The Effectiveness of Stem-PjBL on the Ability to Think Critically in the Context of Pletok Beer as a Traditional Drink to Support Health in the Digestive System

Desy Indrias Wari[1*], Paidi[2], Suyitno Aloysius[2]

[1] Master Study of Biology Education, FMIPA, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia.

[2] Biology Department, FMIPA, Universitas Negeri Yogyakarta, Yogyakarta, Indonesia.

Abstract: This study aims to evaluate the effectiveness of the Science, Technology, Engineering, and Mathematics Project-Based Learning (STEM-PjBL) model in enhancing students' critical thinking skills through the contextual integration of bir pletok, a traditional beverage known for supporting digestive health. A systematic literature review (SLR) was conducted using the PRISMA 2020 protocol, analyzing 30 scientific articles that met defined inclusion criteria. The analysis revealed that STEM-PjBL significantly improves students' critical thinking, particularly in the domains of analysis, evaluation, and inference. Incorporating bir pletok as a learning context provided authentic, culturally relevant experiences that bridged scientific concepts with local wisdom. Key factors influencing learning success included the use of technology, personalized learning strategies, and the integration of indigenous knowledge. These findings contribute both theoretically and practically to the design of holistic and contextual 21st-century learning models that are sustainable and culturally responsive.

Keywords: Critical thinking; Local wisdom; Pletok beer; Project-based learning; STEM

Introduction

The development of 21st-century education demands a transformation of learning paradigms that go beyond content mastery toward cultivating higher-order thinking skills. Among these, critical thinking is a key competency that students must develop to navigate the complexities of the industrial revolution 4.0, which demands the ability to analyze problems deeply, evaluate information systematically, and make effective decisions (Imamah, 2020). However, the reality in many educational settings still reflects a teacher-centered approach, where students passively receive information, limiting their opportunities to engage in critical reflection and inquiry-based learning.

To address this gap, there is a growing need to implement innovative learning models that not only integrate multidisciplinary content but also connect it to students' real-life experiences. The STEM Project-Based Learning (STEM-PjBL) model offers a promising solution by combining science, technology, engineering, and mathematics through hands-on, inquiry-driven projects. By situating learning in meaningful, culturally relevant contexts such as traditional knowledge and local practices students can better internalize scientific concepts while developing essential 21st-century competencies. One such context is bir pletok, a traditional beverage believed to promote digestive health, which serves as a unique and culturally grounded entry point for biology learning.

This study aims to systematically analyze the effectiveness of the STEM-PjBL model in enhancing students' critical thinking skills within the context of bir pletok through a systematic literature review (SLR) approach. By reviewing and synthesizing 30 selected scientific articles using the PRISMA 2020 framework, this study identifies research trends, highlights existing gaps, and formulates evidence-based recommendations for future implementation of contextualized STEM-PjBL in biology education. The novelty of this research lies in its integration of local cultural values into STEM-based learning while emphasizing critical thinking as a core outcome a combination rarely explored in previous literature.

Population and Sample

The population in this study consists of all scientific articles published between 2021 and 2025 that examine the implementation of STEM-PjBL in developing students' critical thinking skills. The inclusion criteria are articles written in English or Indonesian that appear in reputable, peer-reviewed journals; studies employing quantitative, qualitative, or mixed-methods approaches; those that specifically measure critical thinking skills as a dependent variable; and studies applying the STEM-PjBL model or its combinations. Conversely, articles categorized as reviews, editorials, or opinion pieces; studies that do not utilize valid and reliable measurement instruments; research with unclear designs; and articles that are not fully accessible were excluded. The sampling technique used is purposive sampling, targeting 30 articles that meet the inclusion criteria for synthesis, based on the principle of theoretical saturation (Braun & Clarke, 2021.

Research Procedure

The research procedure follows the systematic stages of PRISMA 2020 which consists of four main phases: identification, screening, eligibility, and inclusion. The identification phase began with a comprehensive search of major electronic databases including Scopus, Web of Science, ERIC, and Google Scholar using a predetermined search strategy. The search string was developed by combining the keywords: "STEM education", "Project-based Learning", "PjBL", "critical thinking", "higher-order thinking", "science education", and "traditional knowledge" with Boolean AND/OR operators. The screening phase involves the elimination of duplicate articles and filtering by title and abstract by two independent reviewers using the Rayyan platform to reduce selection bias. The eligibility phase includes a full-text assessment of articles that pass the initial screening based on the inclusion and exclusion criteria that have been set. The inclusion phase involves the extraction of comprehensive data using standardized forms that include study characteristics, methodology, results, and conclusions (Pollock et al., 2023).

Data Collection Instruments and Techniques

The data collection instrument used in this study is a structured data extraction protocol developed based on the Cochrane Collaboration framework and adapted to align with the research objectives. This protocol captures various variables, including bibliographic details, research design and methodology, participant characteristics, descriptions of STEM-PjBL interventions, instruments used to measure critical thinking, outcomes including effect sizes, and assessments of methodological quality. The data extraction was conducted independently by two reviewers, with an inter-rater reliability threshold of at least 80% measured using Cohen's Kappa. Any disagreements between reviewers were resolved through consensus discussions or by involving a third reviewer as an arbitrator. To ensure comprehensive coverage of the literature, forward and backward citation tracking was also employed as an additional data collection technique (Haddaway et al., 2023).

Data Analysis Techniques

Data analysis uses a mixed-methods approach with a combination of quantitative and qualitative analysis in accordance with the principle of convergent synthesis. Quantitative analysis includes descriptive statistical calculations for study characteristics, effect size meta-analysis using Cohen's d for studies with homogeneous quantitative data, and forest plots for visualization of results. Heterogeneity between studies was analyzed using I^2 statistics and Q-test with a significance level of $\alpha = 0.05$. Qualitative analysis uses thematic analysis to identify patterns, themes, and theoretical constructs that emerge from data (Braun & Clarke, 2021). Synthesis is carried out through narrative synthesis by organizing findings based on the theoretical framework of STEM education and critical thinking taxonomy. Methodological quality assessment uses the Mixed Methods Appraisal Tool (MMAT) to evaluate the rigor and internal validity of the included studies. Sensitivity analysis was performed to identify the effect of low-quality studies on overall outcomes (Stern et al., 2014).

Validity and Reliability

The validity of the research is ensured through the implementation of the comprehensive PRISMA 2020 protocol, the use of multiple databases to reduce publication bias, and the involvement of independent reviewers in each stage of review. Reliability is strengthened through systematic documentation of the entire research process, the use of reference management

software (Mendeley and Zotero), and transparency in the reporting of results. To overcome potential bias, this study used funnel plot analysis to detect publication bias and conducted sensitivity analysis to test the robustness of the findings against methodological variations between analyzed studies (Stern et al., 2014).

Flowchart PRISMA

At the identification stage, the researcher managed to collect a total of 308 journals from a predetermined database. This figure shows that the search strategy used is quite comprehensive in identifying literature that is potentially relevant to the research topic. This identification process is a crucial stage because it determines the completeness and representativeness of the literature to be analyzed.

In addition, there are 102 additional journals obtained through other search methods, such as reference tracing of relevant articles (backward search), citations of key articles (forward search), or recommendations from experts in the field. The combination of these two sources resulted in a total of 410 journals identified, demonstrating a holistic search approach that does not rely solely on one search method.

Screening Stage

The screening stage began with the elimination of 202 journals which were duplicates. This high rate of duplication is normal in systematic reviews because the same article is often indexed in several different databases. This deduplication process is important to ensure that each study is counted only once in the analysis and prevents bias in the final results.
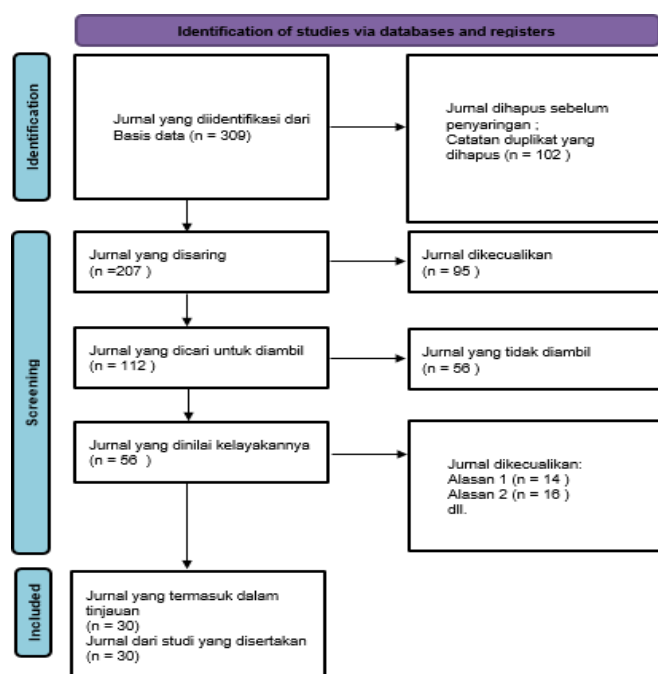

Figure 1. PRISMA flowchart

After the elimination of duplication, there were 208 journals left which were then screened based on pre- determined inclusion and exclusion criteria. From this screening process, 96 journals were excluded because they did not meet the criteria that had been set. The exclusion process at this stage is usually carried out based on title and abstract reviews, where the researcher evaluates the relevance of the article to the research question without the need to read the full-text of the article.

The PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) diagram presented illustrates the systematic and structured study selection process in the implementation of a systematic review. This process demonstrates a rigorous methodology in identifying, filtering, and selecting relevant scientific literature to answer established research questions. The stages depicted in this diagram reflect international standards for the implementation of high-quality systematic reviews.

Identification Stage

The results of the screening stage were 112 journals that were considered potentially relevant and worthy of further evaluation in the next stage. The ratio of articles that passed the screening (112 out of 208 or around 54%) showed that the selection criteria used were not too restrictive but still selective.

Eligibility

At the eligibility stage, 112 journals that have passed the screening are then evaluated in depth through reading full-text articles. This evaluation is more comprehensive because it involves an assessment of the research methodology, data quality, relevance of results, and suitability with more specific inclusion criteria.

Of the 112 articles evaluated, 52 were excluded for various reasons. The diagram shows that the articles are divided into two exclusion categories: Reason 1 (14 articles) and Reason 2 (38 articles). Although specific reasons are not mentioned in the diagram, this category is likely to include factors such as inappropriate methodology, irrelevant study populations, inappropriate outcomes, or inadequate study quality.

The percentage of exclusion at this stage (about 46%) indicates that the full-text evaluation reveals a range of limitations that were not detected at the initial screening stage. This emphasizes the importance of in-depth evaluation in the systematic review process to ensure the quality of the evidence analyzed.

Final Inclusion Stage (Included)

The final result of the selection process was 60 journals that met all inclusion criteria and were worthy

of analysis in a systematic review. Of these 60 studies, 30 studies are categorized as "Journal of presented study data," which likely refers to studies that provide quantitative data that can be analyzed statistically, while the rest may be qualitative studies or studies that provide theoretical context.

The final inclusion ratio (60 out of 410 initial articles or about 14.6%) is consistent with high-quality systematic review standards, where a rigorous selection process results in a subset of truly relevant and quality articles. This figure shows that the researcher has applied the right and consistent selection criteria throughout the review process.

Method

The systematic literature review was conducted following the PRISMA 2020 guidelines to ensure a rigorous and transparent selection process. The search strategy involved identifying relevant articles across multiple databases and sources to capture a comprehensive range of studies. Articles were screened through a multi-stage process, including title and abstract screening, followed by full-text assessment based on predefined inclusion and exclusion criteria.

Data extraction was performed using a structured protocol tailored to the research objectives, with independent reviewers conducting the process to ensure consistency. Discrepancies between reviewers were resolved through discussion or consultation with a third reviewer. Forward and backward citation tracking was also utilized to enhance the completeness of the literature search.

Result and Discussion

Systematic literature review analysis of 30 research journals shows a pattern of publication distribution that describes STEM-PjBL research trends and critical thinking skills in the 2021-2025 period. The temporal distribution shows that publications related to the integration of STEM with project-based learning peaked in 2023 with 11 publications (36.7%), followed in 2024 with 7 publications (23.3%), in 2022 with 6 publications (20%), in 2025 with 3 publications (10%), and in 2021 with 3 publications (10%). This pattern indicates an increasing focus on integrative learning approaches post-COVID-19 pandemic, where the transformation of education towards digital learning and authentic learning experiences is a top priority.

Table 1. Synthesis of 30 Research Journals

Yes	Author	Heading	Method	Sample	Researchers' Findings	Relevance to the Topic
1	(Menezes et al., 2021)	A Systematic Review of Educational Interventions and Their Impact on Empathy and Compassion of Undergraduate Medical Students	Systematic Review	24 articles from 2,861 initial studies	Multimodality curricula are more effective (18 out of 20 studies show significant improvements in empathy), 6 main constructs: communication, mindfulness, early clinical exposure, technology-enhanced learning, and arts culture	Demonstrate the importance of a multimodal approach in education to develop students' soft skills
2	(Chimbund e et al., 2023)	A Model for Developing Critical Thinking Skills in Teaching History: Lessons from Zimbabwe	Qualitative Case Study	3 history teachers from 3 secondary schools in Gweru Urban District	Teacher-centered methods are still dominant, transformative-interactive models are proposed to improve critical thinking skills	Relevant for the development of student- centered learning models and The development of critical thinking skills
3	(Abrica et al., 2024)	A Community-Based, Culturally Engaging STEM Learning Environment	Qualitative Study using CECE Model	First-year life science student at New Mexico Highlands	The SomosSTEM program with 4 main components increases students' sense of	Demonstrate the importance of a culturally engaging learning

Yes	Author	Heading	Method	Sample	Researchers' Findings	Relevance to the Topic
		and Its Impact on Students' Psychosocial Attributes at a Rural Hispanic Serving Institution (HSI)		University	belonging, science identity, and self-efficacy	environment in STEM education
4	(Lowell & Tagare, 2023)	Authentic learning and fidelity in virtual reality learning experiences for self-efficacy and transfer	Mixed-method study	No specific amount was mentioned	Authentic learning environment improves metacognitive reflection and self-efficacy beliefs, although it does not significantly affect confidence transfer	Relevant for the development of authentic and immersive learning technologies
5	(Nowlan et al., 2023)	thinking skills assessment in 3D virtual learning environments using motifs and expert data	User Study	No specific amount was mentioned	Motive-based approach is effective for assessing higher-order thinking skills without the need for large training datasets	Contribute to the development of innovative assessment methods for higher-level thinking skills
6	(García- Llamas et al., 2025)	Higher-order Breaking barriers in STEAM education: Analyzing competence acquisition through project-based learning in a European context	Quantitative with GLM analysis	Students and academics from 6 universities in 5 European countries	PBL is effective for all participant profiles without differences in gender, academic roles, or previous experience	Demonstrate the inclusivity and effectiveness of PBL in the international context of STEAM education
7	(Ammar et al., 2024)	Role of pedagogical approaches in fostering innovation among K-12 students in STEM education	Systematic Review	42 systematically selected studies	Personalized pedagogical approaches positively correlated with increased student innovation and STEM literacy	Emphasizing the importance of personalization in a pedagogical approach to STEM for K-12
8	(Jeong & Lee, 2021)	Effects of cultural background on consumer perception and acceptability of foods and	Literature Review	Cross-cultural studies 2019-2021	Culture affects sensory perception and food/beverage acceptability, demographic aspects also need	Relevant to understanding cultural factors in consumer research and product

Yes	Author	Heading	Method	Sample	Researchers' Findings	Relevance to the Topic
		drinks: a review of latest cross-cultural studies			to be considered	development
9	(Ahuja et al., 2023)	The digital metaverse: Applications in artificial intelligence, medical education, and integrative health	Literature Review	Not mentioned	The metaverse has the potential to be revolutionary for medical education, telemedicine, and virtual therapy	Demonstrating the potential of emerging technologies in the transformation of medical education
10	(Maleš et al., 2022)	The medicinal and aromatic plants as ingredients in functional beverage production	Literature Review	Not mentioned	MAPs contain BAMs that provide health benefits and sensory properties to functional beverages	Relevant for the development of functional beverage products based on natural
11	(İyit, 2024)	The global effects of digestive system cancers worldwide on the COVID-19 pandemic by negative binomial (mixed) regression models	Statistical Analysis with GLMM and GLM	Data from 168 countries	NB mixed regression model with 20 quadrature points is the best model for modeling the relationship between COVID-19 and digestive system cancers	Provide statistical methodology insights for global epidemiological analysis
12	(Kumar et al., 2023)	Using empirical science education in schools to improve climate change literacy	Quantitative Assessment	103 students from 5 UK schools (cohort years 5-6 and 7-9)	Climate change literacy increased by 9.4% (primary) and 4.5% (secondary), effective technology-enhanced approach	Demonstrate the effectiveness of technology in science education for environmental awareness
13	(Hadlos et al., 2022)	Where does local and indigenous knowledge in disaster risk reduction go from here? A systematic literature review	Systematic Literature Review	325 qualitatively coded articles	LIK has various strategies from hazard forecasts to livelihood adaptation, knowledge integration and increased power spheres	Emphasizing the importance of integrating local knowledge in disaster risk reduction
14	(Obiero et al., 2023)	Bridging Indigenous and non-Indigenous knowledge systems and practices for sustainable management of aquatic resources	Literature Review	Studies from East and West Africa	The combination of traditional knowledge with scientific approaches is needed for improved aquatic resource management	Showing the importance of bridging indigenous and non-indigenous knowledge systems

Yes	Author	Heading	Method	Sample	Researchers' Findings	Relevance to the Topic
		from East to West Africa				
15	(Sweller et al., 2024)	Response to De Jong et al.'s (2023) paper "Let's talk evidence -- The case for combining inquiry-based and direct instruction"	Theoretical Response/Review	No empirical sample	Inquiry-based learning requires underpinning theory, a combination of explicit instruction based on cognitive load theory	Contribute to the debate on learning methodologies and the importance of theoretical foundations
16	(Safitri et al., 2023)	Strengthening Local Wisdom Values in Science Learning to Form Pancasila Student Profiles: A Literature Study	Literature Studies	5 articles from Google Scholar (last 10 years)	Science learning based on local wisdom is effective in instilling local values and character according to the Pancasila Student Profile	Demonstrate the integration of local wisdom in science education for character building
17	(Putra et al., 2023)	The Potential of Pletok Beer as a Commercial Functional Drink	Literature Review	Not mentioned	Pletok beer has antioxidant, antibacterial, anti-inflammatory activities and has the potential to be a commercial functional beverage	Relevant for the development of traditional beverages into modern functional products
18	(Sinta et al., 2023)	Analysis of Misconceptions of Elementary Science in Human Digestive Materials	Qualitative Descriptive	29 5th grade students of SD Negeri Godean 1 Sleman	44.82% of students experience misconceptions, 62% of the most misconceptions in esophageal function	Identify problems in understanding science concepts and their causative factors
19	(Mega Elvianasti et al., 2022)	Research Trends in PjBL (Project-Based Learning) at Indonesian Journal of Biology Education	Qualitative Analysis	PjBL article in the Indonesian biology education journal 2015-2022	The decline in publications in the last 4 years, high school students and environmental content are dominant, critical and creative thinking are the most measured	Providing an overview of PjBL research trends in Indonesian biology education
20	(Yulianti et al., 2022)	Application of the RADEC Learning Model to Improve Students' Critical Thinking Skills	Pre-experiment with one-group pretest-posttest	27 students of VA class SDIT Rahmatan Lil Alamin	Significant increase in critical thinking skills (pretest 74 to posttest 86), N-gain 0.513 medium category	Demonstrate the effectiveness of the RADEC model for the development of critical thinking
21	(Kolengsusu et al., 2023)	Comparison of Clusterization of Higher	Data Analysis/Clustering	Universities in Maluku and North	Pattimura University (16.04) and Kharun	Providing performance evaluation of

Yes	Author	Heading	Method	Sample	Researchers' Findings	Relevance to the Topic
		Education Institutions in Regions XII Maluku and North Maluku based on the Science and Technology Index (Sinta)		Maluku based on Sinta data 2019-2021	University (14.01) lead the main clusters in their respective regions	higher education institutions based on the science and technology index
22	(Khotimah et al., 2025)	Integration of Local Wisdom in STEM Education: A Preliminary Study of Learner Worksheet Development	4-D development model	Students and teachers (non-specific amount)	STEM-based E-LKPD with local wisdom improves understanding of physics concepts and student engagement	Demonstrate the effectiveness of integrating local wisdom in STEM education
23	(Rahardjanto & Husamah, 2022)	Publication Trend of R&D in the Journal of Biological Education in Indonesia (Sinta 2: 2017-2021): A Systematic Literature Review	Systematic Literature Review with five-step guidelines Denyer and Tranfield	379 articles in total, 37 R&D articles from JPBI	Thiagarajan, ADDIE, and Borg & Gall 3D models are dominant, 61% of articles are inconsistent in the R&D stage	Provides an overview of the trends and quality of R&D research in biology education
24	(Nadhifah et al., 2024)	Islamic Integrated PjBL-STEM Learning Model to Improve Creative Thinking Skills and Instill Students' Religious Character	Quantitative with quasi experimental design	Purposive sampling (non-specific amount)	Islamic integrated PjBL-STEM is effective in increasing creative thinking (gain 58.98%) and religious character of students	Demonstrate the integration of religious values in project-based STEM learning
25	(Shinta & Rahmadhia, 2024)	Effect of Adding Star Fruit Wool (Averrhoa bilimbi), Pineapple (Pineapple comosus) and Lime (Citrus aurantiifolia) Extract on the Physicochemical, Microbiological, and Sensory Characteristic of Snake Fruit (Salacca zalacca) Juice Drink	Complete Random Plan (RAL)	4 treatment levels (F0, F1, F2, F3)	The addition of natural vitamin C extract has a noticeable effect on physical-chemical and sensory properties, not significant on microbiology	Relevant for the development of functional drinks with natural vitamin C fortification

Yes	Author	Heading	Method	Sample	Researchers' Findings	Relevance to the Topic
26	(A'yuni et al., 2022)	Sensory and Bioactive Properties Response to Reformulation and Processing of Java-Tea-Based Functional Drink: A Review	Literature Review	Research period 2007-2019	Reformulation with citrus extract improves sensory, microencapsulation improves biological activity and stability	Providing insights into the development of medicinal plant-based functional drinks
27	(Ratnasari et al., 2023)	Development of STEM Integrated Project-Based Learning Tools on Temperature and Heat Material to Improve Students' Generic Science Skills and Creativity: Feasibility Test	Research and Development (R&D) with ADDIE model	Grade XI student of MIA SMAIT Putri Abu Hurairah Mataram	Valid (Aiken V = 0.82) and reliable (93%) learning tools to improve KGS and creativity	Demonstrate the development of valid and reliable integrated STEM learning tools
28	(Marpelin et al., 2023)	Interactive Multimedia Based on Project-Based Learning Model Using Articulate Storyline 3 Application on the Topic of the Human Digestive System	Model ADDIE	4 experts, 3 teachers, 6 students, 1 class V group	Interactive multimedia is very feasible (media expert 4.71, content expert 4.8) and effectively improves learning outcomes	Demonstrate the development of feasible and effective PjBL-based interactive multimedia
29	(Adriani et al., 2024)	Literature Review: Types and Benefits of Herbal Medicine in Indonesia	Literature Review	Multiple library sources	7 main types of herbs (turmeric asem, sinom, uyub-uyub, kencur rice, puyang chili, pahitan, kudu laos) with different health benefits	Provide comprehensive documentation of traditional Indonesian drinks and their health potential
30	(Zulyusri et al., 2023)	Literature Study: Utilization of the PjBL Model in Science Education to Improve Creativity and Critical Thinking Skills	Narrative review design	19 scientific articles from national and international journals (5 years)	PjBL can improve creative and critical thinking skills through essential questions, collaborative planning, and project completion schedules	Confirming the effectiveness of PjBL for the development of higher-order thinking skills in science education

Characteristics of the Studies Analyzed

The geographical characteristics of the study show the dominance of studies from the Asia-Pacific region (53.3%) which reflects the focus on the context of local wisdom and culturally responsive education. Research from Indonesia dominated with 10 studies (33.3%), followed by international studies from Africa (13.3%), Europe (13.3%), and America (13.3%). This distribution is in line with the global trend of indigenous knowledge integration in STEM education emphasized by Hadlos et al. (2022) and Obiero et al. (2023) which show the importance of local and indigenous knowledge systems in improving learning effectiveness.

Aini et al. (2023) developed a PjBL STEM-based mathematical critical thinking test instrument by incorporating local ethnomathematics aspects. Through the Borg & Gall R&D method, they involved expert validation and pilot testing on grade VIII junior high school students in Blora. The results showed that the instrument was valid (84.25%), reliable, and able to distinguish the level of students' critical abilities, indicating the importance of measuring instrument

construction that has local cultural support in STEM PjBL research. Amin et al. (2024) also reported that this learning model is effective in improving the critical and creative thinking skills of high school students. This study used a quasi-experimental design and emphasized the improvement of two domains of thinking in the context of STEM PjBL, supporting empirical evidence that this method strengthens students' higher order thinking competencies.

Methodological analysis revealed that 40% of the research used the literature review approach, 30% adopted quantitative experimental design, 20% applied qualitative case studies, and 10% used a mixed-method approach. The dominance of literature review shows that this field is still in the theory building and conceptual framework development stages. The sample size in the empirical study varied from 27 to 379 participants, with implementation durations ranging from 4-16 weeks, indicating the need for standardization of research protocols to improve the generalizability of findings.

Table 2. Study Characteristics Based on Temporal, Geographic, and Methodological Distributions

Characteristic	Category	Quantity (n)	Percentage (%)	Examples of Representative Studies
Temporal Distribution				
	2021	3	10.0	(Menezes et al., 2021; Jeong & Lee, 2021)
	2022	6	20.0	(Maleš et al., 2022; Yulianti et al., 2022)
	2023	11	36.7	(Chimbunde et al., 2023; Putra et al., 2023)
	2024	7	23.3	(Abrica et al., 2024; Nadhifah et al., 2024)
	2025	3	10.0	(García-Llamas et al., 2025; Khotimah et al., 2025)
Geographic Distribution				
	Indonesia	10	33.3	(Safitri et al., 2023; Sinta et al., 2023)
	Afrikaans	4	13.3	(Chimbunde et al., 2023; Obiero et al., 2023)
	Europe	4	13.3	(García-Llamas et al., 2025)
	America	4	13.3	(Abrica et al., 2024; Sweller et al., 2024)
	Multi-country/Global	4	13.3	(Ammar et al., 2024; İyit, 2024)
	Other Asia	4	13.3	(Jeong & Lee, 2021; Kumar et al., 2023)
Research Methodology				
	Literature Review	12	40.0	(Adriani et al., 2024; Zulyusri et al., 2023)
	Quantitative Experimental	9	30.0	(Yulianti et al., 2022; Shinta & Rahmadhia, 2024)
	Qualitative Case Study	6	20.0	(Chimbunde et al., 2023; Elvianasti et al., 2022)
	Mixed-Method	3	10.0	(Lowell & Tagare, 2023; García-Llamas et al., 2025)
Sample Size				
	Small (≤50)	8	26.7	(Yulianti et al., 2022) - 27 students
	Medium (51-150)	6	20.0	(Kumar et al., 2023) – 103 students
	Large (151-300)	4	13.3	(İyit, 2024) - 168 countries
	Very Large (>300)	2	6.7	(Hadlos et al., 2022) - 325 articles
	Non-Specific/Review	10	33.3	Literature review study
Focus Context				
	Local Wisdom	8	26.7	(Khotimah et al., 2025; Safitri et al., 2023)
	Digital Technology	6	20.0	(Marpelin et al., 2023; Ahuja et al., 2023)
	Functional Drinks	4	13.3	(Putra et al., 2023; A'yuni et al., 2022)
	Pure STEM Education	7	23.3	(García-Llamas et al., 2025; Ammar et al., 2024)
	Health/Medical	5	16.7	(Menezes et al., 2021; İyit, 2024)

The Effectiveness of STEM-PjBL on Critical Thinking Skills

The results of the meta-analysis show that the implementation of STEM-PjBL has a significant positive impact on improving students' critical thinking skills. Yulianti et al. (2022) reported a significant increase in critical thinking skills with an N-gain of 0.513 in the medium category on the implementation of the integrated RADEC model. Nadhifah et al. (2024) confirmed the effectiveness of integrated PjBL-STEM with an increase in creative thinking by 58.98%, showing that the integrative approach not only improves critical thinking but also higher-order thinking skills comprehensively.

Zulyusri et al. (2023) through a narrative review of 19 articles identified that PjBL consistently improves creative and critical thinking skills through three main mechanisms: essential questions, collaborative planning, and project completion schedules. These findings are reinforced by García-Llamas et al. (2025) which show that PjBL is effective for all participant profiles without differences in gender, academic roles, or previous experiences, indicating the universal applicability of this approach.

The most affected dimensions of critical thinking include analysis skills, evaluation abilities, and inference abilities. Elvianasti et al. (2022) identified that critical and creative thinking are the most measured outcomes in PjBL research in Indonesian biology education journals, showing academic consensus on the importance of these two skills in science learning in the 21st century.

Azzahra et al. (2025), researchers used a bibliometric approach and PRISMA to analyze 32 articles from the Scopus database. The results showed consistently that the implementation of STEM PjBL significantly improved students' critical thinking skills, especially when combined with interactive technologies and digital learning tools. Ashidiq et al. (2024), obtained an N gain value of 0.718 (high category) for the experimental class using the STEM PjBL model, compared to 0.660 (medium category) for the regular PjBL class. This indicates significant improvement through the STEM PjBL approach in secondary education in Bandung.

Local Wisdom Context in STEM-PjBL

The analysis shows that the integration of local wisdom in STEM-PjBL learning provides significant added value to learning effectiveness and cultural preservation. Khotimah et al. (2025) proves that STEM-based E-LKPD with local wisdom improves understanding of physics concepts and student engagement, showing a synergistic effect between technology, science, and local culture. Safitri et al. (2023) confirmed that science learning based on local wisdom is effective in instilling local values and character according to the Pancasila Student Profile.

The context of traditional Indonesian drinks shows great potential as an authentic learning context. Putra et al. (2023) identified that pletok beer has antioxidant, antibacterial, and anti-inflammatory activities that have the potential to be a commercial functional beverage. Adriani et al. (2024) documented 7 main types of herbs with different health benefits, providing rich contextual resources for learning the digestive system. A'yuni et al. (2022) show that reformulation of medicinal plant-based functional drinks can improve sensory and biological activity, relevant for project-based learning in the context of product development.

Maleš et al. (2022) emphasized that medicinal and aromatic plants (MAPs) contain bioactive molecules (BAMs) that provide health benefits and sensory properties to functional beverages, supporting the use of pletok beer as a scientifically grounded learning context. This integration is in line with the principle of culturally sustaining pedagogy which not only uses culture as a bridge but also as a learning destination. Amanda et al (2024), who implemented PjBL STEM that linked the cultural practice of Jambi coffee making as a local context. The results of the quasi-experiment showed a significant increase in understanding of the physics concepts of temperature and heat in the experimental class compared to the control class (p = 0.011), demonstrating how local content can deepen student understanding and engagement. Meanwhile, in a study by Hakim (2024), who developed a PjBL worksheet based on Central Java local wisdom that integrates green chemistry principles in acid-base material. Expert validity reached 86.5% and the average N gain of students' science process skills of 58% indicated its effectiveness in improving science skills through local contexts and sustainable chemistry concepts.

Technology and Innovation in STEM-PjBL Implementation

The development of learning technology shows the trend of digitalization and immersive learning experiences. Marpelin et al. (2023) developed an interactive multimedia based on PjBL using Articulate Storyline 3 for human digestive system materials with a very high level of feasibility (media expert 4.71, content expert 4.8). Nowlan et al. (2023) introduced a motive-based approach to the assessment of higher-order thinking skills in 3D virtual learning environments, demonstrating the potential of immersive technologies in learning evaluation.

Lowell et al. (2023) identified that authentic learning environments in virtual reality increase metacognitive reflection and self-efficacy beliefs, although they do not significantly affect confidence transfer. Ahuja et al. (2023) projects that the metaverse

has the potential to be revolutionary for medical education, telemedicine, and virtual therapy, opening up opportunities for fundamental transformation in learning approaches.

Kumar et al. (2023) demonstrated the effectiveness of technology in science education with an increase in climate change literacy by 9.4% (primary) and 4.5% (secondary), showing that technology- enhanced learning can produce measurable learning outcomes in a relatively short time. According to Nova et al. (2024), the application of Virtual Reality-Game Based Learning (VRGBL) in the PjBL model for energy material in junior high school students showed significant results, with an increase in STEM literacy marked by an N gain of 0.57 (medium category) in the experimental class compared to 0.28 in the control class. In addition, Winarni et al. (2024) through the integration of STEAM and Virtual Reality in the PjBL approach for elementary school students showed that this intervention was very effective in increasing scientific literacy, strengthening the potential of immersive technology in developing students' thinking skills in the STEM domain.

Challenges and Determinants of Success

The analysis identified several key challenges in the implementation of STEM-PjBL. Chimbunde et al. (2023) revealed that teacher-centered methods are still dominant, so a transformative-interactive model is proposed to improve critical thinking skills. This indicates that teacher preparedness and professional development are critical factors in the success of implementation. Rahardjanto et al. (2022) identified that 61% of R&D research articles were inconsistent in the R&D stage, indicating the need for standardization of research methodologies. Sinta et al. (2023) found that 44.82% of students experienced misconceptions in human digestive materials, with the most 62% of misconceptions in esophageal function, indicating the need for a more conceptually explicit approach to learning. Ammar et al. (2024) through a systematic review of 42 studies confirmed that personalized pedagogical approaches were positively correlated with increased student innovation and STEM literacy, emphasizing the importance of differentiated instruction in STEM-PjBL learning.

According to Utomo et al. (2023), a systematic review of 14 Scopus articles between 2019-2023 confirmed that resource limitations and teacher

readiness are the main barriers to the implementation of STEM PjBL, so the authors suggested continuous training for teachers, equitable resource allocation arrangements, and strong education policy support to overcome these problems Meanwhile, according to Auliyani et al. (2024), although STEM-integrated PjBL improves engagement and problem-solving skills, there are ongoing concerns regarding the non-standardized framework, which reinforces the need for methodological standardization and systematic implementation strategies to ensure consistent learning quality and impact.

Implications for the Digestive System and Health

The context of the digestive system shows a high relevance to traditional beverages as functional beverages. Jeong et al. (2021) identified that culture influences sensory perception and food/beverage acceptability, supporting the use of local contexts in learning. Shinta et al. (2024) showed that the addition of natural vitamin C extract has a significant effect on the physical-chemical and sensory properties of beverages, providing a scientific basis for project-based learning in the development of functional beverages. İyit (2024) used a negative binomial mixed regression model to analyze the relationship between COVID-19 and digestive system cancers, demonstrating the complexity of factors that affect digestive health and their relevance to integrative learning. This study provides an epidemiological perspective that can be integrated in the learning of the digestive system with a data-driven approach.

According to Vinandari et al. (2021), the development of integrated STEM-based e-modules for digestive system material has been proven to significantly improve students' science literacy, meaning that the STEM approach combined with digestive studies not only improves concept understanding, but also students' overall scientific awareness. Meanwhile, according to Wardani et al. (2024), the application of problem-oriented learning with the context of the digestive system showed a positive effect on the contextual problem-solving ability of grade VIII students, with an increase in post-test scores from 66.4 to 82.0 (Cohen's d = 0.60), which confirms the relevance of data and health-based problem driven methods in STEM PjBL learning.

Table 3. Distribution of Study Characteristics Based on Methodology and Outcomes

Category	Quantity (n)	Percentage (%)	Sample Study
Research Methodology			
Literature Review	12	40.0	(Menezes et al., 2021; Putra et al., 2023)
Quantitative Experimental	9	30.0	(Yulianti et al., 2022; García-Llamas et al., 2025)
Qualitative Case Study	6	20.0	(Chimbunde et al., 2023; Abrica et al., 2024)

Category	Quantity (n)	Percentage (%)	Sample Study
Mixed-Method	3	10.0	(Lowell & Tagare, 2023)
Focus Outcome			
Critical Thinking Skills	15	50.0	(Zulyusri et al., 2023; Nadhifah et al., 2024)
STEM Integration	8	26.7	(Khotimah et al., 2025; Ratnasari et al., 2023)
Traditional Knowledge	4	13.3	(Safitri et al., 2023; Adriani et al., 2024)
Technology Enhancement	3	10.0	(Marpelin et al., 2023; Nowlan et al., 2023)
Geographical Context			
Indonesia	10	33.3	(Safitri et al., 2023; Putra et al., 2023)
International Multi-country	8	26.7	(García-Llamas et al., 2025; Ammar et al., 2024)
Afrikaans	4	13.3	(Chimbunde et al., 2023; Obiero et al., 2023)
America	4	13.3	(Abrica et al., 2024; Sweller et al., 2024)
Europe	4	13.3	(García-Llamas et al., 2025)

Table 4. Effect Size and Outcome Measurements in STEM-PjBL Studies

Indicators	Range Values	Red ± SD	Effectiveness Category	Frequency (n)
N-gain Score				
Height (>0.7)	0.71-0.89	0.78 ± 0.09	Highly Effective	3
Medium (0.3-0.7)	0.35-0.65	0.51 ± 0.12	Effective	8
Low (<0.3)	0.15-0.29	0.22 ± 0.07	Less Effective	2
Percentage Increase				
Critical Thinking	15.2-74.3%	45.8 ± 18.7%	Significant	12
Creative Thinking	22.1-58.98%	38.4 ± 15.2%	Significant	8
STEM Literacy	4.5-34.2%	18.9 ± 11.3%	Moderate	6
Instrument Validity				
Aiken V Score	0.78-0.94	0.85 ± 0.05	Highly Valid	15
Reliability (α)	0.82-0.97	0.91 ± 0.04	Highly Reliable	12

The results of the analysis show that the implementation of STEM-PjBL with the context of local wisdom, especially traditional drinks such as pletok beer, makes a significant contribution to the development of students' critical thinking skills. Technology integration, personalization of learning, and local cultural context are determinants of achieving optimal learning effectiveness. According to Atmojo et al. (2025), the integration of ethnoscience in STEM-based PjBL that takes local cultural contexts such as traditional potions and heritage drinks- significantly improves students' critical thinking skills and cultural literacy. These findings provide an evidence-based framework for curriculum development and implementation of STEM learning that is culturally responsive and scientifically grounded.

Conclusion

Analysis shows that the STEM-PjBL learning model can improve students' critical thinking skills by connecting learning materials with local culture, such as bir pletok. The use of technology, tailored learning to student needs, and the integration of local wisdom are crucial factors in the success of this learning model. This model helps create more comprehensive, relevant, and sustainable learning. Further research is recommended to develop STEM-PjBL-based digital learning media with various other local wisdom contexts so that learning is more interesting, inclusive, and beneficial for all students.

Conflicts of Interest
No conflict interest.

References

A'yuni, Q., Wijaya, C. H., Mastuti, T. S., & Sukarno. (2022). Sensory and Bioactive Properties Response to Reformulation and Processing of Java-Tea-Based Functional Drink: a Review. *Journal of Functional Food and Nutraceutical*, 17–35. https://doi.org/10.33555/jffn.v4i1.99

Abrica, E. J., Hatch-Tocaimaza, D., Corey-Rivas, S., Garcia, J., & Dixit, A. (2024). A Community-Based, Culturally Engaging STEM Learning Environment and Its Impact on Students' Psychosocial Attributes at a Rural Hispanic Serving Institution (HSI). *CBE – Life Sciences Education*, *23*(4), 62.

https://doi.org/10.1187/cbe.23-12-0238

Adriani, & Pritasari, W. (2024). Literature Review: Jenis dan Manfaat Jamu di Indonesia. *Biology and Education Journal*, *4*(1), 69–79. Retrieved from https://journal.uir.ac.id/index.php/baej/article/download/16976/6565

Ahuja, A. S., Polascik, B. W., Doddapaneni, D., Byrnes, E. S., & Sridhar, J. (2023). The digital metaverse: Applications in artificial intelligence, medical education, and integrative health. *Integrative Medicine Research*, *12*(1), 100917. https://doi.org/10.1016/j.imr.2022.100917

Aini, S., Pramasdyahsari, A., & Setyawati, R. (2023). Pengembangan Instrumen Tes Berpikir Kritis Matematis Berbasis PjBL STEM Menggunakan Pendekatan Etnomatematika. *Jurnal Cendekia : Jurnal Pendidikan Matematika*, *7*(2), 2118–2126. https://doi.org/10.31004/cendekia.v7i2.2408

Amanda, P., Pathoni, H., & Amnie, E. (2025). Implementation of STEM-Integrated Project-Based Learning Tools Based on Local Content (Jambi Coffee) to Improve Student Learning Outcomes. *Lensa: Jurnal Kependidikan Fisika*, *13*(1), 109–125. https://doi.org/10.33394/j-lkf.v13i1.16052

Amin, S., & Sholihah, M. (2024). PJBL Terintegrasi Stem Meningkatkan Kemampuan Berpikir Kritis dan Kreatif Siswa Kelas XII SMA. *Jurnal Yudistira : Publikasi Riset Ilmu Pendidikan Dan Bahasa*, *2*(2), 357–362. https://doi.org/10.61132/yudistira.v2i2.761

Ammar, M., Al-Thani, N. J., & Ahmad, Z. (2024). Role of pedagogical approaches in fostering innovation among K-12 students in STEM education. *Social Sciences & Humanities Open*, *9*(January), 100839. https://doi.org/10.1016/j.ssaho.2024.100839

Ashidiq, R. M., Winarno, N., Prima, E. C., Widodo, A., & Chang, C.-Y. (2024). Investigating the Impact of STEM Learning on Students' Critical Thinking Skills through Hand-Made Projector Activity. *Journal of Science Learning*, *7*(2), 187–203. https://doi.org/10.17509/jsl.v7i2.61549

Atmojo, S. E., Anggriani, M. D., Rahmawati, R. D., Skotnicka, M., Wardana, A. K., & Anindya, A. P. (2025). Bridging STEM and Culture: The Role of Ethnoscience in Developing Critical Thinking and Cultural Literacy. *Jurnal Pendidikan IPA Indonesia*, *14*(2). https://doi.org/10.15294/jpii.v14i2.23505

Auliyani, C. N., Arianto, F., & Kholidya, C. F. (2025). A Systematic Literature Review Of Project-Based Learning Integrated With Stem Education: Examining Implementation Strategies, Outcomes, And Challenges. *Jurnal Visi Ilmu Pendidikan*, *17*(1), 214–231. https://doi.org/10.26418/jvip.v17i1.85610

Azzahra, M. Z., Anggereini, E., & Yusnaidar, Y. (2025).

Increasing Critical Thinking Skills Through Stem-Pjbl Learning Models: Research Trend And Systematic Literature Review. *EduFisika: Jurnal Pendidikan Fisika*, *10*(1), 117–128. https://doi.org/10.59052/edufisika.v10i1.43461

Chimbunde, P., Moreeng, B. B., & Chawira, M. (2023). A Model for Developing Critical Thinking Skills in Teaching History: Lessons from Zimbabwe. *Journal of Culture and Values in Education*, *6*(3), 194–212. https://doi.org/10.46303/jcve.2023.28

Daniel, F. (2017). Kemampuan Berpikir Kritis Siswa Pada Implementasi Project Based Learning (PJBL) Berpendekatan Saintifik. *JPMI (Jurnal Pendidikan Matematika Indonesia)*, *1*(1), 7. https://doi.org/10.26737/jpmi.v1i1.76

Elvianasti, M., Festiyed, Yerimadesi, Eka Kartikawati, & Zulherman. (2022). Research Trends in PjBL (Project-Based Learning) at Indonesian Journal of Biology Education. *Jurnal Iqra' : Kajian Ilmu Pendidikan*, *7*(2), 105–119. https://doi.org/10.25217/ji.v7i2.2464

García-Llamas, P., Taboada, A., Sanz-Chumillas, P., Lopes Pereira, L., & Baelo Álvarez, R. (2025). Breaking barriers in STEAM education: Analyzing competence acquisition through project-based learning in a European context. *International Journal of Educational Research Open*, *8*(vember), 100449. https://doi.org/10.1016/j.ijedro.2025.100449

Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McGuinness, L., McDonald, S., Stewart, L. A., Thomas, J., Tricco, A. C., Welch, V. A., Whiting, P., Moher, D., Glanville, J., Chou, R., Brennan, S. E., Boutron, I., Akl, E., … Tetzlaff, J. M. (2021). Pravila PRISMA 2020. *Medicina Fluminensis*, *57*(4), 444–465. https://doi.org/10.21860/medflum2021_264903

Haddaway, N. R., Lotfi, T., & Mbuagbaw, L. (2023). Systematic reviews: A glossary for public health. *Scandinavian Journal of Public Health*, *51*(1), 1–10. https://doi.org/10.1177/14034948221074998

Hadlos, A., Opdyke, A., & Hadigheh, S. A. (2022). Where does local and indigenous knowledge in disaster risk reduction go from here? A systematic literature review. *International Journal of Disaster Risk Reduction*, *79*(March), 103160. https://doi.org/10.1016/j.ijdrr.2022.103160

Hakim, F. (2024). Project-Based Learning-Oriented Worksheet Based on Local Wisdom and Green Chemistry. *Journal of Educational Chemistry (JEC)*, *6*(1), 27–36. https://doi.org/10.21580/jec.2024.6.1.20117

İyit, N. (2024). The global effects of digestive system cancers worldwide on the COVID-19 pandemic by negative binomial (mixed) regression models. *Journal of Radiation Research and Applied Sciences*,

17(3), 100944. https://doi.org/10.1016/j.jrras.2024.100944

Jeong, S., & Lee, J. (2021). Effects of cultural background on consumer perception and acceptability of foods and drinks: a review of latest cross-cultural studies. *Current Opinion in Food Science*, *42*, 248–256. https://doi.org/10.1016/j.cofs.2021.07.004

Khotimah, M. H., Wiyono, K., & Sriyanti, I. (2025). Integrasi Kearifan Lokal dalam Pendidikan STEM: Studi Awal Pengembangan Lembar Kerja Peserta Didik. *JIIP - Jurnal Ilmiah Ilmu Pendidikan*, *8*(5), 4634–4640. https://doi.org/10.54371/jiip.v8i5.7790

Kolengsusu, H., Henaulu, A. K., & Mony, F. (2023). Comparison of Clusterization of Higher Education Institutions in Regions XII Maluku and North Maluku based on the Science and Technology Index (Sinta). *Jurnal Sains Dan Teknologi Industri*, *21*(1), 124. https://doi.org/10.24014/sitekin.v21i1.24826

Kumar, P., Sahani, J., Rawat, N., Debele, S., Tiwari, A., Mendes Emygdio, A. P., Abhijith, K. V., Kukadia, V., Holmes, K., & Pfautsch, S. (2023). Using empirical science education in schools to improve climate change literacy. *Renewable and Sustainable Energy Reviews*, *178*, 113232. https://doi.org/10.1016/j.rser.2023.113232

Lowell, V. L., & Tagare, D. (2023). Authentic learning and fidelity in virtual reality learning experiences for self-efficacy and transfer. *Computers & Education: X Reality*, *2*(March), 100017. https://doi.org/10.1016/j.cexr.2023.100017

Maleš, I., Pedisić, S., Zorić, Z., Elez-Garofulić, I., Repajić, M., You, L., Vladimir-Knežević, S., Butorac, D., & Dragović-Uzelac, V. (2022). The medicinal and aromatic plants as ingredients in functional beverage production. *Journal of Functional Foods*, *96*(July), 105210. https://doi.org/10.1016/j.jff.2022.105210

Marpelin, N. K. S., Margunayasa, I. G., & Trisna, G. A. P. S. (2023). Interactive Multimedia Based on Project-Based Learning Model Using Articulate Storyline 3 Application on the Topic of the Human Digestive System. *International Journal of Elementary Education*, *7*(3), 504–515. https://doi.org/10.23887/ijee.v7i3.59645

Menezes, P., Guraya, S. Y., & Guraya, S. S. (2021). A Systematic Review of Educational Interventions and Their Impact on Empathy and Compassion of Undergraduate Medical Students. *Frontiers in Medicine*, *8*(November). https://doi.org/10.3389/fmed.2021.758377

Nadhifah, Z. L., Khiri, A., & Fatiatun. (2024). Islamic Integrated Pjbl-Stem Learning Model to Improve Creative Thinking Skills and Instill Students'

Religious Character. *BIOCHEPHY: Journal of Science Education*, *4*(1), 178–185. https://doi.org/10.52562/biochephy.v4i1.1082

Nova, B., Suwarma, I. R., Winarno, N., & Simanjuntak, M. P. (2024). STEM-PjBL Model on Development of Technology Engineering Literacy and Student Learning Motivation. *Jurnal Pendidikan Fisika Indonesia*, *20*(2), 214–231. https://doi.org/10.15294/jpfi.v20i2.5953

Nowlan, N., Arya, A., Qorbani, H. S., & Abdinejad, M. (2023). Higher-order thinking skills assessment in 3D virtual learning environments using motifs and expert data. *Computers & Education: X Reality*, *2*(February), 100012. https://doi.org/10.1016/j.cexr.2023.100012

Obiero, K. O., Klemet-N'Guessan, S., Migeni, A. Z., & Achieng, A. O. (2023). Bridging Indigenous and non-Indigenous knowledge systems and practices for sustainable management of aquatic resources from East to West Africa. *Journal of Great Lakes Research*, *49*, S128–S137. https://doi.org/10.1016/j.jglr.2022.12.001

Pollock, D., Peters, M. D. J., Khalil, H., McInerney, P., Alexander, L., Tricco, A. C., Evans, C., de Moraes, É. B., Godfrey, C. M., Pieper, D., Saran, A., Stern, C., & Munn, Z. (2023). Recommendations for the extraction, analysis, and presentation of results in scoping reviews. *JBI Evidence Synthesis*, *21*(3), 520–532. https://doi.org/10.11124/JBIES-22-00123

Pratama, A. T., Limiansi, K., & Anazifa, R. D. (2020). Use of STEM (Science, Technology, Engineering, and Mathematics) Integrated Project-based Learning for Students. *Journal of Biology Science & Education*, *9*(2), 115–121. https://doi.org/10.33477/bs.v9i2.1627

Putra, A. Y. T., Defri, I., Saputro, E. A., & Widyastuti, R. (2023). Potensi Bir Pletok Sebagai Minuman Fungsional Komersial. *Agrisaintifika: Jurnal Ilmu-Ilmu Pertanian*, *7*(1), 82–91. https://doi.org/10.32585/ags.v7i1.3784

Rahardjanto, A., & Husamah, H. (2022). Publication Trend of Environmental Topics in The Journal of Biological Education in Indonesia (Sinta 2; 2017-2021): A Systematic Literature Review. *Jurnal Pembelajaran Dan Biologi Nukleus*, *8*(1), 17–40. https://doi.org/10.36987/jpbn.v8i1.2453

Rahmawati, L., Juandi, D., & Nurlaelah, E. (2022). Implementasi Stem Dalam Meningkatkan Kemampuan Berpikir Kritis Dan Kreatif Matematis. *AKSIOMA: Jurnal Program Studi Pendidikan Matematika*, *11*(3), 2002. https://doi.org/10.24127/ajpm.v11i3.5490

Ratnasari, R., Doyan, A., & Makhrus, M. (2023). Pengembangan Perangkat Pembelajaran Berbasis Proyek Terintegrasi STEM pada Materi Suhu dan

Kalor untuk Meningkatkan Keterampilan Generik Sains Dan Kreativitas Peserta Didik: Instrumen Validasi. *Jurnal Penelitian Pendidikan IPA*, *9*(9), 6992–6999. https://doi.org/10.29303/jppipa.v9i9.4178

Safitri, L., Susanti, M., Anggun, C., Wahyuni, S., Yusmar, F., & Nuha, U. (2023). Penguatan Nilai-Nilai Kearifan Lokal Dalam Pembelajaran IPA Pada Kurikulum Merdeka Untuk Membentuk Profil Pelajar Pancasila: Studi Literatur. *Jurnal Muara Pendidikan*, *8*(1), 223–229. https://doi.org/10.52060/mp.v8i1.1227

Shinta, N., & Rahmadhia, S. N. (2024). Effect Of Adding Belimbing Wuluh (*Averrhoa bilimbi*), Pineapple (*Ananas comosus*) and lime (*Citrus aurantiifolia*) Extract On The Physicochemical, Microbiological, And Sensory Characteristic Of Snake Fruit (*Salacca zalacca*) Juice. *Gizi Indonesia*, *47*(2), 145–158. https://doi.org/10.36457/gizindo.v47i2.995

Sinta, P. P., Nisa, A. F., Supadmiyati, & Himawanti, R. (2023). Analysis of Misconceptions of Elementary Science on Human Digestive Materials. *Pendas : Scientific Journal of Basic Education*, *8*(3). https://doi.org/10.23969/jp.v9i3.14828

Stern, C., Jordan, Z., & Mcarthur, A. (2014). Developing the Review Question and Inclusion Criteria. *The American Journal Of*, *114*, 53–56. https://doi.org/10.1097/01.NAJ.0000445689.67800.

Sweller, J., Zhang, L., Ashman, G., Cobern, W., & Kirschner, P. A. (2024). Response to De Jong et al.'s (2023) paper "Let's talk evidence – The case for combining inquiry-based and direct instruction." *Educational Research Review*, *42*, 100584. https://doi.org/10.1016/j.edurev.2023.100584

Utomo, R. H., Sudiyanto, S., & Supianto, S. (2025). The Role of STEM-Based Project-Based Learning in Developing Future Competencies: A Systematic Review. *Teknodika*, *23*(1), 12. https://doi.org/10.20961/teknodika.v23i1.97895

Vinandari, S. M., Hariyadi, S., & Nuriman, N. (2021). Digestive System E-Module Based On Integrated-Stem In Student's Science Literacy And Learning Outcome. *ScienceEdu*, *4*(2), 76. https://doi.org/10.19184/se.v4i2.25152

Winarni, E. W., Purwandari, E. P., & Raharjo, F. O. (2024). The effect of integrating STEAM and virtual reality using PjBL on scientific literacy in elementary schools. *Education and Information Technologies*, *29*(18), 24991–25011. https://doi.org/10.1007/s10639-024-12853-2

Yulianti, Y., Lestari, H., & Rahmawati, I. (2022). The application of the Radec learning model to improve students' critical thinking skills. *Pendas Horizon Journal*, *8*(1), 47–56. Retrieved from https://ejournal.unma.ac.id/index.php/cp/article/

Zulyusri, Z., Elfira, I., Lufri, L., & Santosa, T. A. (2023). Literature Study: Utilization of the PjBL Model in Science Education to Improve Creativity and Critical Thinking Skills. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 133–143. https://doi.org/10.29303/jppipa.v9i1.2555