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SCIENTIFIC CREATIVITY PROJECT-BASED LEARNING FOR TECHNOLOGY-ORIENTED LEARNING: A VALIDITY AND PRACTICALITY ANALYSIS

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Abstract: This study aimed to develop and evaluate the validity and practicality of the Scientific Creativity Project-Based Learning (SCPjBL) model as an instructional approach that integrates scientific creativity, collaborative inquiry, reflective learning, and character-oriented project engagement. This study employed a research and development design involving 180 undergraduate students from two higher education institutions in Indonesia. Data were collected through expert validation sheets, observation instruments, student response questionnaires, and scientific creativity assessments. Three expert validators and four classroom observers participated in the evaluation process. The results showed that the SCPjBL model obtained a validity percentage of 98.00%, while the supporting learning tools and student response questionnaires achieved 97.00% and 99.00%, respectively. Reliability analysis indicated good internal consistency, with Cronbach's Alpha of 0.85. Classroom observations also showed that the model could be implemented practically in project-based learning activities. These findings indicate that SCPjBL is a valid, reliable, and practical instructional model for promoting scientific creativity, collaborative inquiry, reflective learning, and character-oriented problem-solving in higher education.

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INTRODUCTION

Rapid technological transformation driven by artificial intelligence, Industry 4.0, and digital automation has significantly reshaped educational demands in contemporary learning environments. Educational institutions are increasingly expected to develop learners who are not only academically competent but also capable of interdisciplinary problem-solving, digital literacy, creativity, adaptability, collaboration, communication, and responsible decision-making in complex and rapidly changing situations (Bilderback & Thompson, 2025; Mahapatra et al., 2025; Ukhova & Gabelaia, 2025). Consequently, learning systems need to be redesigned through authentic and technology-supported instructional approaches, including project-based learning, maker spaces, remote laboratories, and work-integrated learning that connect theoretical understanding with real-world applications (Castaño et al., 2025; Muzata et al., 2024; Tassilova et al., 2025). In technology-intensive educational contexts, these competencies are also closely associated with responsibility, collaboration, reflective thinking, and ethical decision-making as important components of character-oriented learning (Feryanto et al., 2025; Patturajan et al., 2026).

In response to these changes, educational research has increasingly emphasized the importance of 21st-century competencies, particularly creativity, critical thinking, collaboration, and communication. Studies indicate that project-based learning (PBL) and technology-enhanced PBL effectively improve higher-order thinking, computational thinking, creativity, and collaborative skills because learners engage in authentic inquiry, iterative problem-solving, experimentation, and reflective learning processes (Feryanto et al., 2025; Kuo, 2026; Patturajan et al., 2026; Saad & Zainudin, 2024; Sukardi et al., 2024; Yusuf, 2025). In STEM and applied learning contexts, PBL also creates opportunities for learners to develop innovative ideas and solutions through interdisciplinary and project-oriented activities (DeLisi et al., 2025; Heydemans et al., 2025; Klieger, 2026). Furthermore, scientific creativity has been theoretically associated with the interaction between scientific knowledge and scientific reasoning, where learners apply conceptual understanding through inquiry, experimentation, analysis, and iterative refinement to produce creative ideas and meaningful solutions (Pinar et al., 2025).

Despite these theoretical and empirical developments, many students in higher education still experience difficulties in developing scientific creativity and reflective problem-solving abilities. Previous studies report that learners often struggle to explore scientific knowledge, analyze phenomena, design investigations, and generate innovative solutions in complex learning contexts. Similar problems were identified during the authors' preliminary observations at the two participating higher education institutions. Students tended to complete project tasks procedurally, relied heavily on lecturer guidance, and experienced difficulty connecting prior scientific knowledge with authentic problems, reflective inquiry, and creative solution development. These challenges are influenced by rigid curricula, limited infrastructure, insufficient teacher preparation, conventional assessment systems, and learning environments that do not adequately support experimentation, inquiry, and idea generation. Initial observations in the learning context of this study also indicated that students tended to focus on completing project tasks procedurally, while their ability to connect prior scientific knowledge with authentic problem-solving, reflective inquiry, and creative solution development still required further instructional support.

These initial findings indicated the need for a structured instructional model that explicitly facilitates prior-knowledge activation, scientific reasoning, collaborative inquiry, and creative problem-solving. The Scientific Creativity Project-Based Learning (SCPjBL) model serves as a solution to the primary issues outlined in the introduction of this article, namely students' limited scientific creativity and reflective problem-solving skills caused by completing project tasks procedurally, relying heavily on lecturer guidance, and struggling to connect prior knowledge with authentic phenomena (Hambali & Mardiya, 2023 and Harahap & Ritonga, 2023). By employing an instructional syntax that explicitly fosters prior-knowledge activation, scientific reasoning, and collaborative inquiry, the SCPjBL model transforms learning from routine project completion into a structured, deep learning experience (Bulut Ates & Aktamis, 2024; Saad & Zainudin, 2024). By seamlessly combining authentic scientific exploration, ongoing reflection, and responsible project engagement, this model effectively addresses instructional barriers while equipping students with essential 21st-century competencies aligned with technology-oriented environments (Abuhassna et al., 2024; Demir, 2024)

Existing instructional models also frequently emphasize project completion without sufficiently activating learners' prior knowledge or integrating authentic problems into inquiry-based learning processes (Al Abri et al., 2024). However, prior-knowledge activation is important because it helps learners connect conceptual understanding with hypothesis formation, experimentation, scientific reasoning, and creative problem-solving in technology-rich learning environments. In this regard, project-based learning should not only guide students to produce project outputs, but also facilitate meaningful inquiry, reflective reasoning, responsible participation, and creative engagement with scientific phenomena (Khadija Muhammad Hussain Marvi et al., 2025; Kranz et al., 2023). Several studies in simulation-based and practice-oriented education have demonstrated that authentic project activities, immersive simulations, and work-integrated learning can improve procedural competence, teamwork, systems thinking, responsibility, and reflective decision-making (Fridyatama, 2024). Nevertheless, limited studies have specifically integrated scientific creativity, prior-knowledge exploration, collaborative inquiry, and project-based learning within a single instructional framework. This gap indicates the need for an instructional model capable of integrating authentic learning experiences, scientific reasoning, reflective inquiry, collaborative problem-solving, and character-oriented engagement through structured project-based learning activities.

Therefore, this study proposes the Scientific Creativity Project-Based Learning (SCPjBL) model as an instructional model that integrates scientific creativity, prior-knowledge activation, collaborative inquiry, and reflective project-based learning. Unlike conventional project-based learning approaches that often focus mainly on project completion, SCPjBL emphasizes the connection between authentic scientific phenomena, students' prior knowledge, creative reasoning, and responsible project engagement. This study aims to evaluate the validity, reliability, and practicality of the SCPjBL model and its supporting learning tools in higher education learning contexts.

RESEARCH METHOD

This study employed a research and development (R&D) methodology to develop and evaluate the validity and practicality of the Scientific Creativity Project-Based Learning (SCPjBL) model in higher education learning contexts. Development-oriented educational research commonly assesses instructional products through expert validation, reliability testing, pilot implementation, and practicality analysis before broader classroom application (Chen et al., 2025; Katende et al., 2026). The study was conducted in Indonesia in 2024 and involved 180 undergraduate students from two higher education institutions. Participants were selected through purposive sampling based on their enrollment in relevant project-based learning activities, previous experience with scientific reasoning and problem-solving tasks, and participation in the classroom implementation of the SCPjBL model. Data were collected using expert validation sheets, implementation observation sheets, student activity observation sheets, student response questionnaires, worksheets, and scientific creativity assessment instruments. Three experts in vocational education, instructional design, and scientific creativity validated the model and its supporting learning tools, while four classroom observers assessed implementation practicality: two observed the SCPjBL instructional phases and two observed student learning activities.

The research procedure included model development, expert review, iterative revision, revalidation, and classroom implementation. During implementation, observers assessed the introduction of scientific phenomena, project planning, scientific knowledge exploration, project-task design, project monitoring, project assessment, and reflection activities. These procedures followed rubric-based and iterative model-development practices(Akhter & Zaman, 2024; Asriyadin et al., 2026; Qian, 2025). Validity was analyzed using mean scores from expert evaluations, with scores of 3.25–4.00 categorized as highly valid, 2.50–$<$3.25 as valid, 1.75–$<$2.50 as moderately valid, and 1.00–$<$1.75 as invalid. Reliability analysis combined inter-observer agreement (IOA) and Cronbach's Alpha testing, following recommendations from instructional-model validation studies (Nsabayezu et al., 2025; Shakeel et al., 2023). Inter-observer agreement was used to determine consistency among observers during classroom implementation, while Cronbach's Alpha measured the internal consistency of multi-item instruments. The minimum acceptable inter-observer agreement was set at 75.00%, whereas Cronbach's Alpha coefficients $\geq$0.70 were considered acceptable for instrument reliability (Izah et al., 2023). Practicality was evaluated from classroom observation scores and interpreted as excellent (3.25–4.00), good (2.50–3.24), fair (1.75–2.49), or poor (1.00–1.74). All data were analyzed using SPSS version 25.

RESULT AND DISCUSSION

Result

Expert Feedback and Revision of the SCPjBL Model

The first stage of the results presents expert feedback on the Scientific Creativity Project-Based Learning (SCPjBL) model and its supporting learning tools. The validation process identified several aspects requiring revision before classroom implementation. The revisions mainly concerned the clarity of instructional objectives, the explicit function of each SCPjBL phase, the alignment between learning outcomes and model objectives, and the quality of supporting instructional materials. The expert review showed that the SCPjBL model required clearer differentiation between instructional objectives directly addressed in the study and broader learning impacts positioned beyond the study scope. The first phase of the model also required revision so that it explicitly facilitated students' prior-knowledge exploration and scientific reasoning through scientific phenomena. In addition, the validators recommended that each phase of the SCPjBL syntax state its intended learning objectives more explicitly. Revisions were also made to the lesson plan, student textbook, and scientific creativity test to improve operational clarity and reduce the possibility of memorization-based responses. Table 1 presents the complete expert feedback and corresponding revisions.

Table 1. Expert Feedback and Revisions of the SCPjBL Model

No	Expert Feedback	Revisions Implemented
1	The objectives of the SCPjBL model require clearer differentiation between instructional objectives and broader learning impacts.	SCPjBL objectives were reorganized into instructional objectives addressed in the study and broader impact objectives beyond the research scope.
2	The first phase of SCPjBL syntax should explicitly facilitate exploration of students' knowledge.	Phase 1 was revised to emphasize students' prior knowledge and scientific reasoning through scientific phenomena.
3	Each SCPjBL syntax phase should clearly state its intended learning objectives.	Explicit learning objectives were formulated and embedded in each SCPjBL phase.
4	Phase 1 needs adjustment based on previous feedback.	The initial Phase 1 activity was revised from presenting creative products to exploring creative knowledge.
5	Lesson plan outcomes should use operational verbs aligned with SCPjBL objectives.	Learning outcomes in the lesson plan were revised using measurable operational verbs consistent with SCPjBL.
6	The student textbook requires additional supporting features.	A glossary and index were added to improve readability and conceptual clarity.
7	Scientific creativity test items should avoid phenomena identical to those in the textbook.	Test items were revised using different but contextually aligned phenomena to reduce memorization.

Table 1 shows that conceptually, the validators emphasized the need to clarify model objectives, strengthen the function of the first learning phase, and specify the learning objectives of each SCPjBL syntax. Technically, the validators recommended improvements to the lesson plan, student textbook, and scientific creativity test. These revisions indicate that the initial model required refinement before classroom implementation, particularly in relation to instructional clarity, learning alignment, and assessment quality.

Validity Evaluation of the SCPjBL Model and Supporting Instruments

After revision, the SCPjBL model and supporting instruments were re-evaluated by the expert validators, and all assessed components were categorized as highly valid. The SCPjBL model obtained mean scores of 3.92 for alignment with development needs and 3.83 for relevance to current scientific knowledge, indicating its appropriateness for supporting scientific creativity-oriented learning in higher education contexts. The supporting learning tools also received highly valid ratings, with scores of 3.67 for content relevance, 3.92 for clarity and appropriateness of language use, and 4.00 for both instructional design quality and completeness of required instructional components. Similarly, the student response questionnaire achieved highly valid results across all indicators, with scores of 4.00 for the introduction of a new learning model, ease of understanding learning activities, and completeness of test instructions, while the clarity of lecturers' explanations when using the SCPjBL model obtained 3.83. Table 2 presents the complete validity evaluation results.

Table 2: Validity Evaluation Results of the SCPjBL Model and Supporting Instruments

Evaluated Aspect	Mean Score	Validity Level
SCPjBL model: alignment with development needs	3.92	Highly Valid
SCPjBL model: relevance to current scientific knowledge	3.83	Highly Valid
Learning tools: content relevance	3.67	Highly Valid
Learning tools: clarity and appropriateness of language use	3.92	Highly Valid
Learning tools: instructional design quality	4.00	Highly Valid
Learning tools: completeness of required instructional components	4.00	Highly Valid
Response questionnaire: introduction of a new learning model	4.00	Highly Valid
Response questionnaire: clarity of lecturers' explanations when using SCPjBL	3.83	Highly Valid
Response questionnaire: ease of understanding learning activities	4.00	Highly Valid
Response questionnaire: completeness of test instructions	4.00	Highly Valid

Table 2 shows that all ten evaluated aspects were categorized as highly valid. Four aspects obtained the maximum mean score of 4.00, namely instructional design quality, completeness of required instructional components, introduction of a new learning model, and completeness of test instructions, while learning tools' content relevance received the lowest mean score of 3.67 but still remained within the highly valid category. These results indicate that the SCPjBL model and its supporting instruments met the required validity criteria across the model, learning tools, and response questionnaire components. This finding was further confirmed by the percentage distribution presented in Figure 1, where the SCPjBL model reached 98.00%, the supporting learning tools 97.00%, and the student response questionnaire 99.00%, placing all evaluated components in the very valid category.

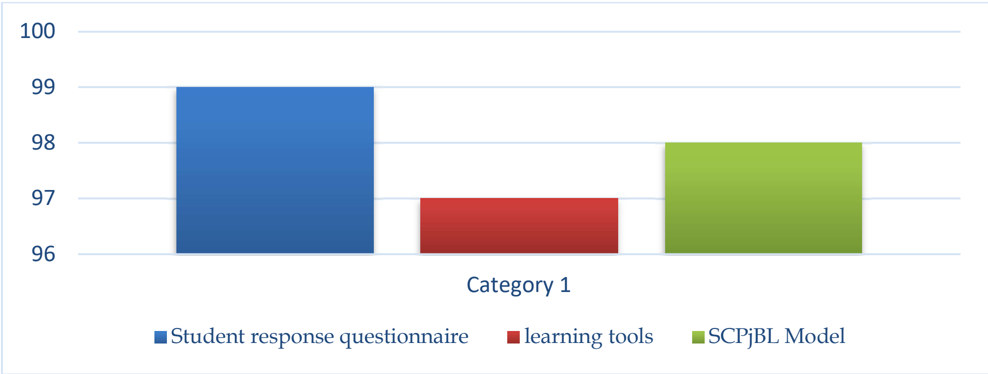

Figure 1. Distribution of Validity Percentages across the Evaluated Components

Based on Figure 1, the student response questionnaire obtained the highest validity percentage, with a score of 99.00%. The SCPjBL model followed with 98.00%, while the supporting learning tools obtained 97.00%. Although the learning tools had the lowest percentage among the three components, the difference between the components was small. This distribution shows that the SCPjBL model, learning tools, and student response questionnaire were consistently rated as very valid by the expert validators.

Reliability Analysis of the SCPjBL Model and Supporting Instruments

Reliability analysis was conducted to determine the consistency of the SCPjBL model validation instrument, learning tools, and student response questionnaire. The results showed that all evaluated components exhibited strong reliability. The SCPjBL model obtained an R calculated value of 0.99, which exceeded the R critical value of 0.98 at $\alpha = 0.05$. The learning tools obtained an R calculated value of 0.95, exceeding the R critical value of 0.94. The student response questionnaire obtained an R calculated value of 0.99, exceeding the R critical value of 0.98. These results indicate that the validation outcomes were consistent across raters and instruments.

Table 3. Reliability Analysis Results of the SCPjBL Model and Supporting Instruments

Evaluated Aspect	R Calculated	R critical value, $\alpha = 0.05$	Reliability Category
SCPjBL model	0.99	0.98	Strong reliability
Learning tools	0.95	0.94	Strong reliability
Student response questionnaire	0.99	0.98	Strong reliability

Table 3 shows that all three evaluated components exceeded their respective critical values. The SCPjBL model and student response questionnaire obtained the highest R calculated values, both reaching 0.99, while the learning tools obtained a slightly lower value of 0.95, which still exceeded the R critical value and was categorized as strong reliability. Cronbach's Alpha analysis of ten assessment items also yielded a coefficient of 0.85, placing the instrument within the good consistency category. Taken together, these results indicate that the expert validation findings were stable and consistent across the evaluated components and that the validation and observation instruments had acceptable internal consistency for assessing the SCPjBL model and its supporting learning tools.

Practicality of Lesson Plan Implementation

The practicality of the SCPjBL model was examined through classroom observations of lesson-plan implementation by two observers across seven project-based learning phases. Overall, the model was categorized as very practical, with average implementation scores of 3.79 from Observer 1 and 3.54 from Observer 2. Observer 1 awarded the highest scores of 4.00 to the scientific knowledge exploration and project implementation monitoring phases, while Observer 2 assigned the highest scores of 3.80 to scientific knowledge exploration, reflective inquiry activities, and assessment of project outcomes based on learning-performance indicators. The greatest difference between observers occurred in the planning of project assignments based on authentic learning scenarios, which received scores of 3.90 and 3.00, respectively. Despite this variation, all scores remained within the practical-to-very-practical range, indicating that the SCPjBL model could be implemented effectively in classroom learning.

Table 4. Observation Results of Lesson Plan Implementation for the SCPjBL Model

Phase	Observer 1	Category	Observer 2	Category
Introduction through authentic scientific phenomena	3.80	Excellent	3.50	Excellent
Planning project assignments based on authentic learning scenarios	3.90	Excellent	3.00	Adequate
Exploration of scientific knowledge and reflective inquiry	4.00	Excellent	3.80	Excellent
Designing and planning project tasks	3.67	Excellent	3.50	Excellent
Monitoring project implementation activities	4.00	Excellent	3.55	Excellent
Assessing project outcomes based on learning performance indicators	3.50	Excellent	3.80	Excellent
Reflecting and evaluating project-based learning experiences	3.67	Excellent	3.67	Excellent
Average	3.79	Very Practical	3.54	Very Practical

Table 4 shows that Observer 1 rated all seven SCPjBL implementation phases in the excellent category, while Observer 2 rated six phases as excellent and one phase planning project assignments based on authentic learning scenarios as adequate. The highest implementation scores from Observer 1 were recorded for the exploration of scientific knowledge and reflective inquiry and for monitoring project implementation activities, whereas Observer 2 assigned the highest scores to the exploration of scientific knowledge and reflective inquiry and to assessing project outcomes based on learning performance indicators. The adequate score for project-assignment planning suggests that this phase may require clearer guidance, more explicit instructions, or more structured support during implementation. Overall, the average scores of 3.79 and 3.54 indicate that the lesson plan was very practical to implement and that the SCPjBL phases could be applied consistently during classroom learning, particularly in scientific knowledge exploration, project monitoring, project assessment, and reflective evaluation.

Practicality of Student Activities in SCPjBL Worksheets

The practicality of the SCPjBL worksheets was evaluated through observations of seven student activity phases, resulting in average scores of 3.72 from Observer 1 and 3.58 from Observer 2, both within the very practical category. The highest scores were recorded for applying scientific knowledge in authentic learning contexts and drawing conclusions from project-based activities, with scores of 4.00 and 3.80 from the two observers. All other phases, including identifying scientific phenomena, collaborative problem-solving, designing solutions, developing project outputs, and analyzing project results, also received excellent ratings.

Table 5. Observation Results of Student Activities in the SCPjBL Worksheet

Phase	Observer 1	Category	Observer 2	Category
Identification of authentic scientific phenomena	3.40	Excellent	3.25	Excellent
Application of scientific knowledge in authentic learning contexts	4.00	Excellent	3.80	Excellent
Collaborative problem-solving skills in learning scenarios	3.67	Excellent	3.40	Excellent
Creative design of solutions or procedures	3.70	Excellent	3.60	Excellent
Development of project outputs	3.52	Excellent	3.67	Excellent
Analysis of project results based on learning performance indicators	3.80	Excellent	3.50	Excellent
Drawing conclusions from project-based learning activities	4.00	Excellent	3.80	Excellent
Average	3.72	Very Practical	3.58	Very Practical

Table 5 shows that both observers rated all seven student activity phases as excellent. The highest scores were recorded for applying scientific knowledge in authentic contexts and drawing conclusions from project-based activities, while identifying authentic scientific phenomena received the lowest scores of 3.40 and 3.25 but remained in the excellent category. Overall, the results indicate that the SCPjBL worksheets effectively supported active, collaborative, creative, and reflective student-centered learning.

Across the validity, reliability, and practicality analyses, the SCPjBL model and its supporting instruments met the required evaluation standards. The model achieved a validity percentage of 98.00%, while the supporting learning tools and student response questionnaire obtained 97.00% and 99.00%, respectively. Reliability was also strong, with calculated R values ranging from 0.95 to 0.99 and a Cronbach's Alpha coefficient of 0.85. In terms of practicality, lesson-plan implementation received average scores of 3.79 and 3.54, while student activities obtained 3.72 and 3.58, resulting in an overall practicality score of 3.66 and an implementation rate of approximately 91.00%. These results confirm that the SCPjBL model was valid, reliable, and practical for higher education contexts, supported consistent measurement, and could be implemented effectively in both lecturer-guided and student-centered project-based learning activities. Its implementation also encouraged collaborative inquiry, reflective learning, responsible participation, and creative problem-solving in authentic learning environments.

Discussion

The findings indicate that the Scientific Creativity Project-Based Learning (SCPjBL) model was valid, reliable, and practical for implementation in higher education learning contexts. The SCPjBL model obtained a validity percentage of 98.00%, while the supporting learning tools and student response questionnaire obtained 97.00% and 99.00%, respectively. Reliability analysis also showed strong consistency, with R calculated values ranging from 0.95 to 0.99 and Cronbach's Alpha reaching 0.85. These findings demonstrate that the SCPjBL model, learning tools, and assessment instruments were conceptually appropriate, structurally coherent, and sufficiently consistent for classroom implementation. These results support previous studies showing that project-based learning creates authentic and iterative learning contexts that strengthen scientific reasoning, creativity, collaborative inquiry, and problem-solving abilities through experimentation, reflection, and project-based activities(Al-Qoyyim & Kurniawan, 2025; AlAli, 2024).

The high validity and reliability results may be explained by the alignment between the SCPjBL syntax, learning objectives, learning tools, and assessment components. The model does not only guide students to complete project tasks, but also structures learning through scientific-phenomena exploration, prior-knowledge activation, project planning, project monitoring, outcome assessment, and reflective evaluation. This alignment made the model relevant to contemporary learning needs that emphasize creativity, collaboration, reflection, responsibility, and problem-solving. Therefore, the SCPjBL model contributes to the development of project-based learning by embedding scientific creativity and reflective inquiry into a structured instructional framework that can be used by lecturers, curriculum developers, and educational institutions.

The practicality findings also show that the SCPjBL lesson plan could be implemented consistently during classroom learning. Most implementation phases were rated excellent by both observers, especially the exploration of scientific knowledge and reflective inquiry, monitoring project implementation activities, and assessing project outcomes based on learning performance indicators. However, the planning of project assignments based on authentic learning scenarios received an adequate score from Observer 2, indicating that this phase may require clearer guidance, more explicit instructions, and more structured project-planning support. These practicality findings align with Vygotsky's Scaffolding Theory (Muhammad et al., 2023 and Tassilova et al., 2025), which asserts that students require structured support (scaffolds) during complex initial stages such as planning authentic projects before they can learn independently. This results indicate that without clear instructions and structure in the initial planning phase, students tend to encounter obstacles, making the provision of more explicit guidance crucial for optimizing project-based learning processes.

This practicality finding suggests that prior-knowledge activation played an important role in supporting students' participation in project planning, scientific reasoning, reflective thinking, and collaborative problem-solving. Previous studies similarly report that eliciting prior knowledge helps learners connect conceptual understanding with hypothesis formation, risk anticipation, and iterative problem-solving processes within authentic learning environments (Johnson, 2026; Zhang, 2026). In the present study, the explicit integration of prior-knowledge exploration into the early phase of SCPjBL appeared to facilitate students' ability to engage more actively in authentic project-based learning activities. This indicates that project-based learning becomes more practical when students are first guided to organize their prior knowledge before entering project-design and problem-solving activities.

The implementation results further indicate that authentic project activities supported the integration of scientific knowledge with reflective learning practices. The strongest student activities appeared in the application of scientific knowledge in authentic learning contexts and drawing conclusions from project-based learning activities. Students were able to identify scientific phenomena, apply scientific knowledge, analyse project results, and develop creative solutions through collaborative inquiry activities. These findings are consistent with studies emphasizing that simulation-based and practice-oriented project learning can strengthen procedural fluency, teamwork, systems thinking, responsibility, and reflective decision-making in technology-intensive educational contexts (Liu et al., 2025; Zhang, 2026 and Schulz, 2024). The strong student activity scores may have occurred because the SCPjBL worksheets guided students through a complete learning cycle, beginning with phenomenon identification and ending with reflective conclusion-making (Buabeng & Amo-Darko, 2025; Isabirye et al., 2025).

This structure helped students move from understanding scientific problems to designing solutions and evaluating project outcomes. The worksheet design also encouraged responsible participation because students were required to engage in collaborative inquiry and complete each project phase systematically. The high student activity scores occurred because the SCPjBL worksheets guided students systematically through a complete learning cycle from identifying scientific phenomena to making reflective conclusions where practice-oriented and simulation-based project learning encouraged students to engage in collaborative inquiry, thereby enabling them to connect scientific knowledge with authentic problem-solving. Furthermore, this structured activity framework directly enhanced students' procedural fluency, teamwork, systems thinking, and reflective decision-making throughout the learning process.

This study contributes to the development of instructional models by integrating scientific creativity, prior-knowledge activation, collaborative inquiry, and authentic learning experiences within a single project-based learning framework. Existing studies have widely discussed project-based learning and scientific creativity separately; however, fewer studies have specifically examined their integration within character-oriented and reflective learning contexts. The SCPjBL model therefore expands project-based learning applications by embedding scientific reasoning, reflective inquiry, responsibility, and creative problem-solving directly into authentic learning activities.

CONCLUSION

This study demonstrates that the Scientific Creativity Project-Based Learning (SCPjBL) model is valid, reliable, and practical for implementation in higher education learning contexts. The model, supporting learning tools, and student response instruments fulfilled expert-validation standards and showed consistent classroom implementation, indicating that scientific creativity can be systematically integrated into project-based learning through structured inquiry, prior-knowledge activation, collaborative problem-solving, reflective learning, and responsible project engagement. The main lesson from this study is that project-based learning becomes more meaningful when students are not only directed to complete project outputs, but are also guided to explore scientific phenomena, connect prior knowledge with authentic problems, develop creative solutions, and reflect on their learning processes. Practically, the findings imply that educational institutions, lecturers, and curriculum developers should design learning environments that combine authentic learning problems, scientific reasoning, collaboration, reflection, and character-oriented participation. However, this study was limited to validity, reliability, and practicality evaluation in two higher education institutions and did not examine long-term learning transfer, effectiveness, or broader educational outcomes. Future studies are therefore recommended to investigate the effectiveness of SCPjBL across broader educational contexts, longer implementation periods, and longitudinal learning outcomes to strengthen evidence regarding its scalability and sustainability.

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