MODESTUM EURASIA Journal of Mathematics, Science and Technology Education, 2025, 21(11), em2725
ISSN:1305-8223 (online)
OPEN ACCESS Research Paper https://doi.org/10.29333/ejmste/17287

Development of STEM hybrid research-based learning model to improve scientific reasoning of undergraduate students

Ahmad Swandi [1,2], Eko Hadi Sujiono [3*], Khaeruddin [3], Abdullah Sinring [4]

[1] Doctoral Program in Educational Sciences, Postgraduate Program, Universitas Negeri Makassar, Makassar, INDONESIA
[2] Science Education Study Program, Universitas Bosowa, Makassar, INDONESIA
[3] Department of Physics, Universitas Negeri Makassar, Makassar, INDONESIA
[4] Department of Guidance and Counseling, Universitas Negeri Makassar, Makassar, INDONESIA

Received 25 June 2025 ▪ Accepted 23 September 2025

Abstract

This study aims to design and evaluate a STEM hybrid research-based learning (STEM-Hybrid RBL) model to enhance undergraduate students' scientific reasoning skills. This research adopted a design and development methodology, comprising six stages: problem identification, literature review, prototype design and development, prototype testing, evaluation, and dissemination. Expert validation revealed high content validity for all aspects. Practicality tests involving lecturers and students showed that the model is easy to implement and well-aligned with science learning needs. Effectiveness was tested using the t-test showed a value of $t(48) = -4.670$ with $p < 0.001$, which means there is a significant difference between the means of the two groups. These findings indicated that the STEM-Hybrid RBL model is pedagogically sound, practically applicable, and effective in supporting students' scientific reasoning development in higher education. Integrating STEM principles with hybrid research-based learning addresses constraints in laboratory access and fosters active, contextual, and collaborative learning.

Keywords: STEM, hybrid research-based learning, scientific reasoning, model development, science education

INTRODUCTION

In the context of 21st century education, the need for students to develop advanced thinking skills particularly in science and technology has become increasingly urgent. Scientific reasoning is widely recognized as a foundational skill in science education, contributing to students' ability to construct knowledge, solve problems, and engage in evidence-based argumentation (Fischer et al., 2014; Kambeyo, 2018). However, evidence from large-scale assessments and research studies shows that students' scientific reasoning skills remain underdeveloped in various educational settings. Jufri et al. (2016) reported that pre-service science teachers in Indonesia demonstrated low scores across several reasoning indicators. Similarly, Piraksa et al. (2014) found that Thai students showed limited competency in hypothesis formulation and variable control, with scores ranging between 0.3 and 0.5 out of 1.

These empirical findings are consistent with our preliminary evaluation of science education students at two universities in Makassar, where the average scientific reasoning score was only 27.5 out of 100. This situation suggests a broader, systemic issue in science learning, one that is often attributed to the continued dominance of conventional teaching methods that prioritize memorization over conceptual engagement and inquiry (Fikriana et al., 2023; Sumarni & Kadarwati, 2020). In such settings, students are rarely given the opportunity to design experiments, test hypotheses, or

This study is part of the thesis of the doctoral program in educational sciences, postgraduate program, Universitas Negeri Makassar, Indonesia.

✉ ahmad.swandi@student.unm.ac.id ✉ e.h.sujiono@unm.ac.id **(*Correspondence)** ✉ khaeruddin@unm.ac.id
✉ abdullah.sinring@unm.ac.id

Contribution to the literature

- This paper shows that STEM-Hybrid RBL can be an alternative in overcoming the limitations of experimental activities due to lack of laboratory capacity and facilities
- This study shows that STEM-Hybrid RBL and its supporting devices can be used to develop scientific reasoning skills.
- This study shows that design and development research (DDR) can be used as a methodology in developing learning models.

reflect on data, which are essential practices for developing scientific reasoning. Compounding this issue is the widespread limitation of laboratory infrastructure in many higher education institutions. In addition, conventional learning which is widely applied in science learning has not fully impacted scientific reasoning skills.

Conventional learning generally still conveys memorization and minimal scientific reading activities, so it does not support the development of contextual and applicable scientific skills (Fikriana et al., 2023; Martawijaya et al., 2023; Sumarni & Kadarwati, 2020). In addition, limited laboratory facilities and experimental activities (Swandi et al., 2020, 2024) and the lack of application of cross-disciplinary approaches such as STEM also end this situation (Martawijaya et al., 2023; Pramesti et al., 2022). The use of technology in learning has not been optimally utilized, thus hindering the creation of active, exploratory, and meaningful learning experiences (Yu et al., 2023). Moreover, science learning is more dominated by theoretical learning in class, and memorization that does not guide students in improving their thinking skills (Martawijaya et al., 2023; Sumarni & Kadarwati, 2020). Therefore, learning strategies and innovations are needed that can overcome these problems.

Recent studies have increasingly emphasized the need for integrated STEM education approaches that not only deliver subject content but also cultivate higher-order thinking skills, such as scientific reasoning, in authentic contexts (AlAli, 2024; Zhan & Niu, 2023). Research-based learning has been shown to foster these competencies by engaging students in inquiry processes that mirror real scientific investigations, promoting both conceptual understanding and transferable skills (Al-Thani & Ahmad, 2025; Brew & Saunders, 2020). In higher education, the combination of STEM integration and research-based pedagogy has proven effective in preparing students for complex problem-solving and interdisciplinary collaboration (Chittum et al., 2017; Van den Beemt et al., 2020). However, few studies have explored how these approaches can be adapted for contexts with limited laboratory resources while maintaining their effectiveness in developing scientific reasoning. Addressing this gap, the present study proposes and evaluates the STEM hybrid research-based learning (STEM-Hybrid RBL) model, guided by a conceptual framework that integrates sociocultural, cognitive, meaningful learning, and connectivist perspectives to support student engagement and learning outcomes.

This model combines the STEM approach with research-based learning, which is designed to encourage collaboration, exploration, and problem solving in an integrated manner among students (DeMara et al., 2021; Pramesti et al., 2022). The hybrid approach that combines online and offline learning allows for the use of digital technology, especially in educational environments with limited laboratory infrastructure (Palloan & Swandi, 2019; Swandi et al., 2024). The cross-disciplinary projects that are part of this model also make a positive contribution to enriching students' learning experiences and broadening their understanding of science concepts in real-life contexts (Pramesti et al., 2022).

Although models such as project-based learning and problem-based learning have been widely implemented in science education and are known to support critical thinking and problem-solving (Pramesti et al., 2022; Sumarni & Kadarwati, 2020), they often lack a systematic integration of authentic research processes. Most existing studies emphasize project completion or problem-solving scenarios but it is still lacking in guiding students to conceptualize problems, and then collect and synthesize data, and find solutions (Miller & Krajcik, 2019). In contrast, the present study focuses on a STEM-Hybrid RBL model that not only integrates cross-disciplinary STEM concepts but also positions students as active researchers even when access to physical laboratories is constrained by utilizing digital tools such as action cameras and blended learning environments. In addition, not many have studied in depth the hybrid model that systematically integrates research-based learning strategies to improve students' scientific reasoning through laboratory activities that have limited tools (Swandi et al., 2024).

The development of a STEM-Hybrid RBL model that is designed contextually and responsive to these needs is important to create a learning framework that encourages students to become active and reflective learners to withstand future challenges (Blotnicky et al., 2018) and have strong concept understanding and scientific communication skills (Fikriana et al., 2023). In addition, by implementing hybrid research learning, the problem of various educational institutions that do not carry out research activities due to laboratory capacity can be overcome.

Thus, the STEM-Hybrid RBL model not only answers the views in previous studies but also makes a significant contribution in creating contextual, collaborative, and research-based learning experiences and provides references and innovative solutions. This model has great potential to increase student engagement, deepen their understanding of science concepts, and strengthen scientific thinking skills in accordance with the demands of 21st century education (Aristika et al., 2021). Therefore, this study aims to develop a valid, practical, and effective STEM-Hybrid RBL model to improve students' scientific reasoning skills. This learning model is expected to improve the quality of science learning and provide students with learning experiences that are appropriate and relevant to the present.

Research Questions

Based on the above rationale, the research questions addressed in this study are as follows

1. How is the conceptual framework of the model?
2. What is the validity level of the developed model?
3. How practical is the model in implementation?
4. How effective is the model in improving students' scientific reasoning skills?

METHOD

Research Design

This research is a DDR that aims to develop a valid, practical, and effective STEM-Hybrid RBL model. The research stages are adjusted to answer the problem formulation and are adjusted from various stages of previous DDR research (Ellis & Levy, 2010). The research stages are problem identification, literature review, prototype design and development (using the ADDIE model), prototype testing; evaluation of test results, and dissemination of research results. The ADDIE model, commonly used in instructional design, was selected due to its systematic and iterative nature, which aligns with the objectives of developing, testing, and refining a new instructional model (Abuhassna et al., 2024; Omoregie et al., 2025).

The complete research process is illustrated in Figure 1, depicting the integration of qualitative and quantitative approaches at each stage. During the problem identification and literature review phases, qualitative methods such as interviews, document analysis, and triangulation involving students, lecturers, and self-evaluation reports were employed. These findings informed the development of the conceptual design and instructional framework.

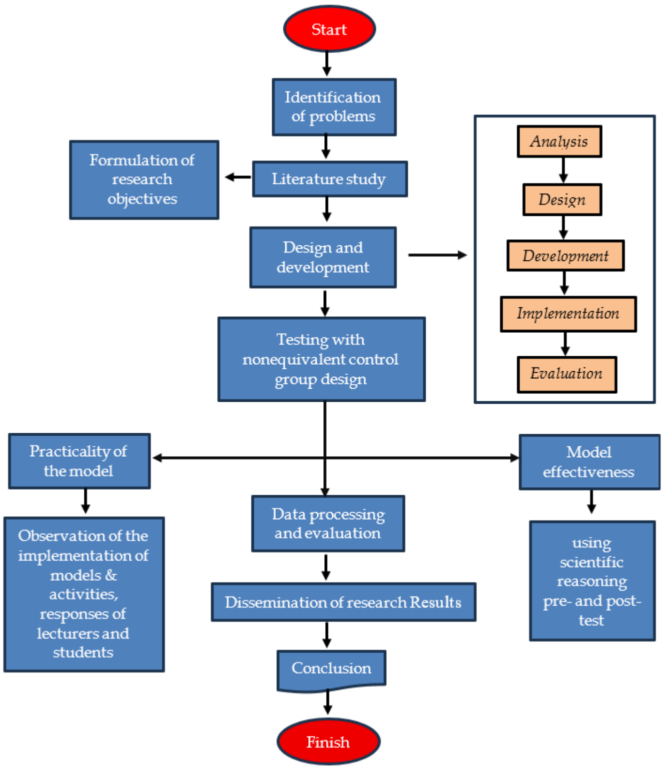

Figure 1. Research flow and data collection methods in STEM-Hybrid RBL model development (Source: Authors' own elaboration)

In the design and development phase, the instructional development followed the ADDIE model. This stage began with a needs analysis for model development, followed by the design of the model and its supporting instructional tools. Three lecturers served as expert validators of the model, student worksheet and material book. Their evaluations formed the basis for revisions, resulting in prototype I. This prototype was then implemented in both individual and group trials. During these stages, the same three lecturers facilitated the learning sessions, observed student engagement, and provided formative feedback, which guided the revisions leading to prototype II.

In the subsequent field implementation, fifteen lecturers were involved in evaluating the model's practicality, while fifty students participated in the model's practicality and testing process, divided into control and experimental groups. All students used the same instructional tools and worksheets. However, prototype I and prototype II were only applied during the individual and group trial stages. At each stage of the trial, both quantitative data (from validity, practicality, and effectiveness rubrics) and qualitative data (including written feedback, observation notes, and group discussions) were collected and analyzed. This iterative process ensured that the final model (prototype III) was informed by both empirical evidence and participant-centered insights, enhancing its contextual relevance and instructional robustness.

Research Subject

The subjects in this study were divided into two parts, namely lecturers and students at one university in Indonesia. There were 15 science education lecturers (six male and nine females). The individual trial involved three students, while the group trial involved 12 students. Furthermore, the field trial involved 50 students (divided into two, namely the experimental class that given treatment in learning using STEM-Hybrid RBL and the control class taught using conventional methods). The sample for each trial was different but shared similar characteristics: fourth-semester elementary school teacher education students taking an integrated science course.

Instrument

The instruments used in this study consisted of validity, practicality, and effectiveness assessments, with a focus on evaluating students' scientific reasoning skills. To address the first research objective, qualitative methods were employed, including document analysis, interviews with students and lecturers, and triangulation of institutional data. For the second objective, expert validation rubrics were used to evaluate the model's structure, integration of STEM components, and content relevance (**Appendix A**). Validity was measured using a 5-point Likert scale. The third objective was examined through observational checklists and feedback forms completed by both lecturers and students during limited trials and field implementation. Practicality was determined based on their responses regarding the usability and clarity of the model, student worksheets (**Appendix B** and **Appendix C**), and instructional materials. The practicality data were analyzed using a 5-point Likert scale to generate a composite score. For the fourth objective, pre- and post-tests were conducted using scientific reasoning instruments (**Appendix D**). These instruments measured five sub-indicators: conservation reasoning (CR), identification and control of variables (ICV), proportional reasoning (PR), correlational reasoning (CoR), and Hypothetico-deductive reasoning (HR). The scientific reasoning test used a two-tier multiple-choice format, adapted from Lawson and Hanson (2016).

Data Analysis

The final validity value uses the Aiken's V equation with five categories, namely invalid ($V \leq 0.00$), low validity ($0.001 \leq V \leq 0.400$), moderate validity ($0.401 \leq V \leq 0.600$), high validity ($0.601 \leq V \leq 0.800$), and very high validity ($0.801 \leq V \leq 1{,}000$) (Novitra et al., 2021). If all items and aspects are declared valid, the next step is to calculate the reliability using the Cronbach's alpha equation. The percentage of practicality based on lecturer and student assessments is obtained by comparing the assessment score with the maximum value with five categories, namely not practical ($0 \leq P \leq 20$), less practical ($21 \leq P \leq 40$), quite practical ($41 \leq P \leq 60$), practical ($61 \leq P \leq 80$), and very practical ($81 \leq P \leq 100$) (Novitra et al., 2021).

The science reasoning skills score is calculated by comparing the score obtained by each student with the maximum score. The assessment is categorized based on 5 indicators, namely very low ($0 \leq N \leq 29$), low ($30 \leq N \leq 64$), sufficient ($65 \leq N \leq 79$), high ($80 \leq N \leq 89$), and very high ($90 \leq N \leq 100$) (Novitra et al., 2021). To find out whether the application of the STEM-Hybrid RBL model is effective in improving scientific reasoning skills, it was analyzed using descriptive statistical tests and independent t-test of gain value tests to compare the increase in scientific reasoning between the experimental class and the control class, by first determining whether the initial abilities (pre-test) of both classes are identical using an independent t-test or Mann-Whitney U test. If there is no significant difference in the initial test scores of the two groups, then an analysis will be carried out to see whether there is a significant difference in the increase in scientific reasoning skills, using an independent t-test on the gain value. While this study used a quasi-experimental non-equivalent control group design, the findings may be cautiously generalized to similar populations particularly in teacher education programs with comparable student characteristics and instructional contexts

RESULTS

Designing a Conceptual Framework for STEM-Hybrid RBL

The STEM-Hybrid RBL model draws upon multiple educational theories–Vygotsky's sociocultural theory, Piaget's cognitive theory, Ausubel's meaningful learning theory, and Siemens' connectivism theory–within a contextual learning paradigm that values real-world relevance and social interaction. Vygotsky's theory highlights the role of social interaction and cultural context in cognitive development, with learning occurring through collaboration in the zone of proximal development (Erbil, 2020; Mohammed et al., 2020). This underscores the model's emphasis on group work and collaborative problem-solving. Piaget's constructivism addresses cognitive development stages, where students build knowledge on existing cognitive structures (Kamaluddin et al., 2023). The model applies this by creating developmentally appropriate tasks that link new information to prior knowledge, fostering deeper understanding and retention.

Ausubel's meaningful learning theory emphasizes linking new concepts to prior knowledge through structured learning and advanced organizers (Agra et al., 2019), a principle embedded in contextual activities that bridge theory and practice. Siemens' connectivism

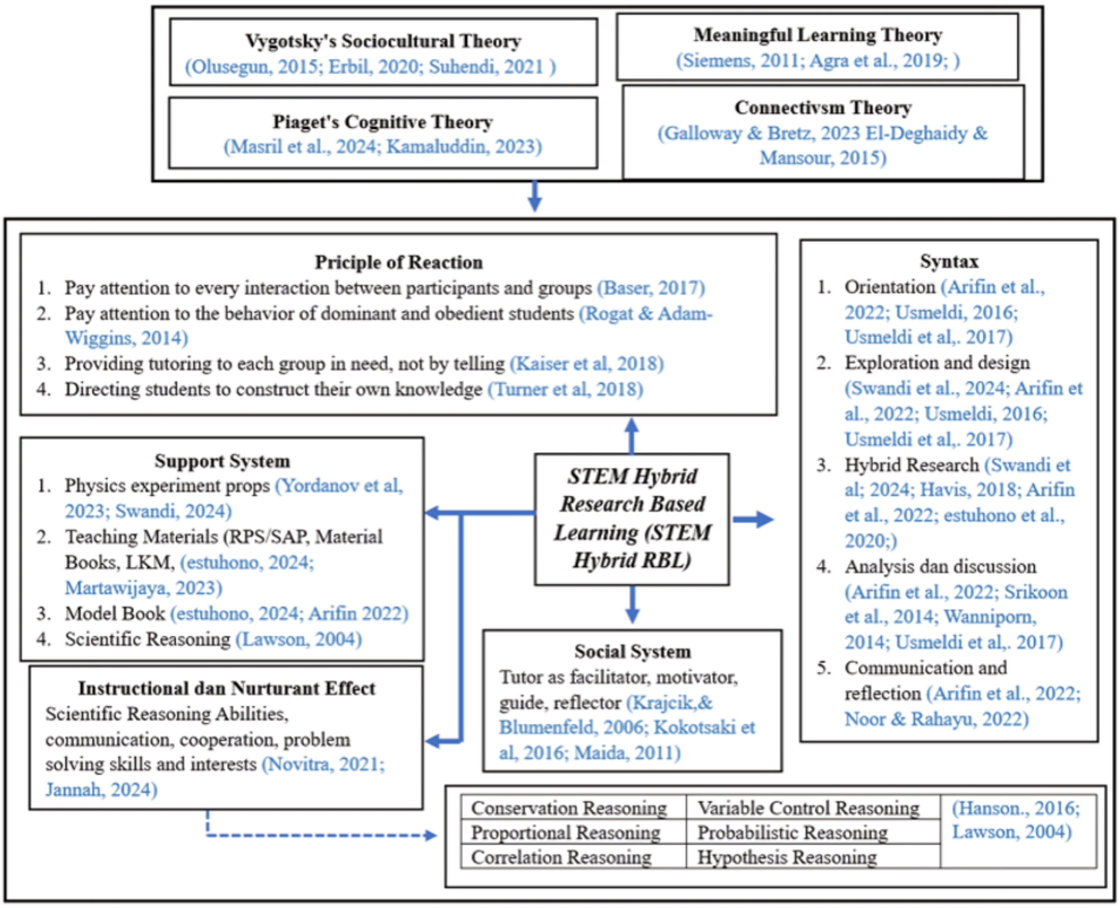

Figure 2. Conceptual framework of the STEM-Hybrid RBL model (Source: Authors' own elaboration)

theory views knowledge as distributed across networks, with learning occurring through navigating and leveraging these connections (Galloway & Bretz, n. d.). Within the STEM-Hybrid RBL model, this translates into the strategic use of digital tools and collaborative networks, encouraging students to access diverse resources and perspectives in a dynamic, interconnected environment.

The STEM-Hybrid RBL model is built on the contextual learning paradigm, which states that learning is most effective when placed in a real-world context (**Figure 2**). This approach emphasizes the relevance of learning to students' lives and future careers, making it more meaningful and engaging. By combining real-world problems and interdisciplinary projects, this model encourages students to apply their knowledge in practical situations, increasing their understanding and retention of STEM concepts (Saldarriaga-Zambrano, 2024).

The STEM-Hybrid RBL model combines these theories to create a learning experience that is

(1) student-centered, encouraging independent exploration and development of knowledge,

(2) contextually relevant, through group-based research projects connected to real-world problems,

(3) optimally integrating technology, creating a hybrid environment that supports evolution and innovation, and

(4) enhancing scientific reasoning skills with the integration of STEM and research-based learning.

Based on these theories, the model was developed by compiling the STEM-Hybrid RBL components consisting of

(1) syntax,

(2) social system,

(3) reaction principle,

(4) support system, and

(5) instructional impact and accompaniment.

The position of the STEM-Hybrid RBL model against other learning models and being the state-of-the-art in this study can be seen in **Table 1**. **Table 1** shows that the syntactic novelty of the STEM-Hybrid RBL model is the integration of ICT that accommodates student activities at each phase. The goal is to train creativity, critical thinking, collaboration, and communication skills integrated with ICT literacy to students. In addition, it also aims to overcome the problem of learning hours in class that have not been able to accommodate all steps of the previous inquiry-based learning model

Table 1. Comparison of research-based learning mode syntax

Brew and Saunders (2020)	Wannapiroon (2014)	Usmeldi (2016)	Haviz (2018)	STEM-Hybrid RBL
Identity unknown, knowledge	Structuring and analyzing problems	Introduction	Facing problems	Introduction: Issues and challenges; zoom connection with action camera
Choose the knowledge you want to know, choosing a relevant topic		Providing references	Data verification collection	Concept exploration and design: Proposing hypotheses, exploring concepts, designing experimental tools
Structured assignment of tasks, inquiry	Designing and planning research	Action/up	Experimental data collection	Hybrid research: Testing experimental tools and data collection
Audience and negotiation	Analysis		Formulation and explanation of the process, research analysis process	Data analysis and discussion: Data analysis to test the hypothesis
Assessment, delivery, new understanding by students	Presenting research findings	Discussion and evaluation		Communication and reflection: Drawing conclusions, hybrid reflection

The STEM-Hybrid RBL model comprises five phases (Arifin et al., 2022; Usmeldi, 2016; Usmeldi et al., 2017). The introductory phase engages students with contextual challenges, clear learning objectives, and research activities supported by triggers, motivation, Zoom access, and action cameras for hybrid learning (Swandi et al., 2024). In the concept exploration and design assistance phase, students receive a conceptual framework, identify relevant theories, and design experimental tools using the STEM approach in worksheets. The hybrid research phase involves testing tools and collecting data with lecturer guidance, conducted both in person and online via action cameras (Brew & Saunders, 2020). During the data analysis and discussion phase, lecturers support data analysis, interpretation, and discussion of results based on research questions and worksheets (Haviz, 2018; Wannapiroon, 2014). The communication and reflection phase concludes the process with student presentations, peer feedback, and guided reflection to consolidate learning.

A close comparison of the syntax elements across the models by Brew and Saunders (2020), Wannapiroon (2014), Usmeldi (2016), and Haviz (2018) reveals several shared stages in research-based learning, such as topic selection, data collection, and analysis. However, the STEM-Hybrid RBL model developed in this study introduces distinct features that reflect current technological and pedagogical demands. For instance, while earlier models begin with conventional methods of structuring problems and planning research, the hybrid model incorporates synchronous online discussions and documentation via action cameras, offering students a more immersive and contextualized entry point. Moreover, the design phase not only includes hypothesis generation and conceptual exploration but also emphasizes the hands-on development of experimental tools, a step that is less visible in previous models. Another notable distinction is the final stage of "hybrid reflection," where students are encouraged to engage in both individual and collaborative reflection, combining live feedback with recorded insights. These modifications position the STEM-Hybrid RBL model as more adaptive and relevant, particularly in resource-constrained or blended learning environments.

With the existence of scientific activities, students through research-based learning with a STEM approach are expected to be able to build their knowledge from various problems/phenomena that they find in everyday life in more depth. In STEM-based learning, students use science, technology, engineering, and mathematics in real contexts that connect their environment to develop STEM literacy in a concept, phenomenon, law and principle of science. Through this, they are able to study through various scientific perspectives so that the understanding obtained will be broader and deeper. The use of hybrid methods with the help of zoom and action camera applications allows the limitations of lab facilities to be overcome so that all students can participate in research-based learning with the help of ICT.

The principle of stress reaction in the role of lecturers as facilitators in

(1) Paying attention to every interaction between students and workers in groups (Baser et al., 2017),

(2) Paying attention to dominant and obedient student behavior (Rogat & Adams-Wiggins, 2014),

(3) Providing guidance to each group for those in general need, and

(4) Directing students directly to build their knowledge.

Table 2. Results of the model validation and supporting tools analysis

Product	Assessment aspects	Average validity	
		Score (V)	Description
STEM-Hybrid RBL model	Supporting theories	0.99	Very high
	Syntax	0.96	Very high
	Social system	0.94	Very high
	Reaction principle	0.94	Very high
	Support system	1.00	Very high
	Instructional impact & accompanying impact	0.96	Very high
	Implementation of learning	0.98	Very high
	Learning environment and management tasks	1.00	Very high
	Evaluation	0.96	Very high
Student worksheet	Table of contents of student worksheet	0.78	High
	Language and illustrations	0.83	Very high
	Presentation	0.80	Very high
	Enhancing innovation and collaborative learning	0.94	Very high
Material book	Content eligibility	0.84	Very high
	Presentation eligibility	0.93	Very high
	English eligibility	0.91	Very high
	Book content graphic design	0.94	Very high
Science reasoning assessment	Material	0.89	Very high
	Construction	0.86	Very high
	Language	0.90	Very high

The model support system is all the main and supporting devices needed in learning (Estuhono, 2022; Hanson, 2016; Yordanov et al., 2023) consisting of

(1) action camera integrated with the zoom application,

(2) teaching materials,

(3) syllabus,

(4) semester learning plan,

(5) student worksheets, and

(6) assessment books.

The impact of the implementation model is divided into two, namely instructional impact which is designed to improve science reasoning skills and accompanying impact (Novitra et al., 2021) are a sense of communication and teamwork, problem-solving skills and interest (Jannah et al., 2024). This model combines strategies to foster curiosity, such as asking open-ended questions, encouraging exploration, and providing opportunities for students to pursue their interests within a STEM framework.

Validity of STEM-Hybrid RBL

The products validated by 3 experts are each physics material expert, STEM approach expert, and learning model expert. Product validation is done in written form and discussed until the validator agrees that the developed product is declared valid. **Table 2** shows the results of the validation analysis reviewed from various aspects for the 3 materials developed.

Based on the validation results, the STEM-Hybrid RBL product was declared valid with a very high category. The model obtained a validity score between 0.94 and 1.00 in all aspects. The student worksheet showed high to very high validity, with the highest score in the aspect of improving learning quality and the lowest score in the content of the student worksheet. The book material was validated with a very high score in all aspects. Likewise, the scientific reasoning assessment instrument was validated very highly. These results indicate that all product components have met the feasibility criteria and are ready to be used in learning. These findings demonstrate that the model was built upon a strong theoretical foundation, aligning with educational theories such as those of Piaget (1973), Novak (2010), and Vygotsky (1978), which emphasize the role of structured experiences in cognitive development.

Formative Evaluation of Prototypes I-III

In line with the principles of DDR, the development of the STEM-Hybrid RBL model was carried out through a series of iterative trials and refinements. These formative evaluations were essential to ensure that each version of the prototype addressed emerging challenges and aligned with the intended learning objectives. A summary of the evaluation findings and adjustments made at each stage is presented in **Table 3**.

Prototype I, reviewed by three expert lecturers, revealed misalignments in the model's syntax and a lack of clarity in integrating STEM tasks with research elements. Revisions at this stage involved restructuring the learning flow and refining the supporting materials based on relevant literature. Prototype II was trialed with 12 students and 3 lecturers through individual and small group sessions, where feedback indicated that some worksheets were too complex, instructions

Table 3. Formative evaluation of prototypes I, II, and III developed through the DDR approach

Prototype	Trial stage	Participants	Key findings & revisions made
I	Expert review	3 lecturers	Feedback: syntax misalignment, unclear integration of STEM tasks with research, unclear impact of accompanying materials and their relevance in the model. Revisions: restructuring of learning stages, simplification of syntax, emphasis on the impact of accompanying materials based on various references from previous studies on the application of STEM, RBL, and inquiry-based learning.
II	Individual and group trials	3 and 12 students	Feedback: Some worksheets are too complex, too many data points are collected, unclear tools, prerequisite competencies have not been met. Revisions: Adjusted media, clarified task instructions, reduced number of practical exercises according to time duration, added several video tutorials to support meeting prerequisites before implementing the learning process.
III	Field trials	50 students, 15 lecturers	Findings: high engagement, improved scientific reasoning, practical implementation feasible in low-resource settings.

Table 4. Analysis of lecturer responses to the STEM-Hybrid RBL model and its tools

Product	Assessment aspects	Average response	
		Percentage	Description
STEM-Hybrid RBL model	Syntax	94.67	Very high
	Social system	92.33	Very high
	Reaction principle	96.00	Very high
	Support system	94.67	Very high
	Instructional impact & accompanying impact	95.33	Very high
	Sender impact	92.85	Very high
Student worksheet	Practicality in use	93.33	Very high
	Relevance of material	94.09	Very high
	Implementation in STEM-Hybrid RBL model	93.48	Very high
	Benefits	94.67	Very high
	Applicability in science learning	94.81	Very high
Material book	Practicality in use	93.78	Very high
	Relevance of material	96.44	Very high
	Implementation and usefulness	93.78	Very high
	Applicability in science learning	95.02	Very high

unclear, and prerequisite knowledge was lacking. The prototype was revised by simplifying tasks, adjusting the media, and adding video tutorials to support student readiness. Prototype III, implemented in field trials with 50 students and 15 lecturers, demonstrated strong practicality and effectiveness, evidenced by high student engagement, improvement in scientific reasoning, and successful implementation in limited-resource contexts.

The Practicality of STEM-Hybrid RBL

Next, an analysis was conducted to determine the practicality of the model and its supporting devices based on assessments by science education lecturers. The results of the analysis are presented in **Table 4**.

The results of the practicality analysis of the model and all product components, have a very high level of practicality. The syntax, support system, reaction principle, and impact of the book model instructional process aspects all scored above 92%, with the highest average response in the reaction principle aspect. The student worksheets were considered very practical in terms of material relevance, implementation model, and usefulness, although the practicality aspect in use scored slightly lower. The book materials also received very high responses, especially in the aspects of material relevance and usability in science learning. These findings indicate that the learning devices developed are not only valid but also very practical to apply in STEM-based science learning. The results of practicality according to students can be seen in **Table 5**.

The results of the practicality of the model and all of the product components according to students show that all aspects assessed received the category "very high" with an average overall percentage of 87.67%. In the implementation of the book model, the aspects of motivation and interest in learning, affective and participatory, and relationships with lecturers reflect students' positive acceptance of the applied learning model. Student worksheets were also rated very high, especially in terms of content and layout and usability in science learning, which indicates that LKM is easy to understand and relevant to use. Likewise, the book material showed a very high level of practicality with the highest scores in the aspects of usefulness and usability in science learning. Overall, these data indicate that students reacted very positively to the use of the developed learning tools, both in terms of content, use,

Table 5. Analysis of student responses to the STEM-Hybrid RBL model and its tools

Product	Assessment aspects	Average response	
		Percentage	Description
Model book implementation	Motivation and interest in learning	87.00	Very high
	Conceptual understanding and reasoning	81.44	Very high
	Skills	83.60	Very high
	Affective and participatory	86.67	Very high
	Self-management	85.07	Very high
	Relationship with lecturers	86.93	Very high
Average		85.12	Very high
Student worksheet	Content and layout of student worksheet	88.96	Very high
	Practicality in use	87.20	Very high
	Applicability in science learning	88.53	Very high
	Benefits	87.70	Very high
	Innovation and learning independence	86.80	Very high
Average		87.85	Very high
Material book	Content relevance	87.60	Very high
	Presentation and language	86.88	Very high
	Implementation	87.20	Very high
	Applicability in science learning	88.00	Very high
	Benefits	89.12	Very high
	Innovation and learning independence	87.20	Very high
Average		87.67	Very high

Table 6. Descriptive analysis of the pre- and post-test

Descriptive statistics	Control class		Experimental class	
	Pre-exam	Post-exam	Pre-exam	Post-exam
Average	38.4	40.8	38.08	53.76
Average	38	40	42	56
Mode	32	40	44	52
Standard deviation	9.38	8	10.76	10.38
Variants	88	64	115.83	107.77

and usefulness in the learning process. This aligns with the argument by Krajcik and Delen (2016) that active learning environments supported by appropriate instructional design enhance students' engagement and cognitive outcomes.

The Effectiveness of STEM-Hybrid RBL

According to Plomp and Nieveen, the effectiveness of the product developed is seen from the level of achievement of an expected goal (Novitra et al., 2021). This means that the STEM-Hybrid RBL learning model is declared effective if it is able to develop scientific reasoning skills. The results of the descriptive analysis of the pretest and posttest for the experimental class and control class are presented in **Table 6**.

Based on **Table 6**, the experimental class showed a clear increase in average scores from pre-test to post-test, supported by higher median and mode values after treatment. This improvement was consistent and substantial, with stable standard deviation and variance indicating uniform score distribution despite the gains. In contrast, the control class showed only a slight increase in average scores and a decrease in variance, suggesting a narrower score range. These results demonstrate that the learning model used in the experimental class had a greater impact on enhancing students' scientific reasoning than conventional learning. A comparison of scientific reasoning sub-skills for the experimental class is presented in **Figure 3**.

The improvement graph shows the average score on all indicators of scientific reasoning ability of experimental class students after participating in the learning. The CoR indicator experienced the highest increase. The CR indicator also showed significant performance. A quite striking increase was also seen in the HR indicator, and in the PR indicator also increased. Although the increase was lower than other indicators, ICV still experienced growth. Overall, the average student score increased, these results indicate that the learning model applied in the experimental class is effective in encouraging an increase in students' scientific reasoning abilities in various aspects. Furthermore, a comparison of the initial and final scores of science reasoning skills for the control class can be seen in **Figure 4**.

The graph shows a comparison of the average pre- and post-test scores of students' scientific reasoning skills in the control class. In general, the increase that occurred was relatively low and tended to be

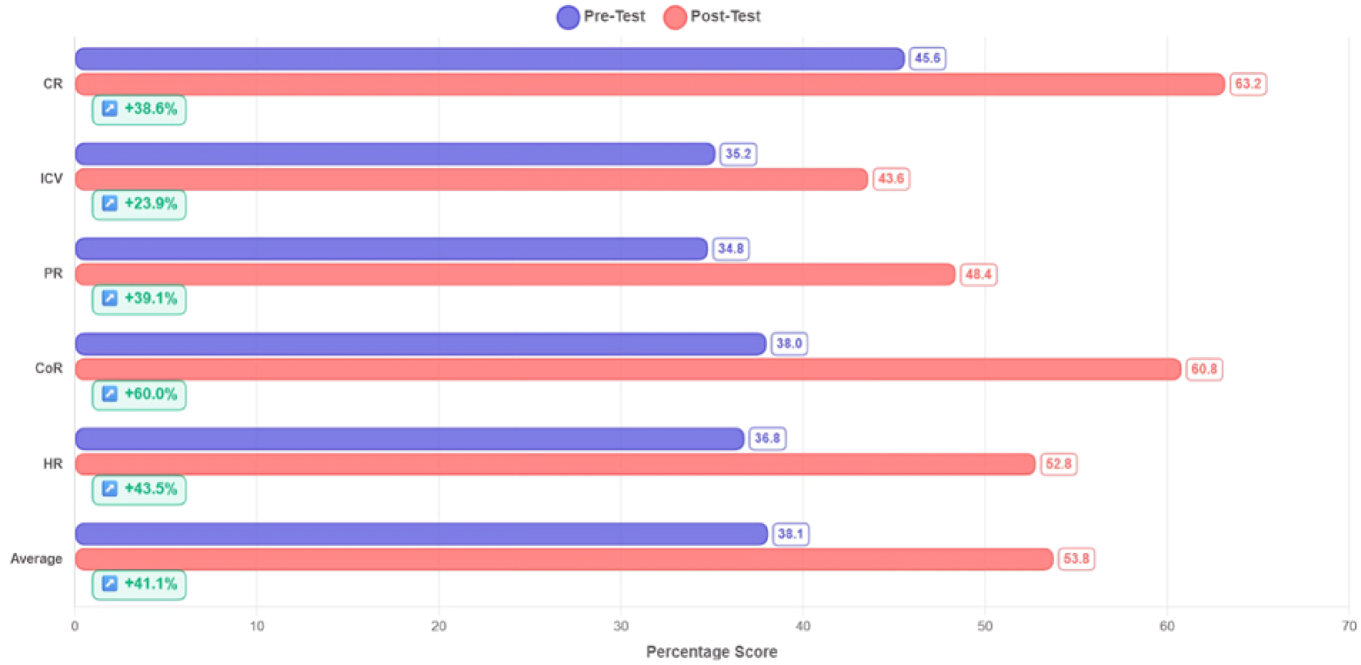

Figure 3. Comparison of average scores of pre- and post-tests on each sub-skill of scientific reasoning for the experimental class (Source: Authors' own elaboration)

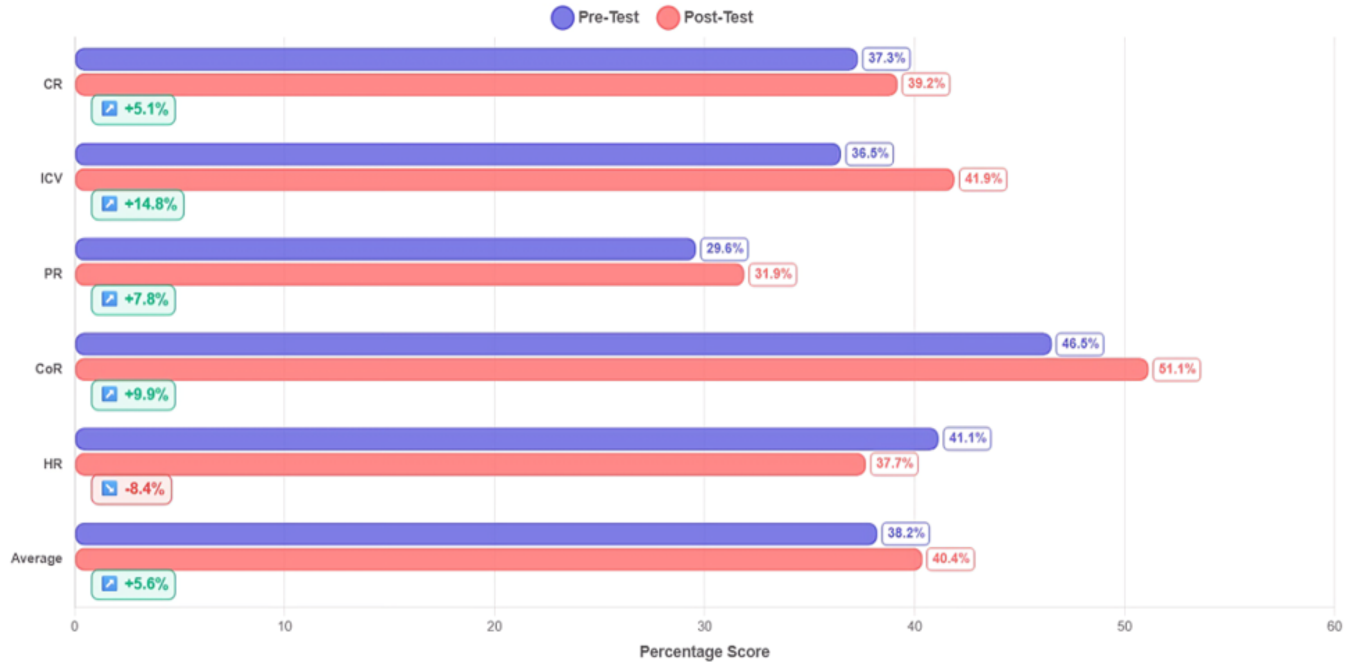

Figure 4. Comparison of pre- and post-test mean scores on each scientific reasoning sub-skill for the control class (Source: Authors' own elaboration)

insignificant. In the Identification and Control Variable indicator, although there was an increase, this value was the highest increase among all indicators. Meanwhile, other indicators such as CoR, CR, and PR experienced very small increases. Even in the HR indicator, the post-test value actually decreased. Overall, the average value only increased slightly. These findings indicate that conventional learning applied in the control class did not have a significant impact on improving students' scientific reasoning abilities.

Inferential Statistical Analysis for Effectiveness Testing

The next step is to conduct an analysis to see whether the initial abilities of the two classes can be considered the same by conducting a t-test. The p-value for the control and experimental classes are 0.415 and 0.008, respectively, indicating that the pre-test data of the experimental class is not normal, so testing is carried out using the Mann-Whitney U test. The test results show a p-value = 0.588> 0.05, so there is no significant difference between the pretest scores of the two groups. In other words, both classes are considered to have the same ability so that they meet the requirements for using the N-gain based independent t-test.

Next, an analysis of the N-gain values of both classes was carried out. The results of the normality test using the Shapiro-Wilk method showed a significance value of 0.749 for the control class and 0.543 for the experimental class which means the data is normally distributed. Furthermore, Levene's test indicated that the assumption of homogeneity of variance was met ($F = 0.713$; $p = 0.403$), so it can be concluded that the data of gain value is homogeneous. Because the requirements for normality and homogeneity are met, the hypothesis test can be continued using the independent t-test.

The results of the independent t-test conducted to analyze the differences in scientific reasoning improvement scores (N-gain) between two groups group showed a statistically significant difference. The t-test then produced a value of $t(48) = -4.670$ with a significance level of $p < 0.001$, indicating that the average difference between the two groups did not occur by chance. In more detail, the experimental group obtained a significantly higher N-gain score than the control group, with an average difference of 21.09 points. The 95% confidence interval for the difference ranged from -30.17 to -12.01, which is completely below zero, thus strengthening the conclusion that there was a statistically significant difference.

Furthermore, this difference also has substantial meaning in a practical context. Cohen's d value of -1.321 indicates that the effect of the treatment given to the experimental group is in the large effect category. This is reinforced by the Hedges' g value of -1.300 and Glass's delta of -1.183, all of which indicate that the difference between the two groups is not only statistically significant, but also practically significant.

DISCUSSION

The development of the STEM-Hybrid RBL model in this study is grounded in the DDR, which provided a structured and iterative pathway throughout the research. This model was not merely tested, but systematically built through multiple integrated stages, starting from problem identification and literature review, followed by the design, testing, and refinement of learning prototypes. At each stage, both qualitative and quantitative data were collected to ensure the model's theoretical relevance, practical feasibility, and effectiveness. Unlike conventional STEM intervention studies that often employ static experimental frameworks, this study applies DDR to support both the creation and contextual validation of a learning model in limited-resource environments. By incorporating early diagnostics, multi-source triangulation, expert validation, and field implementation, this research not only produced a workable pedagogical solution, but also contributed methodologically by exemplifying how DDR can be used to design innovations that are responsive to both theoretical frameworks and real-world classroom needs.

The development of the STEM-Hybrid RBL model is a pedagogical innovation designed to address the challenges of science learning in higher education, especially in the context of limited laboratory facilities. This model combines the STEM characteristic approach with research-based learning to encourage students to develop scientific thinking skills actively and contextually. Evaluation of the model is carried out comprehensively, covering aspects of validity, practicality, and effectiveness, to ensure that this model is feasible to be applied in learning practices.

The evaluation of the validity results show that all devices are in the "very valid" category, reflecting the suitability between the design and the underlying educational theory. The book model, for example, scored high on the aspects of supporting theory and learning syntax, indicating that its conceptual framework is built on a strong and systematic basis. This is in line with the views of Guzey et al. (2016) and Kelley and Knowles (2016) who emphasize the importance of theoretical foundations in developing a conceptual framework for learning models. High validity is also seen in student worksheets and material books that facilitate students in understanding the material and developing scientific skills through illustrations, communicative language, and logistical and systematic structures. Thus, the developed learning tools are not only theoretically valid but also have strong internal coherence to support the preparation of teachers and education personnel in implementing STEM learning (Shernoff et al., 2017).

The practicality of this model is the next consideration, because the success of learning implementation is greatly influenced by the ease and readiness of the devices used in the classroom. The results of the responses indicates that lecturers feel helped in implementing this model without having to make many adjustments to existing learning conditions. Meanwhile, students also gave a positive response, These findings strengthen the claim that this model is not only easy to use by teachers but can also be understood and utilized optimally by students. The practicality of the device is very important in supporting an active, structured, and contextual learning experience. Practicality shows that the teaching aids developed are not only theoretically useful but also practical for users in the classroom. This corroborates the findings of Krajcik and Delen (2016) who emphasized the importance of supporting an active and integrated learning environment in STEM to achieve optimal results (Sahin, 2015; Zembal-Saul et al., 2002). The implementation of STEM makes students active learners most of the time, presenting and sharing their findings with classmates and visitors (Sahin, 2015). Furthermore, the application of learning tools that are contextual to students' lives makes it easier for teachers to teach science concepts (Zembal-Saul et al., 2002).

In terms of effectiveness, the STEM-Hybrid RBL model shows promising results in improving students' scientific reasoning skills. The results of the statistical analysis showed a significant difference between the two groups. The reinforcement analysis was carried out through the calculation of the effect size indicates that this model has a large influence on improving learning outcomes. This value not only shows effectiveness in a statistical sense but also indicates that the model has high practical utility in helping students develop scientific thinking skills in more depth. Given the significant effect size, the model is recommended not only as a classroom strategy but also as a foundation for institutional curriculum development in science education, particularly in resource-limited settings.

Among the indicators of scientific reasoning, the CoR indicator recorded the highest increase, indicates that this learning provides good skills to students in identifying the relationship between physical parameters in experimental situations. The CR indicator also showed significant progress. This is in line with the theory that conservation-related reasoning is a key step in developing more complex scientific understanding, so strengthening this indicator shows the effectiveness of the learning model in encouraging a deep understanding of the basic principles of science (Sari & El Islami, 2020). The improvements recorded in HR and PR indicate that students are not only learning to process information but are also able to make the expected deductions in a scientific context (Fikriana et al., 2023; Pramesti et al., 2022).

Although the ICV indicator experienced the lowest increase, this still shows progress. This indicates that students may need more time or support to understand more advanced concepts related to the ICV in experiments. The significant improvement in the ICV indicator aligns with Piagetian theory, suggesting enhanced operational reasoning due to structured experimental experiences. This finding also aligns with the constructivist principle that learning becomes more effective when students engage directly in scientific investigation processes (Wagh et al., 2017). The integration of research-based learning and the STEM approach can improve students' cognitive skills, which are essential for their preparation to face the challenges of the world and ever-evolving technology

In contrast, the results from the control class illustrated minimal and less significant improvements in scientific reasoning skills. Although the CoR showed an increase, the increase was very small and did not reflect a strong impact of the conventional teaching applied. In the HR, there was even a decrease in post-test scores, highlighting the weaknesses of traditional learning methods in developing thinking skills. This is in line with previous research findings which emphasize that an active and integrated learning approach, as applied in the STEM-Hybrid RBL model, is more effective in facilitating the improvement of scientific reasoning skills among students (Yanto et al., 2019).

This result warrants further reflection on how and why the model led to measurable improvements in students' scientific reasoning, particularly within the context of its classroom implementation. The improvement in scientific reasoning observed among students in the experimental group can be attributed to the systematic integration of research-oriented tasks within the STEM-Hybrid RBL model. Students were required not only to solve problems but also to formulate hypotheses, analyze data, and justify conclusions based on empirical evidence. This inquiry-based process inherently fosters higher-order thinking skills (Arifin et al., 2025; Bhaumik et al., 2024). During class implementation, lecturers noted that students became more engaged when using action cameras to document experiments, which encouraged them to articulate their reasoning more clearly and critically during discussions and reflections.

For instance, in one session, students investigating the efficiency of local solar panels were observed comparing their real-time data with theoretical expectations, then revising their hypotheses collaboratively. Some students voluntarily explored additional sources to support their conclusions, demonstrating increased initiative and scientific curiosity. These behaviors were documented in classroom observation notes and group discussion transcripts, revealing a shift from passive content consumption to active knowledge construction.

These findings align with previous studies emphasizing the role of research-based learning in strengthening students' scientific reasoning (Bao et al., 2009). Moreover, the blended format and contextual learning tasks provided by the model created authentic learning experiences, consistent with Lowell and Moore's opinion that authentic learning by bringing students into the real world provides a better learning experience (Lowell & Moore, 2020). Therefore, the model's effectiveness can be seen as a result of both its pedagogical structure and its capacity to create meaningful, situated learning environments.

This model becomes increasingly relevant when connected to the real challenges faced in science learning in various higher education institutions, especially the limited laboratory and experimental facilities. By combining the STEM approach and the characteristics of research-based learning through a hybrid method, this model offers an innovative alternative solution. Students are not only invited to understand scientific concepts theoretically, but are also trained to think critically, formulate hypotheses, design experiments, and draw interesting conclusions based on data they collect themselves in real contexts even though they are not directly present in the laboratory full time. This process creates a holistic and meaningful learning experience, which can ultimately encourage the creation of graduates who not only master the theory, but are also able to apply it in solving real problems (Haritha & Rao, 2024). This study serves as a reference for educators that the application of the STEM approach and the RBL model in a hybrid manner can improve students' learning experiences, especially in the context of limited laboratory facilities. This model answers the challenges faced in modern educational science and makes a positive contribution to more innovative and research-based learning.

This success not only reflects the design of the device but also emphasizes the importance of learning innovation that is integrative, contextual, and responsive to the needs of today's education world. This approach should be considered as an alternative science learning that is able to answer the challenges of the times and support the transformation of education towards a more meaningful and effective direction. To better appreciate the contribution of this study, it is necessary to look beyond the quantitative results and consider the distinctive features of the model, as well as the opportunities and challenges it presents when applied in educational practice. The STEM-Hybrid RBL model developed in this research brings together the investigative nature of research-based learning with the interdisciplinary structure of STEM education. What sets it apart from conventional STEM or project-based models is the deliberate integration of scientific research phases, such as problem identification, hypothesis formulation, and evidence-based reasoning into the learning process. In contrast to project-based learning, which often emphasizes the end product, this model places greater weight on the process of inquiry and reflection. Its implementation in a hybrid learning format, supported by the use of action cameras and digital tools, also responds to practical limitations in settings with restricted access to laboratories or science equipment.

Several advantages were observed throughout the development and trial phases. The model was well-received by both students and lecturers, particularly for its adaptability in hybrid environments and its focus on developing students' scientific reasoning. Nonetheless, some constraints were also identified. Effective use of the model depends on students' prior exposure to inquiry-based learning and the readiness of lecturers to guide the research process. In addition, while the model proved feasible in the tested context, applying it in different institutional settings may require contextual adjustments, particularly in relation to curriculum structure and technological infrastructure.

CONCLUSION

Based on the results, it can be concluded that the STEM-Hybrid RBL model that has been developed has a strong conceptual foundation, realized through the design of a conceptual framework that integrates the STEM approach and research-based learning model. This design is designed to answer the needs of science learning that is more collaborative, contextual, and fosters high-level thinking skills. The results of the validity test of the device model show a very high level of validity, both in terms of theory, learning syntax, and content suitability, as assessed by experts in related fields. In addition, this model is also stated to be very practical based on the responses of lecturers and students, which show that the model is easy to use and in accordance with the needs in the field. In terms of effectiveness, the application of the STEM-Hybrid RBL model has been proven to be able to significantly improve students' scientific reasoning skills compared to conventional learning models, as evidenced by statistical analysis and large effect sizes. Thus, this model is worthy of being implemented in the context of science learning in higher education as an innovative approach that is able to bridge the limitations of facilities and at the same time improve the quality of students' scientific thinking.

This study offers important implications for higher education, particularly in promoting contextual, active, and research-based science learning. Integrating STEM's interdisciplinary approach with research-based learning can substantially enhance students' scientific reasoning skills, encouraging educators and policymakers to adopt models that go beyond content mastery to foster higher-order thinking–skills essential in today's complex global landscape. For higher education institutions, the findings highlight the need for curriculum innovation and adaptable resources, especially in contexts with limited laboratory access. They also underscore the value of lecturer training to effectively integrate technology and cross-disciplinary strategies, enabling collaborative and reflective learning. More broadly, this model presents a viable pathway for shaping learners who are academically proficient and prepared to address real-world challenges with a critical, solution-oriented mindset.

Limitations and Further Research

This study has several limitations to consider before applying its findings more broadly. The implementation was confined to a single study program in higher education and carried out over a relatively short period, limiting insight into its long-term effectiveness or adaptability to other contexts, such as secondary schools or different subjects. The focus on scientific reasoning also leaves space to examine other aspects of the learning experience, including scientific communication, teamwork, and digital literacy–skills integral to research-based learning. While the model was designed to address laboratory shortages, practical challenges such as limited technological access and varying lecturer readiness still influenced its effectiveness, highlighting the need for adequate technical support and targeted training.

Future research could expand the model's application to different educational levels or disciplines to test its flexibility and relevance. Longitudinal studies across diverse institutions and social settings would offer stronger evidence of their impact on student preparedness for the workplace or further research. Its use in vocational and interdisciplinary programs also warrants exploration to better understand its broader pedagogical potential.

Author contributions: AS: conceptualization, investigation, methodology, data curation, formal analysis, data visualization, writing- original draft, writing - review & editing. **EHS, K, & AbS**: supervision, methodology, writing- original draft, writing - review & editing. All authors agreed with the results and conclusions.

Funding: The research leading to these results received funding from Education Fund Management Institution (LPDP) through the Indonesian Education Scholarship (BPI), Center for Financing and Assessment of Higher Education, Ministry of Higher Education, Science, and Technology, Republic of Indonesia under Grant Agreement 01868/BPPT/BPI.06/9/2023.

Acknowledgments: The authors would like to thank all parties who have helped in this research.

Ethical statement: The authors stated that the study was approved by the Institutional Review Board at Universitas Bosowa on 3 February 2025. Written informed consents were obtained from the participants.

AI statement: The authors stated that generative AI tools (e.g., ChatGPT by OpenAI) were used to check the English language clarity of the manuscript only. No content generation was performed by AI.

Declaration of interest: No conflict of interest is declared by the authors.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

REFERENCES

Abuhassna, H., Adnan, M. A. B. M., & Awae, F. (2024). Exploring the synergy between instructional design models and learning theories: A systematic literature review. *Contemporary Educational Technology, 16*(2), Article ep499. https://doi.org/10.30935/cedtech/14289

Agra, G., Formiga, N. S., & de Oliveira, P. S. (2019). Analysis of the concept of meaningful learning in light of the Ausubel's theory. *Revista Brasileira de Enfermagem, 72*(1), 248-255. https://doi.org/10.1590/0034-7167-2017-0691

AlAli, R. (2024). Enhancing 21st century skills through integrated STEM education using project-oriented problem-based learning. *Geojournal of Tourism and Geosites, 53*(2), 421-430. https://doi.org/10.30892/gtg.53205-1217

Al-Thani, N. J., & Ahmad, Z. (2025). *Teaching and learning with research cognitive theory: Unlocking curiosity and creativity for problem-solving skills*. Springer. https://doi.org/10.1007/978-3-031-87544-1

Arifin, Z., Sukarmin, Saputro, S., & Kamari, A. (2025). The effect of inquiry-based learning on students' critical thinking skills in science education: A systematic review and meta-analysis. *Eurasia Journal of Mathematics, Science and Technology Education, 21*(3), Article em2592. https://doi.org/10.29333/ejmste/15988

Arifin, Z., Sukristyanto, A., Widodo, J., & Rahman, M. R. (2022). Implementation, outcomes, and effectiveness of research-based learning: A systematic literature review. *International Journal of Education and Literacy Studies, 10*(4), 153-163. https://doi.org/10.7575/aiac.ijels.v.10n.4p.153

Aristika, A., Darhim, Juandi, D., & Kusnandi. (2021). The effectiveness of hybrid learning in improving of teacher-student relationship in terms of learning motivation. *Emerging Science Journal, 5*(4), 443-456. https://doi.org/10.28991/esj-2021-01288

Bao, L., Cai, T., Koenig, K., Fang, K., Han, J., Wang, J., Liu, Q., Ding, L., Cui, L., Luo, Y., Wang, Y., Li, E., & Wu, N. (2009). Physics: Learning and scientific reasoning. *Science, 323*(5914), 586-587. https://doi.org/10.1126/science.1167740

Baser, D., Ozden, M. Y., & Karaarslan, H. (2017). Collaborative project-based learning: An integrative science and technological education project. *Research in Science and Technological Education, 35*(2), 131-148. https://doi.org/10.1080/02635143.2016.1274723

Bhaumik, K., Sudhakara Reddy, S., Datta, A., Ismayel, G., & Mabu Sarif, B. (2024). Fostering higher-order thinking: Pedagogical strategies in engineering education. *Journal of Engineering Education Transformations, 38*(1), 86-99. https://doi.org/10.16920/jeet/2024/v38i1/24177

Blotnicky, K. A., Franz-Odendaal, T., French, F., & Joy, P. (2018). A study of the correlation between STEM career knowledge, mathematics self-efficacy, career interests, and career activities on the likelihood of pursuing a STEM career among middle school students. *International Journal of STEM Education, 5*, Article 22. https://doi.org/10.1186/s40594-018-0118-3

Brew, A., & Saunders, C. (2020). Making sense of research-based learning in teacher education. *Teaching and Teacher Education, 87*, Article 102935. https://doi.org/10.1016/j.tate.2019.102935

Chittum, J. R., Jones, B. D., Akalin, S., & Schram, Á. B. (2017). The effects of an afterschool STEM program on students' motivation and engagement. *International Journal of STEM Education, 4*, Article 11. https://doi.org/10.1186/s40594-017-0065-4

DeMara, R. F., Tian, T., & Howard, W. (2021). Longitudinal learning outcomes from engineering-specific adaptions of hybrid online undergraduate instruction. *International Journal of Emerging Technologies in Learning, 16*(23), 171-201. https://doi.org/10.3991/ijet.v16i23.17615

Ellis, T. J., & Levy, Y. (2010). A guide for novice researchers: Design and development research methods. *InSITE, 10*, 107-118. https://doi.org/10.28945/1237

Erbil, D. G. (2020). A review of flipped classroom and cooperative learning method within the context of Vygotsky theory. *Frontiers in Psychology, 11*. https://doi.org/10.3389/fpsyg.2020.01157

Estuhono, E. (2022). Research-based learning models in physics for 21st century students. *AL-ISHLAH: Jurnal Pendidikan, 14*(2), 1803-1814. https://doi.org/10.35445/alishlah.v14i2.1268

Fikriana, M. F., Wiyanto, W., & Haryani, S. (2023). Development of the diary book of science with the STEM approach of discovery in improving students' concept understanding and scientific communication skills. *Jurnal Penelitian Pendidikan IPA, 9*(4), 1641-1649. https://doi.org/10.29303/jppipa.v9i4.3032

Fischer, F., Kollar, I., Ufer, S., Sodian, B., Hussmann, H., Pekrun, R., Neuhaus, B., Dorner, B., Pankofer, S., Fischer, M., Strijbos, J. W., Heene, M., & Eberle, J. (2014). Scientific reasoning and argumentation: Advancing an interdisciplinary research agenda in education. *Frontline Learning Research, 2*(3), 28-45. https://doi.org/10.14786/flr.v2i3.96

Galloway, K. R., & Bretz, S. L. (n. d.). Measuring meaningful learning in the undergraduate general chemistry and organic chemistry laboratories: A longitudinal study. *Journal of Chemical Education, 92*(12). https://doi.org/10.1021/acs.jchemed.5b00754

Guzey, S. S., Moore, T. J., & Harwell, M. (2016). Building up stem: An analysis of teacher-developed engineering design-based stem integration curricular materials. *Journal of Pre-College Engineering Education Research, 6*(1), Article 2. https://doi.org/10.7771/2157-9288.1129

Hanson, S. (2016). *The assessment of scientific reasoning skills of high school science students: A standardized assessment instrument* [MSc thesis, Illinois State University]. http://doi.org/10.30707/ETD2016.Hanson.S

Haritha, G., & Rao, R. (2024). A holistic approach to professional development: Integrating Kolb's experiential learning theory for soft skills mastery. *Journal of Engineering Education Transformations, 37*(Special Issue 2), 415-424. https://doi.org/10.16920/jeet/2024/v37is2/24069

Haviz, M. (2018). Development of research-based learning model in biology education: What is relevance, consistency and practicality? *Journal of Education and Learning, 12*(1), 143-149. https://doi.org/10.11591/edulearn.v12i1.6555

Jannah, E. S. W., Dafik, D., & Kristiana, A. I. (2024). The Development of RBL-STEM learning materials to improve students' information literacy in solving rainbow antimagic coloring problem for ETLE technology. *International Journal of Current Science Research and Review, 7*(1), 155-164. https://doi.org/10.47191/ijcsrr/v7-i1-16

Jufri, A. W., Setiadi, D., & Sripatmi. (2016). Scientific reasoning ability of prospective student teacher in the excellence program of mathematics and science teacher education in University of Mataram. *Jurnal Pendidikan IPA Indonesia, 5*(1), 69-74.

Kamaluddin, K., Sani, N. K., Darmadi, I. W., & Nurgan, N. (2023). Analysis of students scientific reasoning ability and the correlation to students cognitive ability in physics learning. *Jurnal Penelitian Pendidikan IPA, 9*(11), 10173-10179. https://doi.org/10.29303/jppipa.v9i11.5657

Kambeyo, L. (2018). Scientific reasoning skills: A theoretical background on science education. *Reform Forum: Journal for Educational Research in Namibia, 26*(1), 27-36.

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education, 3*, Article 11. https://doi.org/10.1186/s40594-016-0046-z

Krajcik, J., & Delen, I. (2016). How to support learners in developing usable and lasting knowledge of STEM. *International Journal of Education in Mathematics, Science and Technology, 5*(1), 21-28. https://doi.org/10.18404/ijemst.16863

Lowell, V. L., & Moore, R. L. (2020). Developing practical knowledge and skills of online instructional design students through authentic learning and real-world activities. *TechTrends, 64*(4), 581-590. https://doi.org/10.1007/s11528-020-00518-z

Martawijaya, M. A., Rahmadhanningsih, S., Swandi, A., Hasyim, M., & Sujiono, E. H. (2023). The effect of applying the ethno-STEM-project-based learning model on students' higher-order thinking skill and misconception of physics topics related to Lake Tempe, Indonesia. *Jurnal Pendidikan IPA Indonesia, 12*(1), 1-13. https://doi.org/10.15294/jpii.v12i1.38703

Miller, E. C., & Krajcik, J. S. (2019). Promoting deep learning through project-based learning: A design problem. *Disciplinary and Interdisciplinary Science Education Research, 1*(1), 1-10. https://doi.org/10.1186/s43031-019-0009-6

Mohammed, Husam, S., & Kinyo, L. (2020). The role of constructivism in the enhancement of social studies education. *Journal of Critical Reviews, 7*(7), 249-256. https://doi.org/10.31838/jcr.07.07.41

Novitra, F., Festiyed, Yohandri, & Asrizal. (2021). Development of online-based inquiry learning model to improve 21st-century skills of physics students in senior high school. *Eurasia Journal of Mathematics, Science and Technology Education, 17*(9), Article em2004. https://doi.org/10.29333/ejmste/11152

Omoregie, I., Anthony, H., & Braimoh, J. J. (2025). Comparative analysis of instructional models for designing effective online courses: ADDIE, SAM, and Dick & Carey approaches. *Journal of Languages and Translation, 5*(1), 33-45. https://doi.org/10.70204/jlt.v5i1.428

Palloan, P., & Swandi, A. (2019). Development of learning instrument of active learning strategy integrated with computer simulation in physics teaching and learning on Makassar State University. *Journal of Physics: Conference Series, 1157*, Article 032016. https://doi.org/10.1088/1742-6596/1157/3/032016

Piraksa, C., Srisawasdi, N., & Koul, R. (2014). Effect of gender on student's scientific reasoning ability: A case study in Thailand. *Procedia-Social and Behavioral Sciences, 116*, 486-491. https://doi.org/10.1016/j.sbspro.2014.01.245

Pramesti, D., Probosari, R. M., & Indriyanti, N. Y. (2022). Effectiveness of project based learning low carbon STEM and discovery learning to improve creative thinking skills. *Journal of Innovation in Educational and Cultural Research, 3*(3), 444-456. https://doi.org/10.46843/jiecr.v3i3.156

Rogat, T. K., & Adams-Wiggins, K. R. (2014). Other-regulation in collaborative groups: Implications for regulation quality. *Instructional Science, 42*(6), 879-904. https://doi.org/10.1007/s11251-014-9322-9

Sahin, A. (2015). STEM students on the stage (SOS): Promoting student voice and choice in STEM education through an interdisciplinary, standards-focused project based learning approach. *Journal of STEM Education: Innovations and Research, 16*(3).

Saldarriaga-Zambrano, J. C. (2024). Schoolwork in meaningful student learning. *International Journal of Social Sciences, 7*(1), 1-8. https://doi.org/10.21744/ijss.v7n1.2233

Sari, I. J., & El Islami, R. A. Z. (2020). The effectiveness of scientific argumentation strategy towards the various learning outcomes and educational levels five over the years in science education. *Journal of Innovation in Educational and Cultural Research, 1*(2), 52-57. https://doi.org/10.46843/jiecr.v1i2.17

Shernoff, D. J., Sinha, S., Bressler, D. M., & Ginsburg, L. (2017). Assessing teacher education and professional development needs for the implementation of integrated approaches to STEM education. *International Journal of STEM Education, 4*, Article 13. https://doi.org/10.1186/s40594-017-0068-1

Sumarni, W., & Kadarwati, S. (2020). Ethno-stem project-based learning: Its impact to critical and creative thinking skills. *Jurnal Pendidikan IPA Indonesia, 9*(1), 11-21. https://doi.org/10.15294/jpii.v9i1.21754

Swandi, A., Amin, B. D., Viridi, S., & Eljabbar, F. D. (2020). Harnessing technology-enabled active learning simulations (TEALSim) on modern physics concept. *Journal of Physics: Conference Series, 1521*, Article 022004. https://doi.org/10.1088/1742-6596/1521/2/022004

Swandi, A., Wajdi, M., Putri, F., Asrinan, Mahmudah, R., & Sujiono, E. (2024). Student responses to the implementation of experiment-based science learning with the hybrid method assisted by action camera. In *Proceedings of the International Conference on Education and Technology* (pp. 124-129). https://doi.org/10.1109/ICET64717.2024.10778449

Usmeldi, Amini, R., & Trisna, S. (2017). The development of research-based learning model with science, environment, technology, and society approaches to improve critical thinking of students. *Jurnal Pendidikan IPA Indonesia, 6*(2), 318-325. https://doi.org/10.15294/jpii.v6i2.10680

Usmeldi. (2016). The development of research-based physics learning model with scientific approach to develop students' scientific processing skill. *Jurnal Pendidikan IPA Indonesia, 5*(1), 134-139. https://doi.org/10.15294/jpii.v6i2.10680

Van den Beemt, A., MacLeod, M., Van der Veen, J., Van de Ven, A., van Baalen, S., Klaassen, R., & Boon, M. (2020). Interdisciplinary engineering education: A review of vision, teaching, and support. *Journal of Engineering Education, 109*(3), 508-555. https://doi.org/10.1002/jee.20347

Wagh, A., Cook-Whitt, K., & Wilensky, U. (2017). Bridging inquiry-based science and constructionism: Exploring the alignment between students tinkering with code of computational models and goals of inquiry. *Journal of Research in Science Teaching, 54*(5), 615-641. https://doi.org/10.1002/tea.21379

Wannapiroon, P. (2014). Development of research-based blended learning model to enhance graduate students' research competency and critical thinking skills. *Procedia-Social and Behavioral Sciences, 136*, 486-490. https://doi.org/10.1016/j.sbspro.2014.05.361

Yanto, B. E., Subali, B., & Suyanto, S. (2019). Improving students' scientific reasoning skills through the three levels of inquiry. *International Journal of Instruction, 12*(4), 689-704. https://doi.org/10.29333/iji.2019.12444a

Yordanov, T., Mihailov, N., & Gabrovska-Evstatieva, K. (2023). Low-cost remote lab on renewable energy sources with a focus on STEM education. In *Proceedings of the 18th Conference on Electrical Machines, Drives and Power Systems* (pp. 1-5). https://doi.org/10.1109/ELMA58392.2023.10202253

Yu, L., Du, M., & Zhou, X. (2023). E-service-learning during the COVID-19 pandemic: The experiences of mainland Chinese students enrolled at a university in Hong Kong. *Sustainability, 15*(12), Article 9211. https://doi.org/10.3390/su15129211

Zembal-Saul, C., Krajcik, J., & Blumenfeld, P. (2002). Elementary student teachers' science content representations. *Journal of Research in Science Teaching, 39*(6), 443-463. https://doi.org/10.1002/tea.10032

Zhan, Z., & Niu, S. (2023). Subject integration and theme evolution of STEM education in K-12 and higher education research. *Humanities and Social Sciences Communications, 10*(1), 1-13. https://doi.org/10.1057/s41599-023-02303-8

APPENDIX A: ENGLISH VERSION

Table A1. Indicators of the validity of the STEM-Hybrid RBL model

Aspect	Assessment components
Supporting theories	1. STEM approach in learning is relevant as a rationale for the STEM-Hybrid RBL model. 2. Contextual approach is relevant to support the thinking of the STEM-Hybrid RBL model. 3. Inquiry-based learning is relevant to support the thinking of the STEM-Hybrid RBL model. 4. Inquiry-based learning is relevant to support the thinking of the STEM-Hybrid RBL model. 5. Hybrid method with action camera is relevant to support the thinking of STEM-Hybrid RBL model. 6. Piaget's cognitive development theory is relevant to support the thinking of the STEM-Hybrid RBL model. 7. Vygotsky's sociocultural constructivist theory is relevant to support the thinking of the STEM-Hybrid RBL model. 8. Siemens' connectivism theory is relevant to support the thinking of the STEM-Hybrid RBL model. 9. theory of meaningful learning is relevant to support the thinking of the STEM-Hybrid RBL model.
Syntax	1. The phases in the STEM-Hybrid RBL model syntax can be carried out by lecturers. 2. The phases in the STEM-Hybrid RBL model syntax contain a systematic and logical sequence of learning activities. 3. The phases in the STEM-Hybrid RBL model syntax characterize inquiry-based, active learning. 4. The phases in the syntax of the STEM-Hybrid RBL model characterize the development of students' scientific reasoning skills. 5. The phases in the syntax of the STEM-Hybrid RBL model characterize the development of students' cognitive and psychomotor abilities. 6. The phases in the STEM-hybrid RBL model syntax characterize project-based learning. 7. The phases in the STEM-Hybrid RBL model syntax clearly contain the roles of lecturers and students in learning.
Social system	1. The pattern of relationships between students and lecturers in learning activities is stated clearly. 2. The relationship pattern between students and lecturers shows the role of the lecturer as a guide or facilitator. 3. The pattern of relationships between students and lecturers shows the role of lecturers in carrying out investigations. 4. The pattern of student and lecturer relationships in the learning process shows student involvement in hybrid research-based learning. 5. The relationship pattern between students and lecturers in the learning process can be realized based on the syntax of the STEM-Hybrid RBL model. 6. The relationship pattern between students and lecturers in the learning process can be managed by the lecturer. 7. The pattern of student and lecturer relationships is clearly stated.
Reaction principle	1. The behavior of lecturers and students in the introductory phase in the STEM-Hybrid RBL model is clearly stated. 2. The behavior of lecturers and students in the introductory phase in the STEM-Hybrid RBL model can be implemented. 3. The behavior of lecturers and students in the exploration and design phases in the STEM-Hybrid RBL model is clearly stated. 4. The behavior of lecturers and students in the exploration and design phase in the STEM-Hybrid RBL model can be implemented. 5. The behavior of lecturers and students in the hybrid research phase in the STEM-Hybrid RBL model is clearly stated. 6. The behavior of lecturers and students in the hybrid research phase in the STEM-Hybrid RBL model can be implemented. 7. The behavior of lecturers and students in the analysis and discussion phase in the STEM-Hybrid RBL model is clearly stated. 8. The behavior of lecturers and students in the analysis and discussion of the STEM-Hybrid RBL model can be implemented. 9. The behavior of lecturers and students in the communication and reflection phase in the STEM-Hybrid RBL model is clearly stated. 10. The behavior of lecturers and students in the communication and reflection phase in the STEM-Hybrid RBL model can be implemented.

Table A1 (Continued). Indicators of the validity of the STEM-Hybrid RBL model

Aspect	Assessment components
Support system	1. The types of supporting devices are clearly stated in the STEM-Hybrid RBL model. 2. The supporting devices listed are relevant to the STEM-Hybrid RBL model. 3. Supporting devices are used to support learning with the STEM-Hybrid RBL model. 4. Supporting devices can be used by lecturers.
Instructional and accompanying impacts	1. The types of instructional impacts indicate the direction of the learning objectives to be achieved. 2. The types of instructional impacts are clearly stated. 3. The types of instructional impact are stated logically. 4. Types of accompanying impacts support learning objectives. 5. The types of accompanying impacts are clearly stated. 6. The types of accompanying impacts are stated logically.
Learning implementation	1. Planning tasks are clearly stated. 2. Planning tasks can be prepared by the lecturer. 3. The lecturer's interactive tasks for each phase in the syntax are stated clearly. 4. The lecturer's interactive tasks for each phase in the syntax can be carried out by the lecturer. 5. Assignments given to students are stated clearly. 6. Giving assignments to students can be done individually. 7. The role of lecturers in assisting and directing student activities is clearly stated.
Learning environment	1. Preparation of the learning environment for the implementation of the STEM-Hybrid RBL model is clearly stated. 2. Preparation of the learning environment for the implementation of the STEM-Hybrid RBL model can be carried out by lecturers. 3. The tasks of managing learning activities by lecturers are stated clearly. 4. The tasks of managing teaching and learning activities can be carried out by lecturers.
Evaluation	1. The methods for evaluating learning with the STEM-Hybrid RBL model are clearly stated. 2. The learning outcome assessment rules are stated clearly. 3. *Online* tests is used in the STEM-Hybrid RBL model. 4. Evaluation during relevant learning activities is carried out to see students' authentic mastery.

Table A2. Indicators of the validity of the student worksheet

Aspect	Assessment components
Contents of LKM	1. Truth of content (facts, concepts, procedures, principles) 2. Content up-to-dateness 3. Paying attention to the relationship between science, technology, engineering, mathematics 4. Systematic 5. Oriented towards contextual and research-based learning 6. Oriented towards hybrid learning
Language and illustration	1. Readability of language or language used according to the level of cognitive development of students 2. Using good and correct Indonesian 3. The terms used are precise and understandable. 4. Using terms and symbols clearly 5. Illustrations/pictures are clearly legible
Presentation	1. Arousing motivation/interest/curiosity 2. According to the level of student thinking 3. Encourage students to be actively involved 4. Pay attention to students with different abilities/learning styles 5. Interesting/fun
LKM assessment	1. Conformity with learning outcomes 2. Emphasizes real-world or everyday life applications 3. Emphasis on STEM approach 4. Supporting the implementation of project-based learning 5. Supporting the implementation of collaborative learning 6. Supporting the implementation of creative learning 7. Able to invite further student curiosity

Table A3. Indicators of the validity of the material book

Aspect	Sub-aspects	Assessment components
Content eligibility	Suitability of material with course learning outcomes	1. Breadth of material 2. Depth of material
	Accuracy	3. Accuracy of facts and concepts 4. Accuracy of illustrations
	Supporting materials	5. Compliance with developments in science and technology 6. Up-to-date features, examples and references. 7. Contextual 8. Explaining the components of STEM (science, technology, engineering, mathematics)
Presentation eligibility	Presentation techniques	1. Conceptual breakdown 2. Systematic consistency 3. Balance between parts
	Presentation of learning	4. Student-centered 5. Contains instructions for lecturers to guide students in constructing knowledge. 6. Contains information related to online activities/accessible on the Internet 7. Serving variations
	Serving equipment	8. Introduction 9. List of contents 10. Bibliography 11. Evaluation 12. Illustrations that support the message
Language eligibility	Suitability to student development level	1. Compliance with the level of thinking development 2. Conformity to the level of social emotional development
	Communicative	3. Message comprehension 4. Grammar and spelling accuracy 5. Standardization of terms and symbols
	Coherence and unity of ideas	6. Integrity of meaning in chapters, sub-chapters and paragraphs. 7. Links between chapters, sub-chapters, paragraphs, and sentences.
	Layout	8. The layout of each unit is consistent
Graphics and book content design	Layout	1. Placement of layout elements consistent based on pattern 2. The separation between paragraphs is clear 3. Placing decorations/illustrations as a background does not interfere with the title, text, or page numbers. 4. The placement of titles, subtitles, illustrations and image captions does not interfere with understanding.
	Typography	1. Don't use too many fonts 2. Do not use decorative fonts 3. The use of font variations (bold, italic, capital) is not excessive. 4. The font type matches the content material
	Illustration	1. Able to reveal the meaning of an object 2. Accurate and proportional form according to reality 3. The whole illustration is harmonious 4. Images and tables are relevant to the content 5. Figures and tables are presented and explained.

APPENDIX B: ENGLISH VERSION

Table B1. Indicators of STEM-Hybrid RBL model practicality based on student response

Aspect	Assessment components
Motivation and interest in learning	1. Learning carried out using the STEM-Hybrid RBL model makes me have a strong desire to attend lectures. 2. Learning carried out using the STEM-Hybrid RBL model is very interesting. 3. Learning carried out through the STEM-Hybrid RBL model motivates me to excel. 4. Learning carried out through the STEM-Hybrid RBL model can increase my enthusiasm for learning.
Conceptual understanding and reasoning	1. I find it easier to understand the subject matter if learning is carried out using the STEM-Hybrid RBL model. 2. Learning carried out through the STEM-Hybrid RBL model can improve my reasoning in following lessons. 3. Learning carried out through the STEM-Hybrid RBL model can eliminate conceptual errors in me. 4. I can remember concepts longer if learning is carried out through the STEM-Hybrid RBL model. 5. The time required to master learning concepts is shorter if learning is implemented using the STEM-Hybrid RBL model.
Skills	1. Learning implemented through the STEM-Hybrid RBL model helps me think more critically in learning. 2. My creativity increases, if learning is implemented through the STEM-Hybrid RBL model 3. Learning carried out through the STEM-Hybrid RBL model can help me organize my learning strategies. 4. The STEM-Hybrid RBL model helps me develop science reasoning skills, such as analyzing, correlating, predicting, and drawing conclusions based on data.
Affective and participatory	1. I feel more appreciated and brave in expressing my opinion during learning. 2. I feel more enthusiastic and happy to be involved in the learning process using the STEM-Hybrid RBL model. 3. I feel more responsible for the tasks and learning process when using the STEM-Hybrid RBL model. 4. The STEM-Hybrid RBL model encourages me to actively interact and collaborate with friends. 5. The STEM-Hybrid RBL model increases my confidence in conveying ideas or completing assignments. 6. I am satisfied with the way I learn and participate in learning using the STEM-Hybrid RBL model.
Self-management	1. I can make good use of my time if learning is carried out using the STEM-Hybrid RBL model. 2. Learning with the STEM-Hybrid RBL model helps me utilize technology independently in managing learning. 3. Learning carried out through the STEM-Hybrid RBL model can make me more disciplined in learning.
Relationship with lecturers	1. Learning with the STEM-Hybrid RBL model increases attention and closeness between lecturers and students. 2. Learning implemented through the STEM-Hybrid RBL model can make lecturers more active in providing guidance both in face-to-face activities and in online activities. 3. I feel that the lecturers provide constructive feedback on my learning process, both in person and through online platforms.

Table B2. Indicators of the practicality of the student worksheet based on student response

Aspect	Assessment components
Content and layout of student worksheet	1. Interesting student worksheet content 2. Student worksheets appearance is attractive. 3. The language used is easy to understand. 4. The images and illustrations in the student worksheet are legible and match the text. 5. The pictures in the student worksheet help my understanding.
Practicality in use	1. The instructions and descriptions in the LKM are clear and easy to follow. 2. Assignments in structured student worksheet. 3. The STEM approach to each material is clear in the student worksheet. 4. Suitability of student worksheet with the activities and products created. 5. The problems and challenges given motivate learning. 6. The stages in student worksheet are easy to follow and build knowledge.

Table B2 (Continued). Indicators of the practicality of the student worksheet based on student response

Aspect	Assessment components
	1. The content of the student worksheet is contextual and relevant to students' daily lives. 2. Time required to complete the project according to the allocation.
Applicability in science learning	1. Student worksheet makes me active and guided in studying science. 2. Student worksheet allows me to interact and discuss with my friends while studying science. 3. Student worksheet makes my understanding of science learning materials increase. 4. Student worksheet challenges me to apply various science learning strategies. 5. Student worksheet helps me build science knowledge. 6. Student worksheet helped increase my interest in studying science.
Benefits	1. Student worksheet helps me analyze problems and accept challenges. 2. Student worksheet helps me formulate hypotheses and explore concepts. 3. Student worksheet helps me to design experimental props easily. 4. Student worksheet helps me to test and prove physics concepts easily. 5. Student worksheet helps me easily analyze the results of experiments. 6. Student worksheet helps me easily develop concepts and knowledge based on the STEM approach. 7. Student worksheet helped me understand the steps of STEM-Hybrid RBL. 8. Student worksheet helps me improve my scientific thinking/reasoning skills. 9. Student worksheet helps me use tools and materials easily.
Innovation and learning independence	1. Student worksheet encourages me to learn independently and reflectively. 2. Student worksheet helps me think creatively in completing projects.

Table B3. Indicators of the practicality of the material book based on student response

No	Assessment components
Content relevance	1. Book contents interesting material. 2. Conformity between the introduction and the contents of the book. 3. Conformity between competencies/learning objectives and book contents. 4. Conformity between equations/formulas and materials.
Presentation and language	1. Appearance of the book interesting material. 2. The language used is easy to understand, uses common terms and is instructional. 3. The images in the material book are well readable and easy to understand. 4. The illustrations in the material book are in accordance with the text and help my understanding. 5. Selection of colors, fonts, layouts according to.
Implementation	1. Learning strategies in the material book are appropriate. 2. There are no barriers to using the material book.
Usability in learning	1. The examples or problems presented can improve scientific thinking skills. 2. The problems presented encourage learning science. 3. According to needs and contextual. 4. In accordance with student worksheets and science experiment activities.
Usefulness	1. Books help me understand and build knowledge. 2. The material book helps me to design experimental props easily. 3. Material books can increase motivation in studying. 4. The material book helps me easily analyze the results of the experiment. 5. The material book helps me easily develop concepts and knowledge based on the STEM approach.
Innovation and learning independence	1. The material book encourages me to think creatively and find solutions to real problems. 2. The material book helps me to study independently, both online and off-line. 3. The material book is connected to digital learning resources or interactive media that support understanding.

APPENDIX C: ENGLISH VERSION

Table C1. Indicators of STEM-Hybrid RBL model practicality based on lecturer response

No	Assessment components
Syntax	1. Clear learning syntax. 2. Syntax of sequential learning. 3. Learning syntax can be implemented.
Presentation and language	1. Appearance of the book interesting material. 2. The language used is easy to understand, uses common terms and is instructional. 3. The images in the material book are well readable and easy to understand. 4. The illustrations in the material book are in accordance with the text and help my understanding. 5. Selection of colors, fonts, layouts according to.
Implementation	1. Learning strategies in the material book are appropriate. 2. There are no barriers to using the material book.
Social system	1. Social learning systems encourage collaboration, multi-directional communication, and can be implemented easily. 2. Activating students in constructing knowledge. 3. Multi-way communication. 4. Develop collaborative, creative, scientific reasoning skills.
Usefulness	1. Books help me understand and build knowledge. 2. The material book helps me to design experimental props easily. 3. Material books can increase motivation in studying. 4. The material book helps me easily analyze the results of the experiment. 5. The material book helps me easily develop concepts and knowledge based on the STEM approach.
Innovation and learning independence	1. The material book encourages me to think creatively and find solutions to real problems. 2. The material book helps me to study independently, both online and off-line. 3. The material book is connected to digital learning resources or interactive media that support understanding.

Table C2. Indicators of the practicality of the student worksheet based on lecturer response

No	Assessment components
Practicality in use (user-friendly)	1. Student worksheet is easy to use without help from other people. 2. The instructions or directions on the student worksheet are easy to understand. 3. The time required to complete the project is in accordance with the allocation. 4. The language used in student worksheet is easy for students to understand.
Relevance of material	1. The material taught is in accordance with learning achievements and objectives. 2. The material taught in student worksheet is correct and complete. 3. The material taught in the student worksheet is relevant to the material book. 4. Illustrations in the student worksheet are presented clearly and support learning. 5. Student worksheet material is developed in a coherent and systematic manner. 6. The depth and level of difficulty of the material is appropriate to the student's developmental stage. 7. The material is contextual and easy to understand.
Implementation in STEM-Hybrid model	1. Student worksheet is easy to use to gain a conceptual understanding of learning objectives. 2. Student worksheet facilitates lecturers to manage and implement STEM-Hybrid RBL. 3. Student worksheet encourages collaboration between students. 4. Student worksheet encourages students to analyze problems and accept challenges. 5. Student worksheet helps students formulate hypotheses and explore concepts. 6. Student worksheet helps students design products. 7. Student worksheet helps students conduct testing and collect data through experiments. 8. Student worksheet encourages students to use tools and materials appropriately in experiments. 9. Students are able to communicate the results of observations scientifically with the help of student worksheet.
Benefits	1. Student worksheet requires lecturers to choose relevant media, teaching aids and learning resources. 2. Student worksheet is able to guide the measurement of aspects of knowledge, skills and attitudes in science. 3. Student worksheet is able to help students improve their knowledge, skills and attitudes in science.

Table C2 (Continued). Indicators of the practicality of the student worksheet based on lecturer response

No	Assessment components
Applicability in science learning	1. Guiding students in learning science actively. 2. Pay attention to cooperation between students. 3. Helping students construct scientific knowledge 4. Encourage independent learning through a systematic learning flow.

Table C3. Indicators of the practicality of the material book based on lecturer response

No	Assessment components
Practicality in use	1. The book is easy to use without other people's help. 2. The instructions and directions in the book are easy to understand. 3. The language used is easy to understand.
Relevance of material	1. The material taught is in accordance with learning achievements and objectives. 2. The content of the material is correct, complete, and developed in a coherent and systematic manner. 3. The material is written in a simple and easy to understand manner. 4. The illustrations in the book are presented clearly and support learning. 5. The level of difficulty and depth of the material is appropriate to the student's development stage. 6. The material in the book is contextual (relevant to everyday life).
Implementation and benefits	1. The book facilitates lecturers in implementing and managing STEM-Hybrid RBL learning. 2. Books help in the assessment of reasoning skills and scientific knowledge. 3. Books are in line with student worksheet, experimental tools, and other learning resources.
Applicability in science learning	1. Guide students in learning science actively and relevantly to scientific concepts/phenomena 2. Helping students construct knowledge. 3. Helping students in independent learning.

APPENDIX D: ENGLISH VERSION

Table D1. Scientific reasoning skills assessment instrument indicators

Sub-CPMK	Science reasoning sub-skills	Question	Form
Able to evaluate and design potential energy conversion tools	*Conservation reasoning*	1	*Two tier*
	Identification and control variables	2	*Two tier*
	Proportional reasoning	3	*Two tier*
	Correlational reasoning	4	*Two tier*
	hypothetical-deductive reasoning	5	*Two tier*
Able to evaluate and design solar energy conversion tools	*Conservation reasoning*	6	*Two tier*
	Identification and control variables	7	*Two tier*
	Proportional reasoning	8	*Two tier*
	Correlational reasoning	9	*Two tier*
	hypothetical-deductive reasoning	10	*Two tier*
Able to evaluate and design kinetic energy conversion tools	*Conservation reasoning*	11	*Two tier*
	Identification and control variables	12	*Two tier*
	Proportional reasoning	13	*Two tier*
	Correlational reasoning	14	*Two tier*
	hypothetical-deductive reasoning	15	*Two tier*
Able to evaluate and design heat energy conversion tools	*Conservation reasoning*	16	*Two tier*
	Identification and control variables	17	*Two tier*
	Proportional reasoning	18	*Two tier*
	Correlational reasoning	19	*Two tier*
	hypothetical-deductive reasoning	20	*Two tier*
Able to evaluate and design chemical energy conversion tools	*Conservation reasoning*	21	*Two tier*
	Identification and control variables	22	*Two tier*
	Proportional reasoning	23	*Two tier*
	Correlational reasoning	24	*Two tier*
	hypothetical-deductive reasoning	25	*Two tier*

https://www.ejmste.com