

Research-Based Learning (RBL) in Science Education in Higher Education: Conceptualizations, Implementation, Impact, and Future Directions

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Science education in higher education continues to face challenges related to limited student engagement in research activities, insufficient research skills, and the dominance of theoretical instruction. Research-based learning (RBL) is an instructional approach that integrates teaching and research to address these challenges. However, comprehensive reviews focusing on its conceptualizations, implementation, and impact in science education remain scarce. The objective of this study was to methodically examine the conceptual underpinnings, implementation trends, effects, and potential future research avenues of RBL in science education in higher education. The study was conducted in accordance with the PRISMA reporting guidelines. A systematic literature review was conducted by examining publications indexed in the Scopus database between 2015 and 2024. The review was limited to articles published in English and accessible as open-access documents. Using predefined inclusion and exclusion criteria, 23 relevant articles were selected and synthesized through a narrative approach. The results indicate that RBL is grounded in constructivist theory and emphasizes student-centered research activities, real-world problem-solving, autonomous learning, and experiment-based learning. The implementation of RBL generally involves stages of research preparation, investigation, and dissemination, although variations exist across contexts. The findings indicate that RBL positively enhances students' research skills, conceptual understanding, critical thinking, problem-solving skills, and scientific knowledge. Future research should explore institutional support, digital technology

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integration, collaborative learning, reflective practices, and diverse samples. Overall, RBL is an effective pedagogical approach for science education in higher education. RBL supports SDG 4 (Quality Education) by enhancing students' research and lifelong learning skills.

Introduction

Science education plays a crucial role in developing scientifically literate students who are capable of addressing global challenges (Cho, 2022; Perna et al., 2022). Beyond the transmission of scientific knowledge, it aims to foster critical and creative thinking skills (Alberts, 2022; Hyytinen et al., 2019). Through inquiry- and discussion-based learning approaches, students are encouraged to evaluate information, make informed decisions, and solve complex problems (John, 2023; Lu et al., 2020; Mkimbili & Ødegaard, 2020). Skills such as analysis, critique, comparison, and evaluation are therefore fundamental components of learning in the sciences (Hanan Taleb & Chadwick, 2016).

One of the key challenges in science learning lies in students' limited readiness to actively engage in problem-solving processes. Many students experience difficulties in adapting to learning environments that require active participation, critical thinking, and independent inquiry (Bergmann et al., 2021). These challenges are further intensified by the nature of science learning, which often requires substantial conceptual change as students transition from intuitive explanations to scientifically grounded understandings (Ridlo & Nugroho, 2020). Students often face challenges related to limited understanding of research methods, insufficient experience in scientific writing, and low participation in research activities. These difficulties may be further compounded by limited supervisory capacity and support during the research process (Prahmana & Kusumah, 2016).

Excessive theoretical instruction with limited real-world application and inadequate research preparation remain significant challenges in higher education (Martín-Garin et al., 2021). As a result, conventional learning approaches, in which students primarily act as passive recipients of knowledge, may be insufficient to address the demands of science learning (Hegde & Karunasagar, 2021; Puchumni et al., 2019). These challenges highlight the need for instructional approaches that actively engage students in scientific exploration and foster analytical skills that are essential for science education (Aguilera & Perales-Palacios, 2020). In response, educators are increasingly encouraged to develop innovative and evidence-based teaching strategies that promote critical thinking, creativity, and collaborative problem-solving skills needed to meet the demands of the twenty-first century (Hegde & Karunasagar, 2021; Marín, 2020).

One instructional approach that actively engages students is Research-Based Learning (RBL). Research-Based Learning (RBL) is defined as a student-centered learning approach that systematically integrates authentic research processes into teaching and learning activities (Hoffmeister et al., 2020). In this approach, students are actively engaged in key stages of research, including formulating research questions, reviewing relevant literature, designing and conducting investigations, analyzing data, and communicating findings (Treppe & Hildbrand, 2012). Unlike other student-centered approaches such as inquiry-based or project-based learning, RBL places a stronger emphasis on the application of formal research methodologies and the production of new knowledge as a central component of learning. By engaging students in successive stages of the research process, RBL has been reported to support student engagement and active learning (Solovieva et al., 2022; Suyatman et al., 2020; Usmeldi, 2018). Higher education increasingly incorporates research-based instruction



as a fundamental component (Hughes, 2019), as it is well suited to address the diverse academic needs of students (Thiem et al., 2023; Wessels et al., 2021). By integrating RBL into higher education curricula, students can develop discipline-specific research skills, gain experience in designing and conducting research, and effectively communicate their findings (Marín, 2020; Thiem et al., 2023).

RBL has shown potential for supporting the teaching and learning of science by engaging students in authentic research experiences (Marcella & Samofalova, 2022). Research-based learning enables students to apply scientific concepts and research methods in authentic scientific contexts (Zhang & Ranadheera, 2023). The inquiry-oriented nature of science learning makes it particularly compatible with research-based learning approaches (Parker, 2018). Students who actively participate in research-based learning projects will develop scientific competence and scientific literacy (Restović & Bulic, 2024), which are closely related to science education. Science education provides opportunities for students to connect learning with research, develop research competencies, and generate new insights through inquiry and investigation (García-Carmona, 2020). In this regard, several studies have been conducted in the sciences on the potential application of research-based learning, which combines laboratory work (or research projects) with academic instruction (Hughes, 2019). The application of RBL can also be carried out in natural environments or classrooms so that it can help students become competent in the field of science (Restović & Bulic, 2024).

A more comprehensive understanding of the RBL model in science education is needed. One approach to achieving this is to conduct a systematic review of existing research. Several systematic reviews have examined RBL models, including a systematic review to identify RBL in occupational therapy and physiotherapy curricula (Helgøy et al., 2022), RBL methodological design in engineering programs (Del & Galantini, 2024), RBL in higher education (Camacho et al., 2017), implementation, outcomes, and effectiveness of research-based learning (Arifin et al., 2022), and RBL education in Thailand based on publications from 1996 to 2011 (Srikoon et al., 2018). While widely implemented in undergraduate research instruction, the model still lacks a precise and consistent conceptual definition, and scholars continue to debate its theoretical foundations (Behrmann, 2019; Wessels et al., 2021), and academics disagree on a single definition (Parker, 2018). The educational effects of the RBL model remain insufficiently explored (Thiem et al., 2023b). Furthermore, the scholarly literature calls for more robust designs and clearer frameworks in research-based learning implementation (Pourhejazy & Isaksen, 2024). To the best of our knowledge, no systematic review has specifically examined research-based learning models in science education within higher education. Therefore, this article addresses this gap by examining the conceptual foundations, implementation, effects, and future research directions of RBL in science education within higher education.

Research Question:

This systematic literature review addresses the following research questions regarding RBL in science education within higher education:

- (1) How is RBL conceptualized in the literature?
- (2) How is RBL implemented in science education?
- (3) What are the effects of RBL implementation on science education?
- (4) What future research directions have been identified for RBL?

Method

The process of systematic literature review is utilized to investigate, summarize, assess, and analyze evidence by providing a synthesized explanation of important issues relevant to the purpose of this study (Sun et al., 2023). The approach of Systematic Literature Review combines aspects of critical review and a comprehensive search process (Aleknavičiūtė et al., 2023). According to Sawyer (2017), SLR uses a more systematic method to produce more valid and reliable conclusions. In this study, a large-scale data and literature were collected related to the RBL model in science education in higher education. The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines, which provide clear and transparent guidelines for reporting the procedures undertaken in the study, were used in this investigation (Aleknavičiūtė et al., 2023).

Procedure

The Scopus database was used as the primary source for identifying relevant studies. The Scopus database was selected as the primary source for identifying relevant studies due to its extensive coverage of high-quality, peer-reviewed international journals across multidisciplinary fields, including science education. Scopus is widely recognized for its rigorous indexing standards and comprehensive metadata, making it a reliable source for systematic literature reviews. Therefore, it is considered sufficient to capture the majority of relevant publications related to Research-Based Learning (RBL) in higher education. However, limiting the search to a single database may introduce potential publication bias, as relevant studies indexed in other databases or non-indexed sources may not be included. Despite this limitation, clearly defined inclusion and exclusion criteria were applied to enhance the quality and relevance of the selected studies. Data was obtained by considering multidisciplinary research, accessibility, and relevance to the topic. The four stages of the PRISMA guidelines—identification, screening, eligibility, and inclusion—were used to guide the literature search and study selection process. The data search history is as follows: Your query: TITLE-ABS-KEY("research-based learning" OR "research learning" OR "research based teaching") AND PUBYEAR > 2014 AND PUBYEAR < 2025 AND (LIMIT-TO (DOCTYPE,"ar")) AND (LIMIT-TO (LANGUAGE,"English")) AND (LIMIT-TO (OA,"all")) AND (LIMIT-TO (SUBJAREA,"SOCI")). The following is a flowchart illustrating the review selection process (Figure 1). The search was conducted on February 21, 2025.

Inclusion and Exclusion Criteria

To ensure that relevant studies were appropriately included in the review process, inclusion and exclusion criteria are used during the screening step of article selection (Table 1).

Table 1. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
1. Original research	1. Articles in the form of conference papers, book chapters, conference reviews, reviews, and books
2. Articles published between 2015 and 2024	2. Studies not conducted between 2015 and 2024
3. Articles in English	3. Articles in languages other than English
4. Open access articles	4. Inaccessible articles
5. Studies using the RBL learning model in higher education	5. RBL studies conducted at the elementary and secondary school levels
6. Studies focusing on science education, science learning, and educational science.	6. Studies not focused on science education, science learning, or educational science.



The time frame of 2015–2024 was selected to capture recent developments and the growing maturity of Research-Based Learning (RBL) in higher education. A previous systematic review of 50 articles published between 2000 and 2016 reported that most RBL interventions demonstrated positive outcomes in terms of content knowledge, research skills, and scientific attitudes. Notably, more than half of the reviewed studies were published after 2010 (Camacho et al., 2017), indicating a significant increase in scholarly interest and the consolidation of RBL practices, particularly after 2014. Therefore, focusing on the 2015–2024 period allows this study to reflect more current trends, developments, and implementations of RBL in science education.

The restriction to open-access articles was applied to ensure full accessibility and transparency in the data extraction and analysis process. Despite this limitation, the selected articles are considered sufficient to represent current trends and patterns of RBL implementation in science education.

The screening process was conducted through collaborative review meetings involving the research team and an expert in science education. The research team consisted of three researchers and one expert in higher education pedagogy. During the screening process, each article was independently reviewed by the researchers based on the predefined inclusion and exclusion criteria. The results were then compared and discussed collectively during review meetings. In cases of disagreement, consensus was reached through discussion and re-evaluation of the articles against the established criteria. If consensus could not be achieved, a third reviewer was consulted to make the final decision.

To ensure inter-coder reliability and consistency, all researchers used a standardized screening protocol, and initial calibration was conducted by jointly reviewing a subset of articles to align interpretations of the criteria. In addition, inter-coder agreement was assessed quantitatively by calculating the percentage agreement between coders on a subset of the screened and coded articles, including the thematic synthesis stage, which resulted in an agreement rate of 85%, indicating a high level of consistency among coders. This process helped minimize subjective bias and improve the reliability of article selection and thematic analysis.

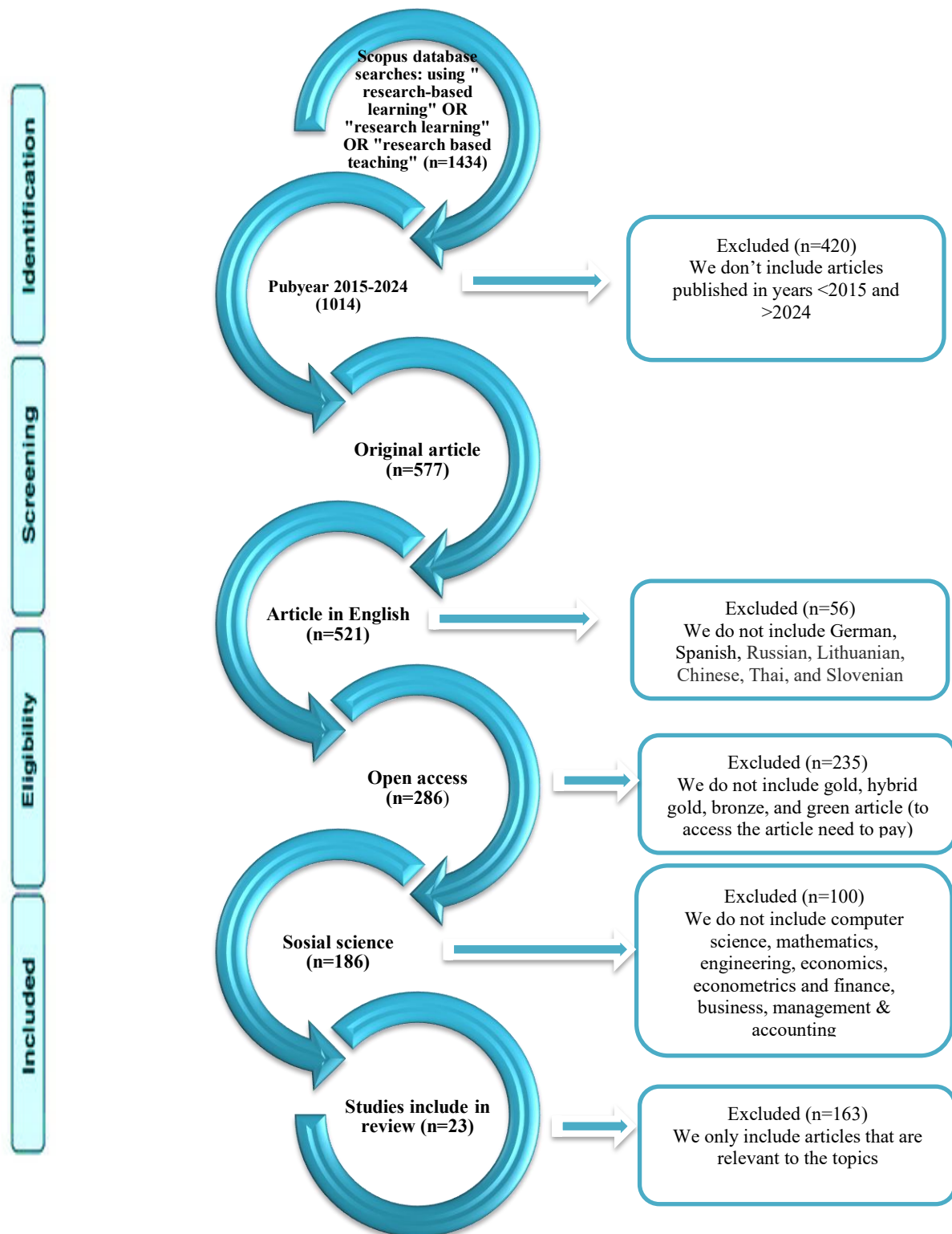


Figure 1. Flowchart illustrating the review selection process

Extraction and Analysis

Microsoft Excel was used to tabulate data and information from the 23 gathered articles. The author, year of publication, research methodology, sample, RBL concept



utilized, stages of the RBL model, type of research project, key findings/important points, study limitations, and recommendations for further research were all included in the extraction table. During content analysis and synthesis, the extraction table was used to systematically document relevant data from each selected study, including study characteristics, RBL concepts, implementation stages, and key findings. The extracted data were then coded, categorized, and compared to identify recurring patterns, similarities, and differences across studies.

The article selection process was conducted based on predefined inclusion and exclusion criteria, which were consistently applied during the screening and eligibility stages. Each article was independently reviewed by the researchers to assess its relevance to the study objectives. The results of the screening were then compared and discussed collaboratively. In cases of disagreement, the researchers re-evaluated the articles through discussion until consensus was reached. When necessary, a third reviewer was involved to resolve discrepancies.

To ensure consistency and reliability in the evaluation process, all researchers followed a standardized screening protocol, and an initial calibration process was conducted by jointly reviewing a subset of articles to align interpretations of the criteria. A narrative synthesis approach was employed to integrate and interpret the findings across studies. This approach enables the systematic organization and explanation of evidence using textual descriptions to identify key themes and relationships (Jahan et al., 2022). This process facilitated the identification and interpretation of key themes across studies.

The data extraction and analysis processes were conducted collaboratively to minimize bias. Each researcher independently reviewed and coded the selected articles using a standardized worksheet. To ensure inter-coder reliability, an initial calibration was conducted by jointly coding a subset of articles to align the interpretation of criteria. The coding results were then compared to assess consistency, and discrepancies were resolved through discussion until consensus was reached. If needed, a third researcher was consulted to make the final decision. A review meeting was subsequently held to verify and finalize the analysis results.

Results and Discussion

This analysis identified 23 relevant studies within the scope of this review. 11 studies were conducted in European countries, including Germany, Spain, Greece, Finland, and Ireland. 6 studies were carried out in Asian countries, including Hong Kong, India, Indonesia, and the United Arab Emirates. 1 study was carried out in Australia, while 5 studies were carried out in the Americas, including Mexico, the United States of America, and Canada. These studies focused on the RBL model in higher education in science education and/or science learning and/or educational science. The most commonly used research method was qualitative research. In addition, other methods used were mix methods and quantitative. Information on the articles analysed is presented in Table 2.

Table 2. Information on the articles analysed

Quantity	Aspect
Year	
2024	7
2023	1
2022	4
2021	5
2020	3
2019	3
Country	
Germany	4
Indonesia	3
Mexico	3
Spain	4
United Arab Emirates	1
Greece	1
India	1
Finland	1
Australia	1
Ireland	1
Hong Kong	1
United States of America	1
Canada	1
Research methods	
Quantitative methods	5
Qualitative methods	11
Mixed methods	7

The Concept of the RBL Model

Research-based learning, real-world problem-solving, independent learning, and a learning environment that prioritizes experimental activities are the hallmarks of the constructivist theory-based RBL approach. Analysis of 23 articles related to the RBL model in science education in higher education revealed diverse conceptualizations of RBL (Table 3).



Table 3. Conceptualizations of RBL across the reviewed studies

No	Author (Year)	RBL Concept
1.	Böttcher-Oschmann et al. (2021); Burke et al. (2024); Hegde & Karunasagar (2021); Mendoza (2021); Olivo-Montaña et al., (2024); Restović & Bulic, (2024)	The fundamental tenet of RBL is that students actively participate in conducting research while being supervised by a lecturer. The research project process is shaped, experienced, and reflected upon by the students. RBL consists of several substantive phases: developing research questions and hypotheses, selecting and implementing research methodologies, examining research data, and presenting findings.
2.	Martín-Garin et al. (2021); Sopandi et al., (2019); Zhang & Ranadheera (2023); Haviz et al. (2024)	RBL is based on constructivist principles. The RBL program guides students through research projects. Students select research projects, conduct literature reviews, learn research methods, provide research materials or assignments, engage students in the research, and ultimately, encourage them to produce a scientific article.
3.	Marín, (2020); Nogales-Delgado et al. (2022); Strachan et al. (2019); Suyatman et al. (2021); Veses et al. (2020)	Give students research projects that tackle real-world issues. Students gain experience in planning and conducting research, learn research skills relevant to the discipline, and develop and present research.
4.	Alvarez et al. (2022)	Research-based activities in laboratory and non-laboratory settings
5.	Agud & Ion (2019); Cuevas-Cancino et al. (2024); Perna et al. (2022)	An inquiry-oriented learning model focused on solving real-world scientific problems.
6.	Pantazidou & Kandris (2020)	Learning strategies informed by research in science education.
7.	Strachan et al. (2019); Zou et al., (2024)	Research-based learning involves students engaging in research-based activities and inquiry, where they acquire a critical grasp of information, practice agency, and hone their research abilities. A curriculum that is largely focused on research-based activities and inquiry rather than the subject matter itself is known as a research-based curriculum.
8.	Shah et al. (2024)	Students are encouraged to interpret and make inferences from observations while conducting independent research under the supervision of an academic supervisor. Instead of just receiving information from the instructor, students become active contributors to knowledge construction.

Based on the synthesis of the study results from 23 articles presented in Table 3, it can be concluded that the concept of the Research-Based Learning (RBL) model in science education shares a common pattern despite being adopted in various contexts and disciplines. The various definitions and conceptual emphases from each study were then synthesized to build a more complete and integrated conceptual picture. This synthesis is formulated into a visual representation that illustrates the relationships between the main elements of the RBL concept, as presented in Figure 2.

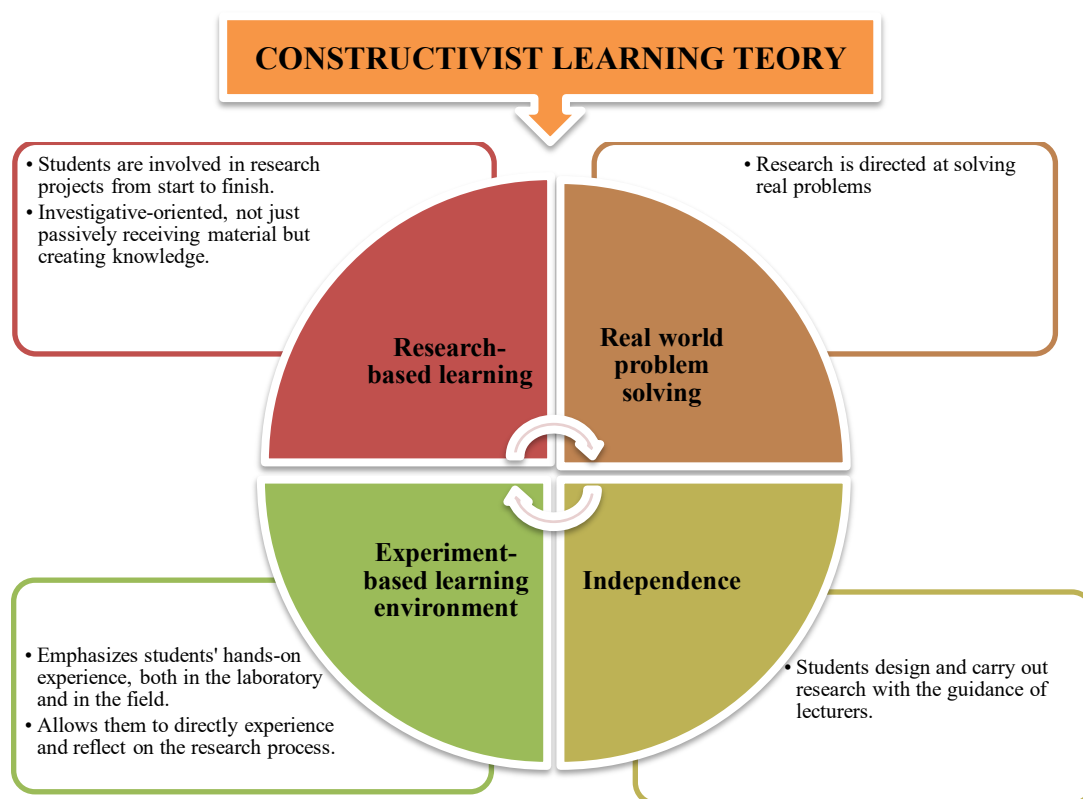


Figure 2. RBL model concept

Based on Constructivism Theory

The RBL model is based on constructivist theory (Haviz et al., 2024; Sopandi et al., 2019). Constructivist theory enables students to actively construct and apply knowledge (Haviz et al., 2024). RBL engages students by encouraging them to identify problems, design solutions, gather and evaluate information, and make inferences (Haviz et al., 2024; Sopandi et al., 2019). An inquiry-based learning approach is the RBL model (Marín, 2020). Inquiry activities are supported by constructivist learning theory, which emphasizes students' experiences and interactions with their environment (Olivo-Montaña et al., 2024). RBL is a student-centered approach grounded in constructivist principles (Martín-Garin et al., 2021).

Research-Based Learning

Students actively participate in carrying out investigations or research projects under the research-based learning model (Burke et al., 2024; Hegde & Karunasagar, 2021; Marín, 2020; Restović & Bulic, 2024; Wessels et al., 2021) under the guidance of a lecturer (Marcella & Samofalova, 2022). Research-Based Learning (RBL) consists of core stages including developing research questions and hypotheses, selecting and implementing research methodologies, examining research data, and presenting findings (Marcella & Samofalova, 2022; Sopandi et al., 2019). The RBL model is a research-based learning approach that gives students the chance to recognize issues, come up with scientific answers, develop a standardized approach, and write a research report (Sopandi et al., 2019).

Real-World Problem Solving

Research activities in science learning conducted using the RBL model are directed at solving real-world problems (Marín, 2020; Nogales-Delgado et al., 2022; Sopandi et al., 2019) and how these are developed can determine student motivation and engagement (Nogales-Delgado et al., 2022). RBL gives students a platform to acquire essential concepts and knowledge from the subject as well as problem-solving strategies and abilities (Suyatman et al., 2021). Designing learning opportunities around genuine and authentic scenarios is a good fit for research-based learning (Böttcher-Oschmann et al., 2021) and can be a challenging approach for students (Nogales-Delgado et al., 2022).

Independent Learning

Students can actively and autonomously participate in specific stages of the research process or the full process, as well as design and conduct their own research projects (Böttcher-Oschmann et al., 2021; Marcella & Samofalova, 2022). Additionally, RBL supports the development of autonomous learning (Marín, 2020). Fundamentally, RBL involves students conducting independent research and being encouraged to evaluate and develop conclusions from their findings under the supervision of an academic supervisor (Shah et al., 2024). RBL fosters student autonomy and independence (Nogales-Delgado et al., 2022). Instead of only being knowledge consumers, students in RBL become active contributors to knowledge creation (Shah et al., 2024).

Experiment-Based Learning Environment

Research-based learning (RBL) also emphasizes an experiment-based learning environment for learning scientific concepts (Alvarez et al., 2022). The stages of research-based learning involve data collection through experiments, where students identify important problems in the field of science (Haviz, 2018). Research activities can be developed through experimental investigations (Park et al., 2023). Students are successfully engaged in the learning process by this research-based instruction, which enables them to integrate knowledge while honing their experimental abilities (Alvarez et al., 2022; Park et al., 2023). RBL in science learning also involves an experiment-based learning environment that emphasizes students' hands-on experiences, both in the laboratory and outside of the laboratory (Alvarez et al., 2022). Such experiences allow students to engage directly in and reflect on the research process (Marcella & Samofalova, 2022; Olivo-Montaña et al., 2024; Strachan et al., 2019).

Implementation of the RBL Model

The implementation stages of RBL vary across studies. The reviewed studies present different approaches to implementing RBL. Table 4 summarizes the RBL model's implementation.

Table 4. Implementation of the RBL model in various research articles

No	Author (Year)	RBL Stages
1.	Sopandi et al. (2019)	<ol style="list-style-type: none"> 1. Analyzing relevant current research 2. Choosing possible research to create 3. Encouraging students to review literature, Teaching research techniques, providing resources or research tasks 4. Engaging students in research

No	Author (Year)	RBL Stages
		5. Ultimately motivating students to produce scientific articles.
2.	Marín (2020)	<ol style="list-style-type: none"> 1. Concrete the educational issue that needs to be resolved. 2. Examine the redefined educational challenge by analyzing the context and determining the best pedagogical strategy. 3. Motivate by going over earlier instances and using the knowledge gained from them in the present project. 4. Come up with a conceptual solution. 5. Put the solution into practice to prototype it. 6. Assess the design to ensure that its goals are met and to pinpoint areas that need improvement. 7. Consider the design process, associated educational opportunities, and their results.
3.	Alvarez et al. (2022)	<ol style="list-style-type: none"> 1. Students get directions on how to assemble their own heaters using existing tools 2. Examining zein nanoparticle production techniques in the scientific literature 3. Choose one or two methods of fabrication 4. Assemble their do-it-yourself (DIY) heating system 5. Create short videos and technical reports
4.	Nogales-Delgado et al. (2022)	<ol style="list-style-type: none"> 1. Lecturers look at students' initial abilities related to basic things, for example English skills, laboratory skills, etc. 2. Lecturers provide a list of literature for students to study. 3. The Adoption of a Schedule 4. Training 5. Experimentation 6. Writing and Rehearsal 7. Final Degree Project (FDP)
5.	Agud & Ion (2019)	<ol style="list-style-type: none"> 1. Develop academic and learning abilities and techniques to get a sufficient degree of autonomy in one's studies while also realizing the significance of continuously updating one's training. (Basic) 2. Encourage critical reading and discussion of the various scientific fields included in the curriculum. (Particular) 3. Handle the data pertaining to the workplace in order to make decisions and generate reports. Examine the completed work critically. (Transversal) 4. Before taking any action, acknowledge and assess the social reality and the relationship with applied aspects. (Transversal)
6.	Suyatman et al. (2021)	<ol style="list-style-type: none"> 1. Create issues 2. Examine the theoretical foundation 3. Describe the issue. 4. Organizing research projects 5. Conduct research and data analysis 6. Describe the findings of the study 7. Produce outcomes reports and presentations
7.	Solovieva et al. (2022)	<ol style="list-style-type: none"> 1. A number of subjects closely associated with the plastic trash project are presented to students. 2. Research team members and students work together to participate in the research project

No	Author (Year)	RBL Stages
		<ol style="list-style-type: none"> 3. Students collect primary data through surveys 4. Students are given two questions, one from the research team and one question they develop themselves 5. Analyze primary data 6. Draw conclusions 7. Presentation of research
8.	Pantazidou & Kandris (2020)	<ol style="list-style-type: none"> 1. Formulate important questions 2. Find answers to important questions through case studies or research projects
9.	Hegde & Karunasagar (2021)	<ol style="list-style-type: none"> 1. Inspiring 2. Ideating 3. Action 4. Refining 5. Reporting 6. Rewarding
10.	Veses et al. (2020)	<ol style="list-style-type: none"> 1. Pre-project preparation (during which the ambassadors were given specialized training and guidance) 2. Real-world experience (the ambassadors collaborated with student volunteers to complete the project) 3. Results were publicly shared by ambassadors at a scientific conference of their choosing.
11.	Martín-Garin et al. (2021)	<ol style="list-style-type: none"> 1. Identify a research issue related to the curriculum so that students can apply pertinent scientific knowledge. 2. Demand that research be able to identify the solution; 3. Refine, which is necessary to maintain the caliber of the research work 4. Reward, which evaluates the activity's effectiveness 5. Report
12.	Pernaa et al. (2022)	<ol style="list-style-type: none"> 1. Literature review 2. Design solution 1 3. Case study 4. Design solution 2
13.	Zhang & Ranadheera (2023)	<ol style="list-style-type: none"> 1. Presentation of materials and inviting guest lecturers from practitioners or academics to share experiences 2. Research projects or literature reviews and data collection from various articles 3. Presentations and discussions 4. Research reports
14.	Burke et al. (2024)	<ol style="list-style-type: none"> 1. Brainstorming 2. Sorting 3. Rating
15.	Restović & Bulic (2024)	<ol style="list-style-type: none"> 1. The study investigated the impact of nature conservation on students' attitudes 2. Both before and after the activity, positive opinions for the preservation of nature were noted. 3. Significant increase in knowledge was noted after completion of the project.
16.	Cuevas-Cancino et al.	The research project uses vertical collaboration with all students and adheres to the RBL paradigm.

No	Author (Year)	RBL Stages
	(2024)	
17.	Olivo-Montaño et al. (2024)	<ol style="list-style-type: none"> 1. Sense the intention 2. Know the context 3. Know the people 4. Frame the insight 5. Explore the concepts 6. Frame the solution 7. Realize (implement)
18.	Zou et al. (2024)	The stages are not mentioned because this study emphasizes research-based curriculum
19.	Shah et al. (2024)	<ol style="list-style-type: none"> 1. Experiment 2. Literature review 3. Drawing conclusions
20.	Strachan et al. (2019)	The stages are not mentioned because this study emphasizes a research-based curriculum that focuses on the SDGs
21.	Mendoza (2021)	Implementation stages were not explicitly described
22.	Böttcher-Oschmann et al. (2021)	<ol style="list-style-type: none"> 1. Preparation phase 2. Fieldwork phase 3. Presentation phase
23.	Haviz et al. (2024)	<ol style="list-style-type: none"> 1. Addressing the problem, when students gather and research the problems 2. Data collection-verification, in which students gather problems 3. Data collection-experimentation, when students identify significant issues or subjects 4. Explanation formulation, in which students create solutions to the issues 5. Research analysis, in which pupils examine the responses

The RBL model implementation table shows that the application of RBL in science education is carried out through various stages, depending on the learning context, research objectives, and student characteristics and field of study. Although there are differences in terminology and the sequence of stages between studies, in general, RBL implementation follows a relatively similar pattern, starting from the preparation stage, through research implementation, to reporting and reflection on research results. To clarify the flow and interrelationships between these implementation stages, the results of the synthesis of various RBL implementation models are presented visually in Figure 3.

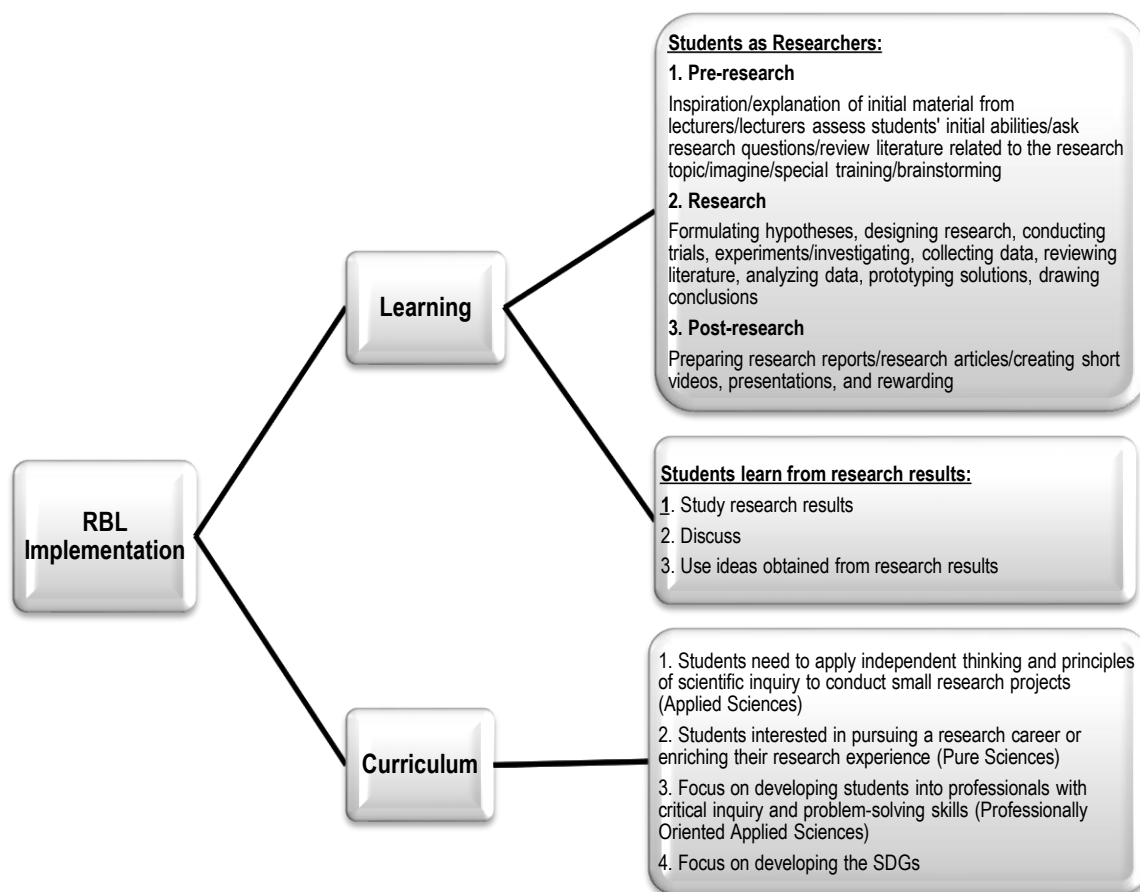


Figure 3. Implementation of the RBL model

Curriculum

Research-based learning can be integrated into science curricula at various levels of higher education. Students can acquire foundational knowledge that they can use in a range of situations thanks to a research-based curriculum (Harland & Wald, 2018). Scholars contend that embedding research skills throughout the curriculum is essential for developing a successful research-based undergraduate curriculum (Hughes, 2019). In pure science, a research-based curriculum is intended for students who want to pursue careers in research or enhance their research experience, whereas in applied science, it emphasizes the need for students to apply independent thinking and scientific inquiry principles to conduct research projects (Zou et al., 2024). Furthermore, the implementation of a research-based curriculum can also be aligned with the Sustainable Development Goals (SDGs) framework by mapping the impact and focus of student research activities to achieve the appropriate SDG targets (Strachan et al., 2019).

Learning

Research and teaching can be linked in a variety of ways. In a popular model, In order to engage students in research, Healey & Jenkins (2009) differentiate between different learning formats along two axes. The first axis indicates whether the focus is on the research process or the research findings. The other axis indicates whether students participate actively or just observe. (Wessels et al., 2021).

Students as Researchers

The implementation of the RBL model in science education positions students as active researchers and is typically conducted through pre-research, research, and post-research stages. In the pre-research stage, students are prepared for the research process by developing research skills and competencies (Böttcher-Oschmann et al., 2021). This stage includes inspirational activities such as workshops and discussions with scientists (Hegde & Karunasagar, 2021), brainstorming research topics (Burke et al., 2024), introductory explanations of research concepts (Zhang & Ranadheera, 2023), training in research methods (Veses et al., 2020a), formulating research questions or problems (Martín-Garin et al., 2021; Pantazidou & Kandris, 2020; Wessels et al., 2021), and conducting literature reviews (Pernaa et al., 2022).

During the research stage, students conduct investigations or experiments in laboratory or field settings (Böttcher-Oschmann et al., 2021). Key activities include formulating hypotheses, designing and conducting investigations (Fernández-López et al., 2024; Hegde & Karunasagar, 2021; Jahan et al., 2022; Nogales-Delgado et al., 2022; Pernaa et al., 2022; Suyatman et al., 2020; Wessels et al., 2021; Zhang & Ranadheera, 2023), collecting and analyzing data (Haviz et al., 2024; Solovieva et al., 2022), identifying solutions (Marín, 2020; Martín-Garin et al., 2021; Olivo-Montañó et al., 2024), and drawing conclusions (Solovieva et al., 2022). This stage emphasizes methodological skill development and reflection on research outcomes (Böttcher-Oschmann et al., 2021).

The post-research stage focuses on communicating research results through reports, articles, videos, presentations, and rewarding activities (Alvarez et al., 2022; Böttcher-Oschmann et al., 2021; Hegde & Karunasagar, 2021; Sopandi et al., 2019).

Students Learn from Research Findings

The RBL model can be implemented by having students learn from research findings in the form of research articles. Activities include first reading and studying relevant research articles (Marcella & Samofalova, 2022; Park et al., 2023; Zhang & Zhang, 2021) and learning the concept of scientific journals as an introductory step (Haviz et al., 2024). Afterward, students analyze the scientific articles and engage in collaborative discussions with both the lecturer and other peers (Park et al., 2023).

Impact of RBL Implementation

An analysis of 23 articles on the RBL model in science education at universities suggests that RBL contributes to students' cognitive, affective, and psychomotor development (Table 5). Each aspect experienced improvement following the model's implementation in learning.

Table 5. Reported impacts of RBL across the reviewed studies

Author	Impact	Quantity
(Agud & Ion, 2019; Haviz et al., 2024; Hegde & Karunasagar, 2021; Sopandi et al., 2019)	Research skills	4
(Sopandi et al., 2019)	Article writing skills	1
(Alvarez et al., 2022; Shah et al., 2024; Solovieva et al., 2022; Veses et al., 2020; Pernaa et al., 2022)	Conceptual understanding	5
(Burke et al., 2024; Hegde & Karunasagar, 2021; Nogales-Delgado et al., 2022; Strachan et al., 2019; Pantazidou & Kandris, 2020; Zou et al., 2024)	Research experience	6
(Suyatman et al., 2021)	Analytical thinking skills	1
(Böttcher-Oschmann et al., 2021; Hegde & Karunasagar, 2021)	Research knowledge	2
(Cuevas-Cancino et al., 2024b; Martín-Garin et al., 2021; Strachan et al., 2019)	Sustainable development	3
(Hegde & Karunasagar, 2021; Zhang & Ranadheera, 2023)	Problem solving	2
(Restović & Bulic, 2024a)	Ecological awareness attitude	1
(Restović & Bulic, 2024a)	Knowledge retention	1
(Olivo-Montaño et al., 2024b)	Critical thinking skills	1
(Mendoza, 2021b)	Socio-cognitive skills	1
(Haviz et al., 2024b)	Scientific literacy	1

RBL has been widely implemented in science education programs (Sopandi et al., 2019). Table 5 shows that RBL implementation has a variety of positive impacts on student competency development. Research experience is the most dominant impact, appearing in the highest number of studies (Burke et al., 2024; Hegde & Karunasagar, 2021; Nogales-Delgado et al., 2022; Pantazidou & Kandris, 2020; Strachan et al., 2019; Zou et al., 2024). This pattern suggests that RBL implementation consistently provides students with opportunities to engage directly in research activities, such as formulating problems, collecting and analyzing data, and preparing scientific reports. This active involvement is key to building authentic experiences that support meaningful learning (Nogales-Delgado et al., 2022; Strachan et al., 2019).

Conceptual understanding was another frequently reported outcome, supported by five studies (Alvarez et al., 2022; Shah et al., 2024; Solovieva et al., 2022; Veses et al., 2020; Pernaa et al., 2022). This indicates that through RBL, students are able to construct deeper knowledge because they learn through a process of investigation and discovery, rather than simply passively receiving information (Alvarez et al., 2022; Shah et al., 2024). Another significant impact was research skills, which emerged in four studies (Agud & Ion, 2019; Haviz et al., 2024; Hegde & Karunasagar, 2021; Sopandi et al., 2019). These skills include the ability to design research, use scientific methods, and systematically analyze data (Agud & Ion, 2019; Haviz et al., 2024; Sopandi et al., 2019). Furthermore, sustainable competencies was found in three studies (Cuevas-Cancino et al., 2024; Martín-Garin et al., 2021; Strachan et al., 2019), through the implementation of research-based learning related to waste management and recovery through the development of innovative, environmentally friendly processes (Martín-Garin et al., 2021). Students have the chance to study firsthand in their professional

disciplines and in pertinent societal contexts through research projects pertaining to environmental conservation, which will promote sustainable development (Cuevas-Cancino et al., 2024) and ecological awareness and knowledge retention (Restović & Bulic, 2024). Several other impacts emerged with lower frequency, such as research knowledge (Böttcher-Oschmann et al., 2021; Hegde & Karunasagar, 2021) and problem-solving (Hegde & Karunasagar, 2021; Zhang & Ranadheera, 2023), which were each found in two studies. Meanwhile, impacts such as article writing skills (Sopandi et al., 2019), analytical thinking skills (Suyatman et al., 2020), ecological awareness (Restović & Bulic, 2024), knowledge retention (Restović & Bulic, 2024), critical thinking (Olivo-Montaña et al., 2024), socio-cognitive aspects (Mendoza, 2021), and scientific literacy (Haviz et al., 2024) were each only found in one study. Despite their low frequency, these impacts demonstrate that RBL has the potential to contribute broadly to various dimensions of student competency.

Future Research RBL

To formulate future research directions, this study systematically analyzed the limitations, challenges, and research gaps reported in the selected articles, particularly those published within the last three years. These aspects were identified through a thematic synthesis of recurring issues, inconsistencies, and underexplored areas across the studies. Each proposed direction is therefore grounded in the reported limitations and empirical findings of the reviewed literature, rather than solely based on general interpretation. This process resulted in six key thematic areas for future research.

Initial Introduction to the Research

According to Shah et al. (2024), it is necessary to give students a basic understanding of the research procedures and instruments used to examine and quantify the effects of microplastics on a number of important soil processes, such as plant growth, soil water evaporation, soil cracking, solute transport, and water infiltration. Daryanes et al. (2025) highlighted the need for a preparatory phase to equip students with knowledge of material concepts and research methods to facilitate their research. Restović & Bulic (2024) also suggested that students' prior knowledge influences their attitudes toward nature conservation. As noted by Perna et al. (2022) that an introduction was necessary for clarity in instruction, and this presented a challenge in their research. The importance of an initial introduction to research before students directly engage in research-based learning could be an interesting topic for future research.

Institutional Involvement in Research-Based Curriculum Development

Developing a research-based curriculum requires support from various parties. Faculty members struggle to articulate expected research skills. There is a communication gap between faculty and students regarding the curriculum's foundation (Zou et al., 2024), as well as a gap between student readiness and faculty perceptions of research engagement (Shah et al., 2024). Institutional barriers to change hinder the adoption of innovative educational concepts (Olivo-Montaña et al., 2024). Future research needs to refine the conceptualization of the research-based curriculum and examine faculty and student engagement in understanding the curriculum (Zou et al., 2024). Some studies suggest that universities face challenges in fostering complex thinking skills (Olivo-Montaña et al., 2024).



Technology Use

Research on the usability, engagement, and acceptance of technology in digital platforms is crucial (Olivo-Montaña et al., 2024). Global economic growth is frequently associated with sustained investment in research and technology (Delgado & Estrada, 2022). Technology is a key component of research-based learning initiatives that track and advance environmental education in communities along butterfly migration routes (Cuevas-Cancino et al., 2024). Digital literacy and educational technology are now essential components of Education 5.0, making it easier to access a multitude of materials and educational possibilities. A strong technology infrastructure is necessary for the successful implementation of Education 5.0, which is defined under the concepts of Open Science (Olivo-Montaña et al., 2024), therefore, studies related to technology use offer significant opportunities for continued development and integration into research-based learning.

Collaboration

Collaboration in research-based learning is essential. Various forms of collaboration can be undertaken, including collaboration between peers, companies, scientists or researchers, the community, and among others. Lack of peer interaction is a significant challenge in active learning (Zhang & Ranadheera, 2023). Facilitating collaboration between students, educators, and professional scientists will help develop a broader and more diverse learning community (Olivo-Montaña et al., 2024). Analyzing the impact of community partnerships on educational outcomes is crucial. Collaborating with industry partners can connect students with potential colleagues, providing insights into the components of their career paths, hence having a major impact on encouraging students to actively participate in research-based learning (Zhang & Ranadheera, 2023). Future research could explore interdisciplinary collaboration in educational settings (Cuevas-Cancino et al., 2024).

Reflection

Frequent feedback is essential to support student learning (Haviz, 2018; Marcella & Samofalova, 2022). Students are the main agents of their own learning in inquiry-based learning techniques, which promote critical thought, inquiry, and investigation of the material and learning process (Haviz, 2018; Olivo-Montaña et al., 2024). Students should be encouraged to think critically about how they learn and assess themselves. Opportunities to develop their critical and scientific thinking as well as their strengths are examined. Feedback sessions might serve as a direction for this self-evaluation (Olivo-Montaña et al., 2024). Future research can explore perspectives related to the implementation of feedback sessions that can support inquiry-based learning.

Expanding the Research Sample

Small samples can limit general conclusions or generalizations (Marcella & Samofalova, 2022; Park et al., 2023). Future research could expand the sample size (Park et al., 2023), implement it at different levels (Marcella & Samofalova, 2022), and contrast the results with those of teams from different fields and colleges throughout the world (Marín, 2020) to address the problem directly, practically, and effectively, and could make a strong contribution to narrowing the gap between research and practice.

Limitations

This study successfully identified several important findings regarding the concept, implementation, impact, and future research of RBL learning in science education in higher education. However, there are several limitations that need to be considered. These limitations include using only the Scopus database with articles published between 2015 and 2024. It is possible that pertinent research published in other languages or concealed within paid papers will be missed if the search is limited to English and open access. Strict inclusion criteria, like concentrating only on college students, may also restrict how broadly the results can be applied. However, the analysis's findings offer a solid basis for more study on the subject.

Theoretical and Practical Contributions

Theoretically, this study contributes to advancing the conceptual understanding of Research-Based Learning (RBL) in science education by developing an integrative synthesis of its core components across studies. This study identifies and organizes key dimensions of RBL, including its conceptual foundations, implementation stages, and learning outcomes, into a more coherent and structured framework. In addition, the findings highlight inconsistencies and variations in how RBL is defined and implemented, thereby clarifying its distinguishing characteristics and positioning it more explicitly within constructivist learning theory. This synthesis provides a more systematic basis for understanding RBL and supports the development of a clearer conceptual framework for future research.

Practically, this study provides recommendations for educators in designing and implementing RBL in higher education. The findings can be used by universities to develop curricula that emphasize research and problem-solving skills, and by policymakers as a reference for promoting the integration of research-based learning within higher education systems.

Conclusion

Based on a systematic review of 23 selected studies, this study provides a synthesis of the current evidence on RBL in science education. The analysis revealed that RBL is consistently grounded in constructivist theory and is characterized by the integration of authentic research processes, real-world problem solving, and the development of student autonomy within inquiry-driven learning environments. Across the reviewed studies, two main orientations of RBL implementation were identified: students as active researchers and students learning from research outcomes.

Furthermore, the reviewed studies consistently reported positive impacts of RBL implementation, particularly in enhancing students' research skills, conceptual understanding, and higher-order thinking abilities, including analytical thinking, critical thinking, and problem-solving skills. However, the findings also indicate that these outcomes are influenced by contextual factors such as instructional design, student readiness, and institutional support. In several studies, RBL was also linked to addressing real-world challenges, including environmental and sustainability issues, thereby contributing to the achievement of the Sustainable Development Goals (SDGs).

The synthesis of the reviewed literature also highlights several research gaps, which form the basis for future research directions, including the need to explore early research exposure, strengthen institutional support, integrate digital technologies, enhance collaborative and reflective practices, and expand research contexts and sample diversity.



Based on the findings, future research should focus on developing a more standardized RBL framework, particularly in response to the wide variation in implementation stages identified across studies. In addition, further investigation is needed to strengthen underrepresented learning outcomes such as critical thinking and scientific literacy, which appeared less frequently compared to research experience and conceptual understanding. Future studies should also examine the causal factors influencing RBL effectiveness, including student readiness, instructional design, and institutional support. Moreover, expanding research contexts across different regions and disciplines, as well as employing more rigorous research designs, is necessary to improve the generalizability of findings.

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Reference

- Agud, I., & Ion, G. (2019). Research-based learning in initial teacher education in catalonia. *Center for Educational Policy Studies Journal*, 9(2), 99–118. <https://doi.org/10.26529/cepsj.564>
- Aguilera, D., & Perales-Palacios, F. J. (2020). What Effects Do Didactic Interventions Have on Students' Attitudes Towards Science? A Meta-Analysis. *Research in Science Education*, 50(2), 573–597. <https://doi.org/10.1007/s11165-018-9702-2>
- Alberts, B. (2022). Why science education is more important than most scientists think. *FEBS Letters*, 596(2), 149–159. <https://doi.org/10.1002/1873-3468.14272>
- Aleknavičiūtė, V., Lehtinen, E., & Södervik, I. (2023). Thirty years of conceptual change research in biology – A review and meta-analysis of intervention studies. *Educational Research Review*, 41(September). <https://doi.org/10.1016/j.edurev.2023.100556>
- Alvarez, M. M., Del Carmen Flores-Cruz, L., Pedroza-González, S. C., & Trujillo-De Santiago, G. (2022). Fabrication of Maize-Based Nanoparticles at Home: A Research-Based Learning Activity. *Education Sciences*, 12(5). <https://doi.org/10.3390/educsci12050307>
- 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>
- Behrmann, L. (2019). The halo effect as a teaching tool for fostering research-based learning. *European Journal of Educational Research*, 8(2), 433–441. <https://doi.org/10.12973/eu-er.8.2.433>
- Bergmann, M., Schöpke, N., Marg, O., Stelzer, F., Lang, D. J., Bossert, M., Gantert, M., Häußler, E., Marquardt, E., Piontek, F. M., Potthast, T., Rhodius, R., Rudolph, M., Ruddat, M., Seebacher, A., & Sußmann, N. (2021). Transdisciplinary sustainability

- research in real-world labs: success factors and methods for change. *Sustainability Science*, 16(2), 541–564. <https://doi.org/10.1007/s11625-020-00886-8>
- Böttcher-Oschmann, F., Groß Ophoff, J., & Thiel, F. (2021). Preparing Teacher Training Students for Evidence-Based Practice Promoting Students' Research Competencies in Research-Learning Projects. *Frontiers in Education*, 6. <https://doi.org/10.3389/educ.2021.642107>
- Burke, E., Savage, C., Begley, J., Sioufi, S., Smith, S., Stoyanov, S., & O'Tuathaigh, C. (2024). Exploring the Clinical Usefulness of Undergraduate Medical Research: A Mixed-Methods Study. *Medical Science Educator*, 34(4), 823–830. <https://doi.org/10.1007/s40670-024-02035-7>
- Camacho, M. H., Valcke, M., & Chiluitza, K. (2017). Research Based Learning in Higher Education: a Review of Literature. *INTED2017 Proceedings*, 1, 4188–4197. <https://doi.org/10.21125/inted.2017.1004>
- Cho, E. H. (2022). Cultivating Science Literacy Through the General Education Curriculum. *The Korean Association of General Education*, 16(5), 203–216. <https://doi.org/10.46392/kjge.2022.16.5.203>
- Cuevas-Cancino, M. D. L. O., Peña-Becerril, M., Mondragon-Estrada, E., & Camacho-Zuñiga, C. (2024). Incorporating vertical collaboration to address sustainable development goals: the Monarch Route Project. *Frontiers in Education*, 9. <https://doi.org/10.3389/educ.2024.1246889>
- Daryanes, F., Zubaidah, S., & Mahanal, S. (2025). Building Students' Research Skills in Environmental Science Courses with Research Team-Based Learning. *Eurasia Journal of Mathematics, Science and Technology Education*, 21(1), em2567–em2567. <https://doi.org/10.29333/ejmste/15893>
- Del, A. A., & Galantini, K. (2024). Research Training: Unraveling the Research Methodological Design Challenge in Engineering Programs. *International Journal of Engineering Pedagogy*, 14(7), 30–53.
- Delgado, C. L. P., & Estrada, L. (2022). Pedagogical Conditions and Challenges for the Development of Research Skills. *Revista Electronica de Investigacion Educativa*, 24. <https://doi.org/10.24320/redie.2022.24.e09.3937>
- Fernández-López, J., Borrás-Rocher, F., Viuda-Martos, M., & Pérez-Álvarez, J. Á. (2024). Using Artificial Intelligence-Based Tools to Improve the Literature Review Process: Pilot Test with the Topic “Hybrid Meat Products.” *Informatics*, 11(4). <https://doi.org/10.3390/informatics11040072>
- García-Carmona, A. (2020). From Inquiry-Based Science Education to the Approach Based on Scientific Practices: A Critical Analysis and Suggestions for Science Teaching. *Science and Education*, 29(2), 443–463. <https://doi.org/10.1007/s11191-020-00108-8>
- Hanan Taleb, A. M., & Chadwick, C. (2016). Copyright © Journal of Educational and Instructional Studies in the World 67 Enhancing Student Critical and Analytical Thinking Skills At a Higher Education Level in Developing Countries: Case Study of the British University in Dubai. *Journal of Educational and Instructional Studies in the World*, 6, 2146–7463. <http://www.criticalthinking.com/cornell-critical-thinking-tests.html>
- Harland, T., & Wald, N. (2018). Curriculum, teaching and powerful knowledge. *Higher Education*, 76(4), 615–628. <https://doi.org/10.1007/s10734-017-0228-8>
- Haviz, M. (2018). Development of Research-Based Learning Model in Biology Education: What is Relevance, Concistency and Practicality? *Journal of Education and Learning (EduLearn)*, 12(1), 143–149. <https://doi.org/10.11591/edulearn.v12i1.6555>
- Haviz, M., Nasrul, E., Azis, D., Maris, I. M., & Wahyudi, F. (2024). the Use of Socio-Scientific Issues To Promote Prospective Biology Teachers' Scientific Literacy and



- Research Skill Development. *Jurnal Pendidikan IPA Indonesia*, 13(2), 285–300. <https://doi.org/10.15294/v7kbh850>
- Healey, M., & Jenkins, A. (2009). *Developing undergraduate research and inquiry research*.
- Hegde, S., & Karunasagar, I. (2021). Building Research Competence in Undergraduate Students. *Resonance*, 26(3), 415–427. <https://doi.org/10.1007/s12045-021-1139-7>
- Helgøy, K. V, Bonsaksen, T., & Røykenes, K. (2022). Research-based education in undergraduate occupational therapy and physiotherapy education programmes: a scoping review. *BMC Medical Education*, 22(1). <https://doi.org/10.1186/s12909-022-03354-2>
- Hoffmeister, T., Koch, H., & Tremp, P. (2020). *Forschendes Lernen als Studiengangsprofil*. Germany: Springer Vs.
- Hughes, G. (2019). Developing Student Research Capability for a ‘Post-truth’ World: Three Challenges for Integrating Research Across Taught Programmes. *Teaching in Higher Education*, 24(3), 394–411. <https://doi.org/10.1080/13562517.2018.1541173>
- Hyytinen, H., Toom, A., & Shavelson, R. J. (2019). Enhancing Scientific Thinking Through the Development of Critical Thinking in Higher Education. In *Redefining Scientific Thinking for Higher Education: Higher-Order Thinking, Evidence-Based Reasoning and Research Skills* (p. 59). Switzerland: Springer International Publishing. https://doi.org/10.1007/978-3-030-24215-2_2
- Jahan, S. S., Nerali, J. T., Parsa, A. D., & Kabir, R. (2022). Exploring the Association between Emotional Intelligence and Academic Performance and Stress Factors among Dental Students: A Scoping Review. *Dentistry Journal*, 10(4). <https://doi.org/10.3390/dj10040067>
- John, J. A. (2023). Role of Science in Developing Critical Thinking. *International Journal of Scientific Development and Research (IJS DR)*, 8(3), 1246–1250.
- Lu, Y. Y., Lin, H. S., Smith, T. J., Hong, Z. R., & Hsu, W. Y. (2020). The effects of critiqued driven inquiry intervention on students’ critical thinking and scientific inquiry competency. *Journal of Baltic Science Education*, 19(6), 954–971. <https://doi.org/10.33225/jbse/20.19.954>
- Marcella, V., & Samofalova, Y. (2022). Data-driven and research-based learning approaches to environmental education in university contexts: Two case studies in Italy and Germany. *Language Learning in Higher Education*, 12(2), 567–586. <https://doi.org/10.1515/cercles-2022-2064>
- Marín, V. I. (2020). Research-based learning in education studies: Design inquiry using group e-Portfolios based on blogs. *Australasian Journal of Educational Technology*, 36(1), 1–20. <https://doi.org/10.14742/ajet.4523>
- Martín-Garin, A., Millán-García, J. A., Leon, I., Oregi, X., Estevez, J., & Marieta, C. (2021). Pedagogical approaches for sustainable development in building in higher education. *Sustainability (Switzerland)*, 13(18). <https://doi.org/10.3390/su131810203>
- Mendoza, G. A. A. (2021). Socio-Cognitive Presence and Transactional Distance in a Learning Community for Graduate Student Research Training. *International Journal of Learning in Higher Education*, 29(1), 1–22. <https://doi.org/10.18848/2327-7955/CGP/v29i01/1-22>
- Mkimbili, S. T., & Ødegaard, M. (2020). Inquiry-based science teaching in community secondary schools in Tanzania: role played by the language of instruction. *Cultural Studies of Science Education*, 15(4), 1121–1142. <https://doi.org/10.1007/s11422-020-09973-9>
- Nogales-Delgado, S., Encinar Martín, J. M., & Román Suero, S. (2022). Teaching How to Research: A Case Study on Chemical and Industrial Engineering Degrees. *Education Sciences*, 12(10). <https://doi.org/10.3390/educsci12100673>
- Olivo-Montañó, P. G., Sanabria-Z, J., Molina-Espinosa, J. M., Quintero-Gámez, L., Velarde-

- Camaqui, D., Sánchez-Salgado, L. A., Gonzalez-Mendoza, M., Breda, A., Morales-Maure, L., & Alvarez-Icaza, I. (2024). MAICC model: development of complex thinking through citizen science project evaluation. *Frontiers in Education*, 9. <https://doi.org/10.3389/feduc.2024.1392104>
- Pantazidou, M., & Kandris, K. (2020). Examples of applying research-based learning principles to the redesign of an environmental geotechnics course. *International Journal of Engineering Pedagogy*, 10(1), 31–50. <https://doi.org/10.3991/ijep.v10i1.11181>
- Park, J., Yoon, H. G., & Lee, I. (2023). Research-Based Teaching: Analyzing Science Teachers' Process of Understanding and Using Academic Papers To Teach Scientific Creativity. *Journal of Baltic Science Education*, 22(1), 57–72. <https://doi.org/10.33225/jbse/23.22.57>
- Parker, J. (2018). Undergraduate research, learning gain and equity: The impact of final year research projects. *Higher Education Pedagogies*, 3(1), 145–157. <https://doi.org/10.1080/23752696.2018.1425097>
- Pernaa, J., Kämppe, V., & Aksela, M. (2022). Supporting the Relevance of Chemistry Education through Sustainable Ionic Liquids Context: A Research-Based Design Approach. *Sustainability (Switzerland)*, 14(10). <https://doi.org/10.3390/su14106220>
- Pourhejazy, P., & Isaksen, K. R. (2024). Exploring the curricular and pedagogical decision criteria for research-based learning design in undergraduate studies. *Evaluation and Program Planning*, 103. <https://doi.org/10.1016/j.evalprogplan.2024.102409>
- Prahmana, R. C. I., & Kusumah, Y. S. (2016). The Hypothetical Learning Trajectory on Research in Mathematics Education Using Research-Based Learning. *Pedagogika*, 123(3), 42–54. <https://doi.org/10.15823/p.2016.32>
- Puchumni, P., Tungradabkul, S., & Magee, R. (2019). Using Information Retrieval Activities to Foster Analytical Thinking Skills in Higher Education in Thailand: A Case Study of Local Wisdom Education. *Asian Journal of Education and Training*, 5(1), 80–85. <https://doi.org/10.20448/journal.522.2019.51.80.85>
- Restović, I., & Bulic, M. (2024). Research-Based Learning About Nature Conservation Influences Students' Attitudes and Knowledge. *Education Sciences*, 14(12). <https://doi.org/10.3390/educsci14121410>
- Ridlo, Z. R., & Nugroho, C. I. W. (2020). Report and recommendation of implementation research-based learning in improving combinatorial thinking skills embedded in STEM parachute design activities assisted by CCR (cloud classroom). *Universal Journal of Educational Research*, 8(4), 1413–1429. <https://doi.org/10.13189/ujer.2020.080434>
- Sawyer, R. K. (2017). Teaching creativity in art and design studio classes: A systematic literature review. *Educational Research Review*, 22, 99–113. <https://doi.org/10.1016/j.edurev.2017.07.002>
- Shah, T. M., Jannesarahmadi, S., Shokri-Kuehni, S., Ellinger, D., Brose, A., Or, D., & Shokri, N. (2024). Research-based learning as an innovative approach for teaching students of environmental engineering: a case study of the emerging field of microplastics in soil. *Discover Education*, 3(1). <https://doi.org/10.1007/s44217-024-00189-5>
- Solovieva, N., Dani, A., Kane, P., Thomson, S., Hamam, D., & Solaimani, F. K. (2022). Developing effective student learning environment: Case study from Sharjah, United Arab Emirates. *Frontiers in Education*, 7. <https://doi.org/10.3389/feduc.2022.955873>
- Sopandi, W., Sukyadi, D., & Sukardi, R. R. (2019). The implementation of guided research-based learning with graduate school students of an elementary education study program. *Pedagogika*, 134(2), 82–98. <https://doi.org/10.15823/p.2019.134.5>
- Srikoon, S., Bunterm, T., Nethanomsak, T., & Tang, K. N. (2018). Effect of 5P model on academic achievement, creative thinking, and research characteristics. *Kasetsart Journal of Social Sciences*, 39(3), 488–495. <https://doi.org/10.1016/j.kjss.2018.06.011>



- Strachan, S. M., Marshall, S., Murray, P., Coyle, E. J., & Sonnenberg-Klein, J. (2019). Using Vertically Integrated Projects to embed research-based education for sustainable development in undergraduate curricula. *International Journal of Sustainability in Higher Education*, 20(8), 1313–1328. <https://doi.org/10.1108/IJSHE-10-2018-0198>
- Sun, L., Kangas, M., Ruokamo, H., & Siklander, S. (2023). A systematic literature review of teacher scaffolding in game-based learning in primary education. *Educational Research Review*, 40(June), 100546. <https://doi.org/10.1016/j.edurev.2023.100546>
- Suwito, A., Parta, N. I., Irawati, S., & Dika, J. W. (2019). Reducing main problem of proposals undergraduate research through research-based learning activity students. *TEM Journal*, 8(4), 1213–1217. <https://doi.org/10.18421/TEM84-15>
- Suwito, W. E. C., Reffiane, F., & Sary, R. M. (2021). The Development of Interactive Learning Media Based on PBL Learning Models on Theme 9 Sub-theme 3 for Fifth Grade Elementary ASchool. *Journal of Education Technology*, 5(1), 30. <https://doi.org/10.23887/jet.v5i1.29180>
- Suyatman, Saputro, S., Sunarno, W., & Sukarmin. (2020). The implementation of research-based learning model in the basic science concepts course in improving analytical thinking skills. *European Journal of Educational Research*, 10(3), 1051–1062. <https://doi.org/10.12973/EU-JER.10.3.1051>
- Suyatman, Saputro, S., Sunarno, W., & Sukarmin. (2021). The Conceptual Framework for Problem and Research-Based Learning (PRBL) Model in Learning the Natural Sciences to Empower Students' Analytical Thinking Skills. *Journal of Physics: Conference Series*, 1842(1), 1–9. <https://doi.org/10.1088/1742-6596/1842/1/012051>
- Thiem, J., Preetz, R., & Haberstroh, S. (2023). How research-based Learning Affects Students' Self-Rated Research Competences: Evidence from a Longitudinal Study Across Disciplines. *Studies in Higher Education*, 48(7), 1039–1051. <https://doi.org/10.1080/03075079.2023.2181326>
- Tremp, P., & Hildbrand, T. (2012). Forschungsorientiertes Studium – universitäre Lehre: Das «Zürcher Framework» zur Verknüpfung von Lehre und Forschung. *Blickpunkt Hochschuldidaktik*, 122, 101–116. https://www.academia.edu/Documents/in/Research-based_Teaching_and_Learning
- Usmeldi. (2018). The effectiveness of research-based physics learning module with predict-observe-explain strategies to improve the student's competence. *Journal of Physics: Conference Series*, 1013(1), 1–8. <https://doi.org/10.1088/1742-6596/1013/1/012041>
- Veses, V., Del Mar Jovani-Sancho, M., González-Martínez, R., Cortell-Ballester, I., & Sheth, C. C. (2020). Raising awareness about microbial antibiotic resistance in undergraduate dental students: A research-based strategy for teaching non-laboratory elements of a microbiology curriculum. *BMC Medical Education*, 20(1). <https://doi.org/10.1186/s12909-020-1958-3>
- Wessels, I., Rueß, J., Gess, C., Deicke, W., & Ziegler, M. (2021). Is research-based learning effective? Evidence from a pre–post analysis in the social sciences. *Studies in Higher Education*, 46(12), 2595–2609. <https://doi.org/10.1080/03075079.2020.1739014>
- Zhang, & Ranadheera. (2023). Redevelopment of undergraduate food microbiology capstone projects for unprecedented emergency remote teaching during the COVID-19 pandemic: then and now. *Microbiology Australia*, 44(3), 140–143. <https://doi.org/10.1071/MA23041>
- Zhang, X., & Zhang, D. (2021). Teaching of Remote Sensing Technology for Landscape Architecture in the Context of Spatial Information Technology. *International Journal of Emerging Technologies in Learning*, 16(15), 125–138. <https://doi.org/10.3991/ijet.v16i15.24885>

Zou, T. X. P., Lee, J. C. Y., Yu, K. S., Chow, K. L., Barry, T. J., Leung, L. Y. Y., & Brew, A. (2024). Faculty members' perceptions and students' experiences of research-based curricula: a multiple case study of four undergraduate programmes. *Higher Education*, 88(3), 1205–1225. <https://doi.org/10.1007/s10734-023-01166-x>

