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Developing Guided Problem Based Learning for Critical Thinking and Learning Independence in Elementary Science

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Abstract

This study developed Guided Problem Based Learning (GPBL) and examined its validity, practicality, implementation, critical-thinking changes, and learning independence profiles. Elementary problem-based instruction requires guidance that supports inquiry while transferring responsibility to pupils. An ADDIE study was conducted in three elementary schools in Palangka Raya, Indonesia, from January to June 2026. A limited trial involved 15 pupils, followed by a one-group pretest–posttest trial with 80 pupils. Data comprised expert reviews, essay tests, observations, questionnaires, and interviews. The six-phase model connected contextual problems, clarification, scaffolded discussion, inquiry, reflection, and independent conclusions. Model, content, and language validation reached 91.67%, 92.50%, and 90.83%; pupil and teacher responses reached 88.00% and 90.56%, while implementation reached 83.33%. Mean critical-thinking scores increased from 55.94 to 65.25, a 9.31-point difference, $t(79) = 5.224$, $p < .001$, 95% CI [5.76, 12.86], with $d_z = 0.58$ and a low normalized gain of 0.21. Observed and self-reported independence reached 83.81% and 86.18%. GPBL was feasible and practical in the participating classrooms, with preliminary evidence of improved critical thinking. The uncontrolled design limits causal attribution, while independence measures describe implementation and post-instruction profiles rather than growth.

Keywords: guided problem-based learning; scaffolding; critical thinking; learning independence; elementary science

INTRODUCTION

Elementary science should engage pupils with problems that can be observed, investigated, and explained using evidence. This orientation situates critical thinking within the process of understanding phenomena rather than merely answering test questions. Reviews of science education emphasize connections among learning activities, knowledge, and intended skills (Koyunlu Ünlü & Dökme, 2022; Andrews et al., 2023). For changes of state, these connections can be developed through observations of everyday events and comparisons between explanations and experimental evidence.

Critical thinking involves selecting information, analyzing relationships, evaluating reasons, and drawing defensible conclusions. Its development requires opportunities for practice and assessment aligned with the intended thinking processes (Vincent-Lancrin, 2023; Mastuti et al., 2022). Research on elementary pupils' critical thinking also suggests that support needs should be understood within specific classroom

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contexts (Hartini et al., 2025). Consequently, visibly active participation does not necessarily indicate that every pupil independently evaluates evidence.

Problem Based Learning (PBL) provides a framework for organizing instruction around problems. Conceptual accounts and systematic reviews identify investigation, information seeking, and solution construction as important components (Ardianti et al., 2022; Anggraeni et al., 2023; Yu & Zin, 2023). However, presenting a problem at the beginning of a lesson does not explain how pupils who are not yet ready to manage an investigation will receive support. The design challenge is to provide guidance while ensuring that pupils conduct the reasoning themselves rather than reproduce the teacher's answers.

Research on elementary PBL and contextual learning illustrates varied implementations, including instructional videos and presentation media (Ellyana & Tegeh, 2023; Harahap et al., 2025; Cahyani & Setyaningsih, 2024). Reviews of elementary science PBL also indicate that pedagogical issues should be examined alongside learner characteristics (Kusrianto, 2025). These findings support the relevance of problem-based instruction. Nevertheless, differences in media, content, educational level, and instruments mean that results across implementations cannot be treated as a uniform estimate of impact.

Guidance can take the form of questions, problem representations, procedural directions, and feedback adapted to pupils' difficulties. Research on teacher guidance in elementary inquiry provides a basis for examining scaffolding as responsive classroom action (Sasse et al., 2025). Studies integrating PBL with guided inquiry worksheets and comparing PBL with guided inquiry highlight the need to clarify connections between the problem-solving sequence and investigative support (Anbiya et al., 2023; Juniar & Siahaan, 2024). In other contexts, scaffolding research also connects instructional support with independence and the correction of pupils' errors (Adinda et al., 2024; Purwasih & Rahmadhani, 2022).

Learning independence is operationalized here as engagement, responsibility, initiative, management of resources and time, reflection, and persistence. The term overlaps with self-regulation but is not treated as equivalent to the full construct of self-regulated learning. Elementary education research emphasizes teacher strategies and instructional context in supporting independence (Bukit et al., 2022; Putra Sanjaya, 2021). Confidence and motivation also require consideration when pupils are expected to make decisions about their learning (Laili, 2021; Anyichie & Butler, 2023).

Connections between reasoning and self-regulation provide a rationale for examining critical thinking and independence within the same instructional sequence. Pupils need to decide what information to seek, assess the quality of reasons, and reconsider their strategies (Omarchevska et al., 2022; Simonovic et al., 2023). Prompts and explicit instruction should also be examined in relation to pupils' ability to transfer strategies to subsequent tasks (Pieplenbosch et al., 2024). A model intended to support independence must therefore explain how support is reduced and how individual responses follow collaborative work.

The needs analysis reported in the source dissertation identified teacher-dominated explanations, pupils' difficulties in planning investigations, and a need for more structured worksheets in the participating schools. Teachers required guidance on prompting questions, role allocation, and reflection appropriate for Grade IV pupils. These findings established a local development need; they do not imply that all elementary schools experience identical conditions.

This study develops GPBL as an architecture of support embedded in six instructional phases, from problem presentation to independent conclusions. Its proposed contribution is an operational account of relationships among instructional phases, forms of support, and the transfer of responsibility. The study describes the product and its revisions, evaluates validity and practicality, and examines changes in critical-thinking scores following implementation. Learning independence profiles provide complementary evidence.

Product feasibility, implementation, test-score changes, and the inferential limits of each source of evidence are distinguished throughout.

METHODS

The study employed educational research and development through Analysis, Design, Development, Implementation, and Evaluation (ADDIE) (Branch, 2009). ADDIE provided the product-development framework, while formative evaluation informed revisions to instructions, materials, and guidance strategies. The main product was a GPBL model for science instruction, supported by a model handbook, lesson modules, student worksheets, scaffolding guidance, and assessment instruments. Evaluation criteria distinguished product validity, user practicality, implementation of instructional phases, and preliminary learning-outcome changes.

The study was conducted between January and June 2026, during the second semester of the 2025/2026 academic year, at SDN 6 Panarung, SDN 7 Panarung, and SDN 8 Panarung in Palangka Raya, Indonesia. Schools were purposively selected based on the suitability of the grade and content, teacher willingness, and accessibility for instructional support. The limited trial involved five pupils from each school, totaling 15 pupils. The integrated trial involved 25 pupils from SDN 6 Panarung, 25 from SDN 7 Panarung, and 30 from SDN 8 Panarung, totaling 80 pupils. Participation across the two development stages totaled 95, whereas paired analyses used the 80 integrated-trial pupils.

The analysis phase combined classroom observations, teacher interviews, and document review to identify guidance needs for learning about changes of state. The design phase specified six instructional phases and mapped teacher activities, pupil activities, and indicators of critical thinking and independence. Development comprised material preparation, reviews of the model, content, and language, and revision. The limited trial assessed worksheet readability and usability. Following revision, the integrated trial evaluated the model in Grade IV science classrooms and informed product evaluation.

Validity evidence comprised ratings by three experts in each of the model, content, and language assessment tables, using a maximum score of four. Practicality was examined through responses from pupils and three teachers. Implementation was observed across the six GPBL phases. The critical-thinking test contained ten case-based essay questions addressing selection of important information, identification of relevant information, reasoned solutions, data analysis, conclusions, and solution evaluation. Test scores were reported on a 0–100 scale. Critical-thinking and independence observations each covered eleven indicators. The independence questionnaire was administered after instruction as a self-report measure; it was not treated as a pretest–posttest measure.

Changes in critical thinking were assessed using a one-group pretest–posttest design. Validation and response percentages were calculated by dividing obtained scores by maximum possible scores and multiplying by 100. Test analysis drew on the paired analysis reported in the dissertation, including the mean difference, a 95% confidence interval, and a paired standardized effect. The effect d_z was defined as the mean difference divided by the standard deviation of differences and therefore differs from an effect comparing independent groups. Normalized gain was calculated by dividing the change in group means by the possible improvement toward the maximum score of 100. This represents gain based on class means rather than the mean of individual normalized gains.

Interview evidence, observation notes, and expert suggestions were used descriptively to explain needs and revision decisions. No claim is made to a thematic analysis involving undocumented coding procedures. Detailed assessment tables in the dissertation provided the numerical basis for validity, practicality,

and implementation reporting. Aggregate figures in the summative evaluation summary differed from the detailed tables and were not combined into new estimates because their weighting was not explained.

Reporting remains within the limits of the available source evidence. Individual data, test and questionnaire reliability coefficients, interrater agreement, detailed session counts, and an ethics approval number were not sufficiently available for reporting in this article. These details were therefore neither reconstructed nor assumed. Inferential results are presented as analyses reported in the dissertation and could not be independently reanalyzed from individual records. Schools are identified as research sites, while pupils' identities are omitted.

RESULTS AND DISCUSSION

Model Development and Product Refinement

The needs analysis directed development toward three connected issues: pupils required concrete problems, investigation required structure, and group work needed to lead to individual responsibility. The final product organized teacher support across six phases. Table 1 connects each phase with its support and expected pupil output. This sequence represents the model's operational design; support intensity should still respond to pupil performance rather than change solely because a new phase begins.

Table 1. GPBL Phases and the Transfer of Responsibility

Phase	Teacher support	Pupil output
Guided Problem Presentation	Contextual phenomena and initial questions	Important information and initial predictions
Guided Clarification	Clarification of terms and structured questions	Facts, information needs, and a work plan
Scaffolded Group Discussion	Role allocation and prompts for reasons	Alternative solutions with supporting reasons
Guided Inquiry	Procedural directions and observation tables	Observation data and initial explanations
Guided Reflection	Reflective questions and feedback	Evidence evaluation and revised answers
Independent Conclusion	Monitoring and reduced intervention	Individual conclusions in pupils' own words

During the limited trial, lengthy worksheet instructions were simplified, prompting questions were made more closely related to changes of state, and observation tables were organized into columns for objects, observed changes, and types of change. Roles were allocated because some pupils continued to wait for more active peers. Reflection guidance focused on what pupils had learned and which difficulties remained. These revisions demonstrate that development addressed barriers to material use rather than merely assigning names to instructional phases.

The integrated trial revealed further needs for transition markers, dedicated reflection time, completed-table examples, and graduated prompts. Analysis tasks explicitly requested reasons. A one-page summary helped teachers consult the instructional sequence during lessons. These revisions are consistent with the view that inquiry guidance should respond to classroom conditions (Sasse et al., 2025), while problem-solving support should be reduced to create opportunities for more independent performance (Muslim et al., 2025).

Model Validity and Practicality

Table 2 summarizes detailed product-quality assessments. Model validity reached 91.67%, content validity 92.50%, and language validity 90.83%. These findings indicate expert acceptance of the product and its component alignment. They provide feasibility evidence based on the instruments used, rather than construct-validity coefficients or evidence that GPBL caused all observed learning outcomes.

Table 2. Product Validity and User Responses

Component	Percentage	Assessment basis
Instructional model	91.67%	Rationale, phases, social system, response principles, and support
Science content	92.50%	Content, presentation, and alignment with materials
Language	90.83%	Readability, instructions, and consistent terminology
Pupil responses	88.00%	Usability across the six phases
Responses from three teachers	90.56%	Score of 163 out of 180

Within model validation, the rationale and supporting system received 100%, whereas teacher response principles and classroom implementability each received 83.33%. These differences directed revisions toward how teachers identify support needs and reduce intervention. Language assessment also highlighted instructional clarity and age-appropriate wording. Validation therefore informed refinement rather than serving only to assign a highly valid classification.

Pupils' highest response concerned problem presentation (92%) and their lowest concerned drawing conclusions (83%). Teacher responses showed a similar pattern: problem presentation and information collection each reached 93.33%, while drawing conclusions reached 86.67%. Both user groups perceived the final phase as relatively demanding. This pattern supports materials that facilitate movement from discussion to individual responses. Studies of guided discovery materials and problem-based instruction provide context for designing support alongside activities rather than adding it after instruction has begun (Darmayanti et al., 2023; Maftuh et al., 2023).

Implementation and Critical Points in Reducing Support

Table 3 shows an overall implementation percentage of 83.33%. Problem presentation received the highest percentage, whereas independent conclusions received the lowest. These data locate implementation difficulties more specifically than a single overall score. Successfully initiating learning through a problem was not consistently followed by independent performance at the end of the lesson.

Table 3. Implementation of the Six GPBL Phases

Phase	Percentage
Guided Problem Presentation	95.83%
Guided Clarification	83.33%
Scaffolded Group Discussion	79.17%
Guided Inquiry	91.67%
Guided Reflection	79.17%
Independent Conclusion	70.83%
Overall mean	83.33%

These findings clarify the role of scaffolding in the model. Pupils need to learn how to construct evidence-based responses, while teachers need to avoid taking over their reasoning. Connections between constructivism and PBL provide a framework for understanding dialogue as a space for meaning making (Salsabila & Muqowim, 2024). However, overly uniform support can sustain dependence. Light, moderate, and intensive prompts should therefore be selected according to observable pupil responses and reduced when similar tasks can be completed independently.

The relatively high implementation of inquiry suggests that concrete materials supported observation activities more readily than they supported evaluation of reasons and reflection. Science inquiry reviews and guided inquiry applications position activity organization as an important instructional component (Morris, 2025; Ogunjimi & Gbadeyanka, 2023; Nicholus et al., 2023). Nevertheless, some cited studies concern different educational levels and subjects. They inform design considerations rather than establish equivalent outcomes for the present sample.

Changes in Critical Thinking

Test results for 80 pupils are presented in Table 4. The mean increased by 9.31 points from pretest to posttest. The reported confidence interval excluded zero, and the paired test indicated a statistically significant difference. The paired effect d_z of 0.58 indicates a moderate standardized change, whereas the normalized gain of 0.21 indicates low improvement relative to the maximum possible score. These measures address different questions and should be interpreted together.

Table 4. Summary of Changes in Critical-Thinking Scores

Measure	Result
Number of pairs	80 pupils
Pretest, M (SD)	55.94 (18.30)
Posttest, M (SD)	65.25 (16.48)
Mean difference (SD of differences)	9.31 (15.95)
95% CI of the difference	5.76 to 12.86
Paired test	$t(79) = 5.224$; $p < 0.001$
Paired standardized effect	$d_z = 0.58$
Normalized gain based on group means	0.21; low

Numerically, d_z can be traced to $9.31/15.95 \approx 0.58$, and normalized gain to $(65.25 - 55.94)/(100 - 55.94) \approx 0.21$. These calculations check the consistency of reported summaries but do not replace individual-data analysis. The dissertation refers to an examination of difference-score normality, although complete statistics were unavailable in the results summary. Accordingly, this article does not claim to have independently verified the test assumptions.

Observed critical thinking averaged 84.26%. Selecting important information reached 89.38%, whereas evaluating the strengths and weaknesses of solutions reached 78.75%. This pattern suggests that identifying information was relatively easier than assessing solution quality. Studies of critical thinking through PBL and decision-based learning support activities that require pupils to state the basis for their choices (Wardani & Fiorintina, 2023; Haniko et al., 2023; Plummer et al., 2022). High observation percentages are not equated with test scores because the instruments, task conditions, and levels of assistance differed.

The PBL literature provides conceptual support for examining problems and constructing reasons. However, systematic reviews also document diverse model adaptations (Anggraeni et al., 2023; Yu & Zin,

2023). This study extends that discussion by identifying independent conclusions as a comparatively weak implementation point. Its contribution is local development evidence identifying accepted components and areas requiring further support, rather than a claim that every form of GPBL will necessarily be more effective.

Using evidence, comparing explanations, and questioning reasons can connect science activities with argumentation. Research on science argumentation and project-based science learning identifies task structure as a relevant consideration (Demircioglu et al., 2023; Markula & Aksela, 2022). Meaningful-learning research likewise supports connections between prior knowledge and investigation (Ferreira et al., 2022). In this study, these mechanisms remain plausible theoretical explanations; they were not tested through mediation analysis or systematically coded interaction recordings.

Learning Independence Profiles and Instructional Implications

Observed independence averaged 83.81%, compared with 86.18% on the post-instruction questionnaire. Observed active engagement reached 88.75%, management of time and resources 80.63%, and planning improvements 79.38%. Questionnaire responses followed a similar pattern, with active engagement at 90.00% and improvement planning at 82.50%. Table 5 compares indicators representing strengths and development needs without combining the two methods into a single score.

Table 5. Comparison of Learning Independence Profiles

Indicator	Observation	Post-instruction questionnaire
Active engagement	88.75%	90.00%
Initiative in seeking information	83.13%	85.50%
Time and resource management	80.63%	83.50%
Reflection on learning	82.50%	85.00%
Planning learning improvements	79.38%	82.50%
Mean across all 11 indicators	83.81%	86.18%

Similar patterns in observations and self-reports support the interpretation that participation was stronger than improvement planning. However, the post-instruction questionnaire cannot establish growth without an equivalent baseline. Indicator-level observation summaries also do not establish individual trajectories across sessions. Learning independence profiles is therefore the more appropriate description of these results. The findings are relevant to elementary independence research emphasizing teacher strategies and learning conditions as important supports (Bukit et al., 2022; Putra Sanjaya, 2021).

In practice, teachers should reserve time for reflection, require each pupil to write a conclusion, and examine pupils' reasons before providing complete model answers. Improvement plans can focus on one specific difficulty and one subsequent action. Research on critical thinking in preschool and higher education illustrates the breadth of the discussion, although application to Grade IV requires age-appropriate adaptation (O'Reilly et al., 2022; Campo et al., 2023). Studies of factors associated with critical thinking also remind us that outcomes are not determined solely by the instructional model (Rosmaini, 2023).

Further development should connect critical-thinking objectives with clearly assessable tasks. Problem-based STEM learning offers one context for integrating skills (Alali, 2024), while research on elementary science assessment highlights alignment between indicators and tasks (Putri et al., 2022). In GPBL, this alignment requires questions about evidence and reasons within worksheets, discussions, individual conclusions, and assessment rubrics. Such refinement is more focused than adding activities without examining the thinking processes they demand.

Discussion

Taken together, the findings identify a distinction between making problem-based instruction workable and enabling pupils to reason independently. Expert acceptance and positive user responses indicate that the instructional sequence and its materials were suitable for the participating classrooms. The lower implementation of independent conclusions, however, shows that support during inquiry did not automatically translate into independent performance. The critical-thinking gain and the independence profiles therefore need to be interpreted alongside the phase-level evidence rather than as interchangeable indicators of success.

The contribution of GPBL is its operational connection between problem solving and the gradual transfer of responsibility. This interpretation is consistent with research on responsive teacher guidance (Sasse et al., 2025) and adaptations of PBL for critical thinking (Yu & Zin, 2023). The present findings extend that rationale by locating the transition from collective investigation to individual conclusions as a specific development priority. They do not establish that reduced guidance itself caused the observed score change, because the amount of support and its withdrawal were not separately measured.

Research Implications

For classroom practice, GPBL should be used with an explicit plan for moving from shared investigation to individual explanations. Teachers can use pupils' written reasons and conclusions to decide whether to retain, adjust, or reduce prompts, while reserving time for reflection and a specific improvement plan. Model handbooks and teacher development should therefore emphasize responsive prompting and evidence of individual responsibility, alongside completion of the six phases. The relatively weaker conclusion and improvement-planning indicators provide a focused basis for these refinements.

Research Limitations

Interpretation is limited by the one-group design, purposive school selection, and focus on a single topic. Score changes may relate to the instruction provided, but maturation, repeated testing, teacher attention, and other classroom influences cannot be separated. The paired analysis also did not model pupils' clustering within schools. Statistical significance is therefore not treated as evidence of GPBL's causal superiority over other instruction.

Instrument documentation and data availability further constrain interpretation. Reliability coefficients, interrater agreement, complete test-assumption statistics, and individual records were unavailable for independent verification. The post-instruction independence questionnaire cannot establish change from baseline, and observation percentages cannot be equated with essay-test scores. These limitations restrict conclusions to product development, observed implementation, and preliminary score changes in the participating classrooms.

Future Research and Recommendations

Further evaluation should include a credible comparison group, report instrument reliability and interrater agreement, and measure learning independence at equivalent baseline and follow-up points. Records of the prompts provided and the conditions under which they are reduced would allow the proposed transfer of responsibility to be examined directly. Follow-up across additional science topics and schools should assess whether pupils sustain evidence-based reasoning when teacher support decreases. Before wider testing, the study documentation should also provide the relevant research permissions and consent procedures.

CONCLUSION

This study developed a six-phase Guided Problem Based Learning model that connects contextual problems, clarification, scaffolded discussion, inquiry, reflection, and independent conclusions in Grade IV science. Expert validation of the model, content, and language reached 91.67%, 92.50%, and 90.83%, respectively, while pupil and teacher responses of 88.00% and 90.56% supported its practicality in the three participating schools. Implementation reached 83.33%, with independent conclusions remaining the most demanding phase. Critical-thinking scores increased from 55.94 to 65.25, with a paired standardized change of d_z = 0.58 and a low normalized gain of 0.21; the one-group design limits these results to preliminary evidence of change rather than causal effectiveness. Observed and self-reported learning independence reached 83.81% and 86.18%, respectively, describing favorable profiles with continuing needs in improvement planning and time management. The findings imply that effective use of GPBL requires responsive prompts, protected reflection time, and individual evidence-based conclusions so that collaborative inquiry leads toward greater responsibility. Comparative testing, equivalent independence measures over time, and complete instrument documentation are needed to establish the model's effectiveness and sustainability.

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