science process skills and learning outcomes on the topic of fluids.
Delimanugari (2024) [6]	R&D (ADDIE) module/e-module development	Grade IV IPAS (Indonesia)	Project-based e-module validated and trialed; positive user responses, with revision recommendations.
Hindun *et al*. (2024) [11]	Pretest-posttest control group	Middle school (Indonesia)	PjBL improved science literacy and collaboration; supports broader learning outcomes.

Table 3: Practical measurement options for interest/motivation and learning outcomes in PjBL-based science modules.

Construct	Example measures	Implementation tips within a module
Situational interest / task value	Short interest scale (Likert), relevance ratings, reflection prompts.	Measure at 2–3 points (start, midpoint, end) to track triggering and maintenance of interest (Hidi & Renninger, 2006) [10].
Science motivation (multidimensional)	SMQ-II (intrinsic, self-efficacy, grade/career, self-determination).	Adapt wording for school level; pilot for clarity; report reliability if publishing (Glynn *et al*., 2011) [9].
Achievement (conceptual understanding)	Topic-aligned pre/post tests; constructed-response items; concept maps.	Align items to module learning objectives and inquiry activities; include items assessing explanation with evidence.
Performance/product quality	Rubric for artifacts (accuracy, evidence use, creativity, communication).	Share rubric early; include peer feedback and revision cycles; triangulate with teacher observation.

Table 4: Example concise produact rubric for a PjBL science module (adaptable across topics).

Criterion	Developing	Proficient	Advanced
Scientific accuracy	Some errors; key ideas missing.	Mostly accurate; minor errors.	Accurate and precise; concepts well integrated.
Evidence & reasoning	Claims without evidence.	Uses some evidence; reasoning partly clear.	Strong evidence; clear reasoning linking data to claims.
Investigation quality	Limited data; method unclear.	Adequate data; method mostly clear.	Robust data; method well justified and replicable.
Communication	Unclear visuals/text; hard to follow.	Clear enough; main message understandable.	Engaging and clear; visuals support explanation effectively.

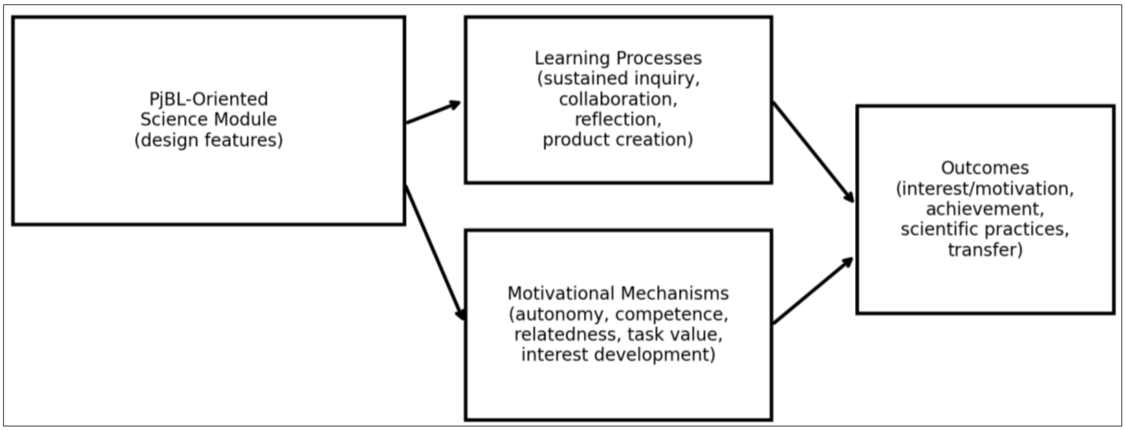


Fig 1: Conceptual framework linking PjBL-oriented science modules to student interest/motivation and learning outcomes.

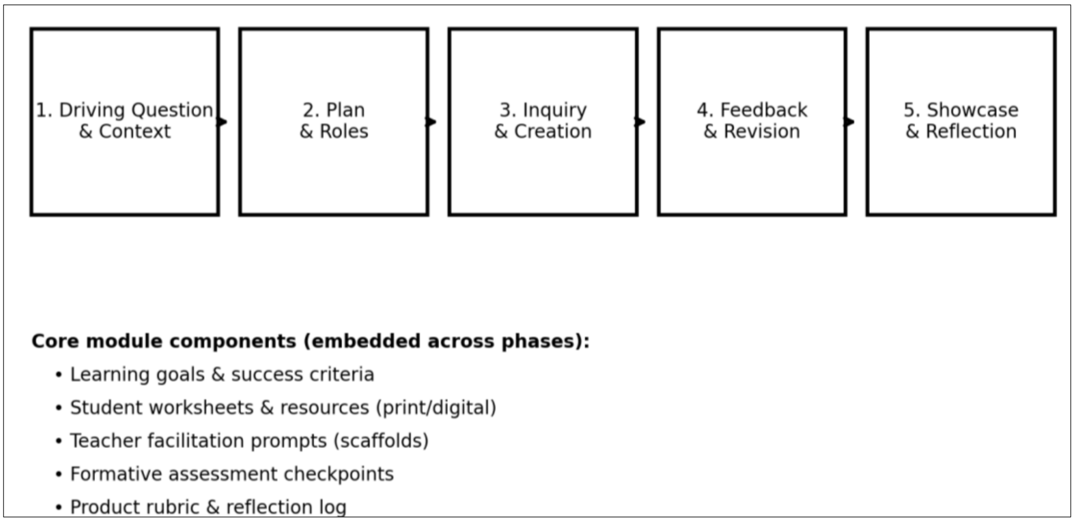
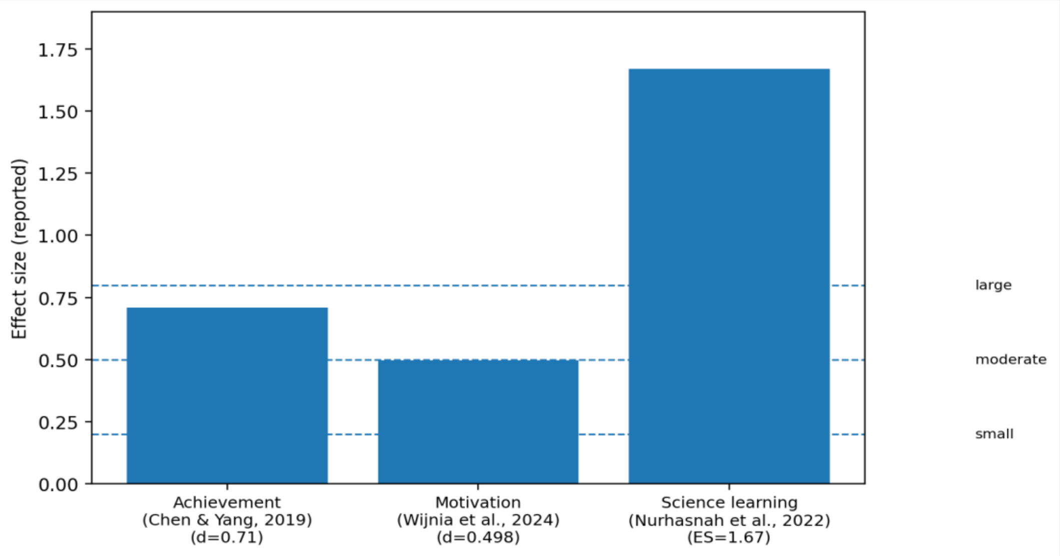


Fig 2: PjBL module architecture: a pragmatic phase sequence and embedded components.



Note: Effect sizes are reported as in the source publications and are not directly comparable across syntheses due to different inclusion criteria and effect size metrics.

Fig 3: Reported effect sizes from selected meta-analyses (achievement, motivation, science learning), included to illustrate magnitude ranges.

5. Conclusion

The urgency of using PjBL-oriented science learning modules lies in the dual need to improve students' interest in science and to raise learning outcomes through richer, practice-oriented learning experiences. Evidence up to 2024 indicates that PjBL can deliver meaningful achievement gains (Chen & Yang, 2019; Nurhasnah *et al*., 2022) [4, 17] and can also improve motivation-related constructs, including interest and task value (Wijnia *et al*., 2024) [24].

However, PjBL is not self-running. High-quality modules are essential to translate PjBL principles into feasible classroom sequences that balance autonomy with guidance, make assessment explicit, and support equitable participation. For practitioners, the practical message is straightforward: invest in module quality (driving question, scaffolds, checkpoints, rubrics, reflection), then implement iteratively with feedback. For researchers and policymakers, the priority is to support scalable module development and teacher capacity so that motivational gains are not occasional successes but routine outcomes.

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