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Humanizing STEM Education in Primary Schools: Integrating Ethnopedagogy and Digital Learning for Sustainable Futures

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Abstract. The rapid advancement of science and technology, coupled with increasing global sustainability challenges, has highlighted the need for more holistic and culturally responsive STEM education. However, existing studies on ethnopedagogy, STEM education, digital learning, scientific literacy, and sustainability education are often investigated separately, resulting in fragmented pedagogical approaches. This study aims to synthesize current research trends and propose a conceptual Humanistic Ethno-STEM Model for Sustainable Citizenship that integrates local wisdom, cultural values, inquiry-based learning, STEM integration, digital storytelling, scientific literacy, and sustainability education. A Systematic Literature Review (SLR) following the PRISMA 2020 guidelines was conducted using publications retrieved from international databases. The selected studies were analyzed through descriptive analysis, bibliometric mapping, and thematic synthesis to identify dominant themes, research trends, and knowledge gaps. The findings revealed five major themes: Humanistic STEM Education, Ethnopedagogy, Digital Learning, Scientific Literacy, and Sustainability Education. The review indicates that although each theme contributes positively to student learning outcomes, relatively few studies integrate these dimensions within a unified educational framework. Based on the synthesis, a Humanistic Ethno-STEM Model for Sustainable Citizenship is proposed, consisting of four interconnected components: Input (local wisdom and cultural values), Process (inquiry-based learning, STEM integration, and digital storytelling), Output (scientific literacy, critical thinking, and cultural awareness), and Outcome (sustainable citizenship). The proposed model contributes a novel theoretical framework that bridges cultural responsiveness, technological innovation, scientific literacy, and sustainability-oriented learning. This study provides implications for curriculum development, instructional design, and educational policy while offering directions for future empirical validation, particularly in culturally diverse contexts such as Papua, Indonesia.

Keywords: STEM education; ethnopedagogy; digital learning; primary education; sustainable education

INTRODUCTION

The rapid advancement of digital technologies, artificial intelligence, and Society 5.0 has transformed educational priorities worldwide. Contemporary education is expected not only to equip learners with disciplinary knowledge but also to develop critical thinking, creativity, collaboration, communication, and problem-solving skills required to respond to increasingly complex social, environmental, and technological challenges (Haryono et al., 2017). Within this changing educational landscape, STEM (Science, Technology, Engineering, and Mathematics) education has emerged as a prominent interdisciplinary approach for preparing learners to participate effectively in knowledge-based economies and sustainable societies. STEM learning encourages students to connect scientific concepts with technological applications, engineering design processes, and mathematical reasoning while solving authentic problems. Previous studies have demonstrated that STEM education can contribute positively to students' scientific literacy, innovation capacity, problem-solving abilities, and twenty-first-century competencies (Atmojo, Lukitoaji, et al., 2025). These benefits make STEM particularly relevant in primary education, where foundational knowledge, attitudes, learning habits, and ways of understanding the surrounding world begin to develop.

At the same time, contemporary educational development is increasingly influenced by global sustainability agendas, particularly the Sustainable Development Goals (SDGs). SDG 4 emphasizes inclusive, equitable, and high-quality education while promoting lifelong learning opportunities for all. Consequently, educational innovation cannot be evaluated solely on the basis of technological sophistication or academic achievement. Learning environments should also be culturally responsive, socially meaningful, human-centered, and capable of supporting sustainable ways of thinking and acting. This perspective has encouraged scholars to reconsider whether current STEM education practices sufficiently accommodate humanistic values, cultural diversity, local wisdom, and community knowledge systems (Marcone, 2022). Although STEM has frequently been promoted as an important pathway toward educational transformation, its implementation may still prioritize technological competence, measurable cognitive achievement, and economic competitiveness while providing insufficient attention to cultural identity, ethical awareness, environmental responsibility, and social relationships (Imad et al., 2023). Such limitations highlight the importance of humanizing STEM education by connecting scientific and technological learning with the cultural and social contexts in which learners live.

One promising approach to achieving this goal is the integration of ethnopedagogy and ethnoscience into STEM education. Ethnopedagogy refers to educational practices grounded in local cultural values, traditions, community practices, and indigenous knowledge, whereas ethnoscience emphasizes connections between community-based knowledge systems and formal scientific concepts. These perspectives provide opportunities for teachers to contextualize abstract STEM concepts through phenomena, practices, technologies, and environmental knowledge familiar to students. Rather than positioning local culture and modern science as competing forms of knowledge, an integrated approach can encourage learners to examine relationships between them critically and meaningfully. Previous research suggests that culturally responsive STEM learning can improve scientific literacy, critical thinking, engagement, and cultural awareness because academic concepts are connected with students' lived experiences and sociocultural environments (Marosi et al., 2021). In primary schools, such connections are particularly important because young learners often construct understanding more effectively when new concepts are related to familiar experiences, local environments, and meaningful everyday practices.

However, several unresolved tensions remain within the literature. STEM education is frequently associated with technological advancement and future-oriented innovation, while ethnopedagogy emphasizes cultural continuity, local identity, and preservation of community knowledge. This creates an important pedagogical question concerning how technological innovation and cultural sustainability can be balanced within a unified learning framework (Maduddin et al., 2024). In addition, digital technologies are increasingly incorporated into STEM learning through interactive multimedia, virtual environments, digital storytelling, simulations, and other technology-supported learning resources. Although these tools may increase engagement and facilitate conceptual understanding, their educational value depends on how meaningfully they are integrated into learning activities. Digital technology that is disconnected from students' cultural and social realities may lead to superficial engagement rather than meaningful understanding. Conversely, digital learning grounded in local narratives, community knowledge, and authentic environmental problems may provide opportunities to connect technological literacy with cultural identity and human-centered learning.

The existing literature also reports variations in the effectiveness of ethnoscience-based and culturally responsive STEM approaches across educational levels, subject areas, geographical locations, and sociocultural contexts. These variations suggest that the outcomes of integrated STEM learning cannot be understood independently of contextual factors. Scientific literacy, for example, is frequently identified as an important outcome of STEM education, yet researchers employ different conceptual definitions, indicators, instruments, and assessment procedures. Such methodological diversity may contribute to inconsistencies among reported findings and make cross-study comparison more challenging (Prayogi et al., 2023). Similar challenges occur in studies of digital learning, where technology may function as an instructional medium, a creative production tool, a collaborative environment, or a mechanism for presenting culturally relevant content. Therefore, understanding Humanistic STEM Education requires attention not only to whether ethnopedagogy and digital technologies are included but also to how they interact pedagogically to support scientific understanding, cultural awareness, learner agency, and sustainability-oriented values.

Several review studies have examined STEM education, ethnoscience, culturally responsive pedagogy, scientific literacy, digital storytelling, and educational technology. Nevertheless, the existing reviews remain relatively fragmented because many concentrate on only one dimension of this broader educational landscape. Some reviews emphasize STEM effectiveness, while others focus primarily on ethnoscience integration or technology adoption without examining how cultural knowledge, digital learning, scientific literacy, and sustainability can interact within a unified pedagogical framework (Qingna, 2021). Furthermore, rapid developments in artificial intelligence, digital learning environments, and post-pandemic educational transformation have altered the technological context in which contemporary STEM education operates. Reviews conducted before these developments may therefore provide only a partial representation of current educational possibilities and challenges. Variations in inclusion criteria, methodological rigor, quality appraisal, and synthesis procedures across previous reviews further complicate efforts to establish an integrated understanding of current evidence (Zawacki-Richter et al., 2025).

A comprehensive synthesis is therefore needed to examine the relationships among ethnopedagogy, digital learning, scientific literacy, and STEM education within the context of primary schooling. Primary education represents a particularly significant setting because foundational scientific understanding, cultural identity, social values, curiosity, and environmental awareness develop simultaneously during this stage (Qingna, 2021). Integrating local wisdom with scientific inquiry and digital learning may enable primary students to understand STEM not merely as a collection of technical disciplines but as a meaningful way of interpreting and responding to problems within their communities and environments. From this perspective, Humanistic STEM Education can be conceptualized as an approach that combines scientific inquiry, technological innovation, engineering and mathematical thinking, local cultural knowledge, and human-centered values to promote meaningful and sustainable learning (Zawacki-Richter et al., 2025). Such an approach may help bridge the perceived divide between technological progress and cultural sustainability by positioning both as complementary components of educational development.

Accordingly, this systematic literature review aims to synthesize current evidence concerning the integration of ethnopedagogy and digital learning within STEM education and to develop a conceptual framework for Humanistic STEM Education in primary schools. The review investigates major research trends and thematic developments related to ethnopedagogy, digital learning, and STEM education in primary education; examines how ethnopedagogy has been integrated into STEM learning to support scientific literacy and culturally responsive education; analyzes the roles of digital approaches, including digital storytelling and interactive multimedia, in supporting humanistic STEM learning; and synthesizes the evidence to formulate a conceptual framework for Humanistic STEM Education. Finally, the review considers the implications of these findings for developing sustainable and culturally responsive STEM education in primary schools. Through this synthesis, the study seeks to contribute an integrated perspective that connects technological innovation, scientific literacy, cultural identity, local knowledge, and sustainability as interdependent dimensions of future-oriented primary education.

METHODS

This study employed a Systematic Literature Review (SLR) approach to identify, evaluate, and synthesize previous research concerning the integration of ethnopedagogy, digital learning, scientific literacy, and STEM education in primary schools. The SLR approach was selected because it provides a systematic, transparent, and reproducible procedure for examining existing evidence and identifying research trends, theoretical developments, methodological approaches, and empirical findings within a particular field (Syahrir et al., 2024a). The review process followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA 2020) guidelines. PRISMA provides an internationally recognized framework for conducting systematic reviews through four principal stages: identification, screening, eligibility assessment, and inclusion. These stages were applied to increase transparency in study selection and minimize potential selection bias (Qingna, 2021).

Relevant studies were retrieved from four major academic databases: Scopus, Web of Science (WoS), ERIC (Education Resources Information Center), and Dimensions. These databases were selected because of their extensive coverage of peer-reviewed international publications in education, science education, STEM education, and educational technology. The literature search focused on publications from 2020 to 2025. Search terms were developed based on the main concepts addressed in the review and combined using Boolean operators AND and OR. The primary search string included combinations of *"STEM Education," "STEM Learning," "Integrated STEM," "Ethnopedagogy," "Ethnoscience,"* *"Indigenous Knowledge," "Local Wisdom," "Culturally Responsive Teaching," "Digital Learning," "Digital Storytelling," "Educational Technology," "Interactive Multimedia," "Animation Learning," "Scientific Literacy,"* and *"Science Literacy."* Additional search terms related to *Humanistic Education, Sustainable Education,* and *Education for Sustainable Development (ESD)* were also applied to identify studies relevant to culturally responsive and sustainable STEM education.

Study selection was guided by predefined inclusion and exclusion criteria. Studies were included when they were peer-reviewed journal articles published between 2020 and 2025, written in English, available in full-text format, and focused on STEM education, science education, ethnopedagogy, ethnoscience, digital learning, scientific literacy, or sustainability education within primary, elementary, or basic education contexts. Conference proceedings, book chapters, editorials, dissertations, duplicate records, studies without accessible full texts, articles unrelated to the review focus, and studies with insufficient methodological information were excluded. During the identification stage, records obtained from all four databases were exported and combined in a reference management system, after which duplicate records were removed. Titles and abstracts were subsequently screened to determine their relevance to the research objectives (Cardwell et al., 2021). The remaining articles underwent full-text assessment based on the established eligibility criteria, and studies satisfying all requirements were retained for qualitative synthesis. The entire selection procedure was documented using a PRISMA 2020 flow diagram (Willie & Africa, n.d.).

To ensure the credibility of the evidence, the included articles underwent a quality appraisal. The assessment considered the clarity of the research objectives, appropriateness of the research design, transparency of data collection procedures, validity and reliability of the findings, and relevance of each study to the review objectives. Based on these criteria, studies were categorized as having high, moderate, or low methodological quality, and only studies meeting acceptable quality standards were retained. A structured data extraction form was then used to record information systematically, including authorship, publication year, country, research objectives, research design, educational level, STEM approach, ethnopedagogical elements, digital learning components, scientific literacy outcomes, sustainability-related outcomes, and key findings. The extracted information was organized into summary tables to support comparison across studies.

The selected literature was analyzed using a combination of bibliometric analysis and thematic analysis. Bibliometric mapping was conducted using VOSviewer version 1.6.**20** to examine keyword co-occurrence, thematic clusters, research relationships, and emerging trends. Network visualization, overlay visualization, and density visualization were used to represent the intellectual structure of the literature (Kumar, 2025). Thematic analysis was subsequently conducted following Braun and Clarke's six-stage procedure, consisting of data familiarization, initial coding, theme generation, theme review, theme definition, and report production (Ahmed et al., 2025). Themes emerging from the bibliometric analysis were further interpreted through thematic synthesis to identify relationships among STEM education, ethnopedagogy, digital learning, scientific literacy, and sustainability. Finally, the integration of bibliometric and thematic findings was used to formulate a conceptual framework for Humanistic STEM Education in primary schools, providing an integrated representation of the intellectual structure, thematic development, and emerging research directions within the field (Poojar et al., 2017; Kostikova et al., 2023).

RESULTS AND DISCUSSION

Study Selection and Characteristics of the Reviewed Studies

The study selection process followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines to ensure transparency and methodological rigor in identifying, screening, and selecting relevant literature (Purnama et al., 2023). During the identification stage, 145 records were retrieved, consisting of 135 records obtained from academic databases and 10 records identified through supplementary sources. Before screening, 70 records were removed, including 20 duplicate records, 20 records identified as ineligible through automated screening procedures, and 30 records excluded for other reasons. The remaining records were screened based on titles and abstracts, followed by full-text eligibility assessment. During this process, articles were excluded because of limited relevance, unavailable full text, publication in languages other than English, or insufficient information for methodological evaluation. Ultimately, 14 studies fulfilled the inclusion criteria and formed the evidence base for descriptive analysis, bibliometric mapping, thematic synthesis, and conceptual framework development.

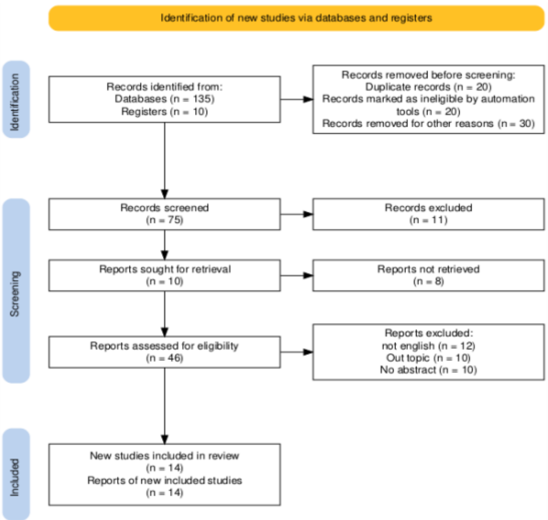

Figure 1. PRISMA Flow Diagram of the Study Selection Process

The included studies represented diverse methodological approaches, although empirical designs were dominant. Quasi-experimental and experimental studies were frequently used to examine the effectiveness of Ethno-STEM, ethnoscience-based instruction, project-based STEM, and digital learning interventions in improving scientific literacy, critical thinking, cultural literacy, and learning outcomes (Atmojo, Anggriani, et al., 2025; Mahlianurrahman et al., 2023a; Suryanti et al., 2024). Research and Development approaches were also used to design educational products such as augmented reality e-books, gamified learning environments, environmental learning modules, and technology-assisted instructional media (Ee et al., 2025; Isnaniah et al., 2025; Maulidiyah, 2017; Patras et al., 2025). Other methodological approaches included mixed methods, systematic literature reviews, case studies, and theoretical analyses, which expanded the empirical findings by providing conceptual perspectives on STEM integration, technology adoption, sustainability, and the humanization of STEM education (Hasani et al., 2021; Imad et al., 2023; Marcone, 2022; Syahrir et al., 2024b).

Most empirical studies focused on primary or elementary education, indicating increasing scholarly attention to developing STEM competencies, scientific literacy, cultural awareness, and higher-order thinking from an early age (Atmojo, Anggriani, et al., 2025; Mahlianurrahman et al., 2023a; Suryanti et al., 2024). However, several studies involved pre-service teachers or higher education contexts to examine instructional development, digital inquiry, or broader theoretical perspectives on Humanistic STEM (Imad et al., 2023; Marcone, 2022; Prayogi et al., 2023). Taken together, the reviewed studies demonstrate that Humanistic STEM principles are relevant across educational levels, although the strongest empirical evidence in the current corpus remains associated with elementary education.

Publication and Geographical Trends

The publication pattern indicates a growing interest in the intersection of STEM education, ethnopedagogy, digital learning, scientific literacy, and sustainability. The reviewed corpus showed relatively limited publication activity during 2021 and 2022, followed by increasing attention in subsequent years. Three studies appeared in 2023, two in 2024, and the largest concentration occurred in 2025, when six studies represented 42.86% of the reviewed literature. One additional study in 2026 further indicates the continuing development of this research area. The increase in recent publications suggests that culturally responsive STEM learning, digital transformation, scientific literacy, and sustainability are becoming increasingly interconnected priorities within contemporary educational research (Atmojo, Anggriani, et al., 2025; Imad et al., 2023; Marcone, 2022).

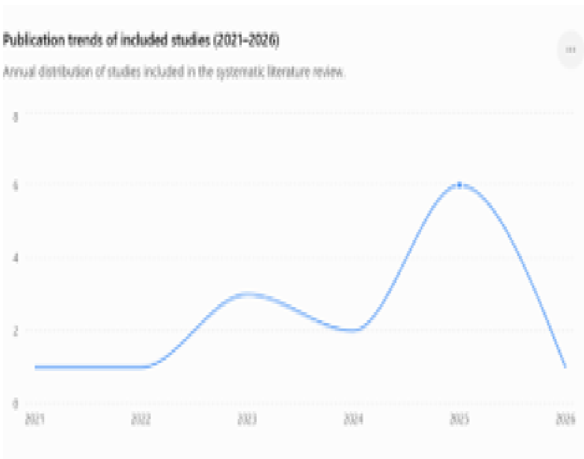

Figure 2. Publication Trends of Included Studies (2021–2026)

Geographically, Indonesia contributed the largest proportion of studies, accounting for eight of the fourteen publications. The United States, Australia, and Malaysia each contributed two studies. The prominence of Indonesian research is consistent with the strong emphasis placed on local wisdom, ethnoscience, and culturally responsive education in a country characterized by substantial cultural and ecological diversity. Indonesian studies frequently examined how community traditions, local environmental knowledge, and indigenous practices could be connected with science and STEM instruction to make learning more contextual and meaningful (Atmojo, Anggriani, et al., 2025; Mahlianurrahman et al., 2023a; Prayogi et al., 2023). Nevertheless, the concentration of evidence in a relatively small number of national contexts also indicates a limitation. Broader cross-cultural research is required to determine whether the emerging Humanistic STEM framework can be effectively adapted to different cultural, socioeconomic, and educational environments.

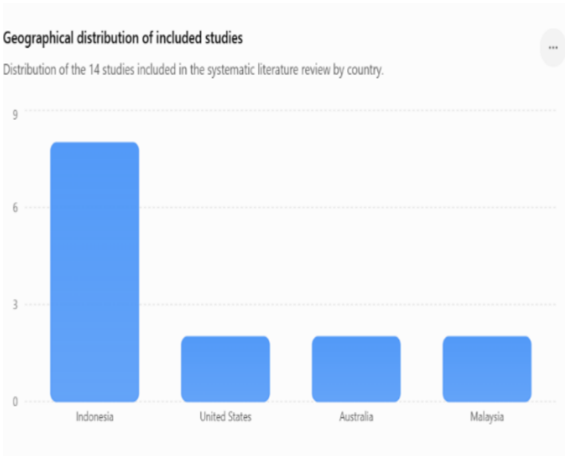

Figure 3. Geographical Distribution of Included Studies

Bibliometric Structure and Emerging Research Directions

Keyword co-occurrence analysis using VOSviewer revealed that the intellectual structure of the reviewed literature extends beyond conventional STEM concepts. The network visualization identified several interconnected thematic clusters involving STEM education, ethnopedagogy, sustainability, digital transformation, educational effectiveness, culture, and values. A culturally oriented cluster was characterized by keywords such as *ethnopedagogy*, *culture*, *value*, *observation*, and *interview*. This configuration indicates that local culture is increasingly regarded not simply as contextual background but as a pedagogical resource through which scientific knowledge can be constructed and interpreted.

A second cluster connected sustainability, SDGs, future-oriented education, higher education, and digital transformation. The emergence of this cluster demonstrates that contemporary STEM education is increasingly linked to wider social and environmental objectives. STEM is therefore being positioned as a means of preparing learners not only for technological environments but also for sustainable citizenship and responsible participation in society. Another cluster, represented by terms such as *effectiveness*, *impact*, *questionnaire*, *evidence*, and *influence*, reflects the growing emphasis on empirically assessing the outcomes of STEM-related interventions. STEM education itself occupied a central position connecting cultural, technological, sustainability, and effectiveness dimensions.

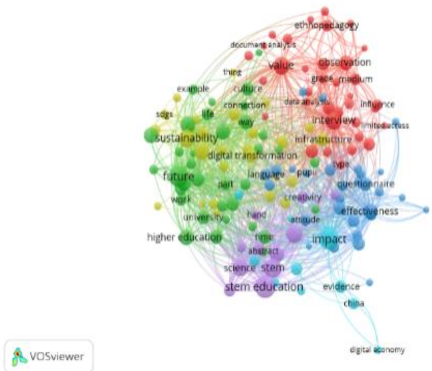

Figure 4. Keyword Co-occurrence Network Visualization Using VOSviewer

The overlay visualization provided additional evidence of thematic evolution. Earlier studies were more strongly associated with broad terms such as STEM education, science, future, and higher education, whereas later studies increasingly incorporated ethnopedagogy, culture, value, sustainability, and digital transformation. More recent keywords, including effectiveness, infrastructure, limited access, influence, and SDGs, indicate that scholarly attention has shifted toward questions of implementation, educational impact, equity, technological accessibility, and sustainability. This progression suggests that the field is gradually moving from asking whether STEM education is beneficial toward examining how STEM can become culturally meaningful, socially responsible, technologically accessible, and sustainable.

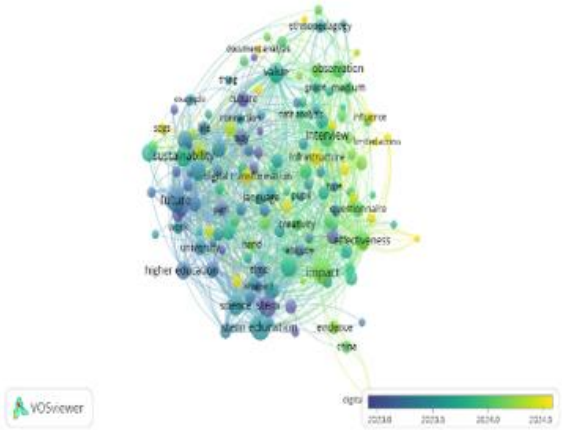

Figure 5. Overlay Visualization of Keyword Co-occurrence Network

The density visualization reinforced these observations. Highly prominent keywords included *future*, *sustainability*, *STEM education*, *impact*, *value*, and *interview*, whereas concepts such as ethnopedagogy, culture, digital transformation, and effectiveness occupied important interconnected areas. This distribution suggests that research is increasingly converging around five broad domains: STEM education, cultural values and ethnopedagogy, digital transformation, scientific and educational outcomes, and sustainability. Collectively, the bibliometric findings provide an empirical basis for conceptualizing Humanistic STEM as an emerging integrative research direction rather than as a purely theoretical proposition.

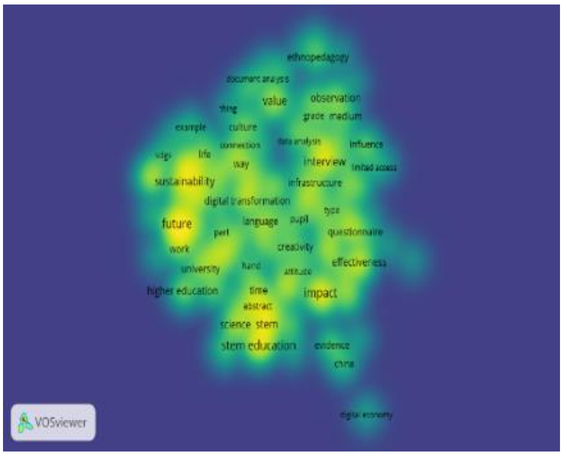

Figure 6. Density Visualization of Keywords in Humanistic STEM Education Research

Humanistic STEM, Ethnopedagogy, and Local Wisdom

The thematic synthesis identified five major themes: Humanistic STEM Education, Ethnopedagogy and Local Wisdom, Digital Learning and Multimedia Innovation, Scientific Literacy Development, and Sustainability Education and Future Citizenship. A central finding across these themes is a gradual transformation from technocentric STEM education toward a human-centered paradigm. Conventional STEM education has often emphasized scientific knowledge, technological competence, engineering skills, mathematics, innovation, and workforce preparation. Although these objectives remain important, this orientation may insufficiently address cultural diversity, ethical reasoning, local knowledge, and social responsibility (Imad et al., 2023).

Humanistic STEM expands this orientation by recognizing learners as culturally situated individuals whose experiences, identities, values, and communities shape how scientific knowledge is understood. Imad et al. (2023) advocate re-humanizing STEM through empathy, equity, diversity, ethical awareness, and attention to learners' lived experiences. Similarly, Marcone (2022) emphasizes that contemporary sustainability challenges cannot be understood exclusively through scientific and technological perspectives; Humanities and Social Sciences are also necessary for examining social, cultural, ethical, and environmental dimensions. The reviewed evidence therefore indicates that the future development of STEM education involves expanding rather than abandoning scientific rigor.

Ethnopedagogy provides an important mechanism for achieving this transformation. Atmojo, Anggriani, et al. (2025) found that ethnoscience-integrated STEM learning strengthened elementary students' critical thinking and cultural literacy by connecting science with local cultural practices. Aprilia et al. (2025) similarly demonstrated that ethnoscience-based Contextual Teaching and Learning improved students' learning outcomes by relating academic concepts to culturally familiar experiences. Mahlianurrahman et al. (2023a, 2023b) reported that Nyerayo-based Science, Environment, Technology, and Society learning improved scientific literacy through the incorporation of local cultural values. Prayogi et al. (2023) additionally demonstrated that ethnoscience combined with inquiry in a digital environment strengthened critical thinking.

These findings indicate that local wisdom is not merely supplementary material added to a conventional science curriculum. Instead, it can function as a contextual resource through which students explore scientific phenomena and relate formal scientific explanations to community practices. Ethnopedagogy consequently provides a bridge between scientific knowledge and indigenous or community-based knowledge systems. This relationship is particularly relevant in culturally diverse primary education settings because young learners construct knowledge through interactions with family, community, environment, language, and cultural experience.

Digital Learning as a Humanistic Pedagogical Tool

Digital learning represented another prominent theme. The reviewed studies examined augmented reality, ICT-integrated STEM learning, digital inquiry modules, gamification, interactive multimedia, Smart Box media, and related forms of technology-enhanced learning (Isnaniah et al., 2025; Patras et al., 2025; Prayogi et al., 2023; Susanta et al., 2025; Syahrir et al., 2024a). Overall, digital technologies were associated with improvements in motivation, engagement, conceptual understanding, critical thinking, and literacy development. For example, Isnaniah et al. (2025) found that an augmented reality e-book featuring local wisdom improved learning outcomes and engagement. Susanta et al. (2025) demonstrated that digital STEAM-Inquiry modules supported literacy development across urban and rural elementary contexts, while Syahrir et al. (2024a, 2024b) highlighted ICT integration as an important component of STEM innovation and teacher competency development.

However, the synthesis shows that technology is most valuable when it supports pedagogical meaning rather than functioning as an instructional goal in itself. This distinction is central to Humanistic STEM Education. Digital technology can provide immersive experiences and richer representations, but technological sophistication alone does not guarantee culturally responsive or meaningful learning. Infrastructure limitations, unequal access, and differences in teacher digital competence remain important constraints, particularly in rural and underserved areas (Susanta et al., 2025; Syahrir et al., 2024b).

Within this context, digital storytelling offers particular potential because it combines technological affordances with narrative and cultural meaning. Although the reviewed studies employed different forms of digital technology, their findings support the principles underlying digital storytelling. Narratives, animation, multimedia, and interactive representations can connect abstract STEM concepts to learners' experiences, local environments, cultural traditions, and sustainability issues. Digital storytelling can therefore function as a bridge among scientific knowledge, cultural identity, emotional engagement, and digital innovation. This perspective is consistent with findings that technology-supported contextual learning can strengthen engagement and conceptual understanding (Isnaniah et al., 2025; Prayogi et al., 2023; Susanta et al., 2025).

Scientific Literacy and Sustainable Citizenship

Scientific literacy emerged as one of the most consistently reported outcomes across the reviewed studies. Suryanti et al. (2024) demonstrated that STEAM-Project-Based Learning improved elementary students' scientific literacy through authentic investigations and problem-solving activities. Mahlianurrahman et al. (2023b) found comparable improvements when scientific learning was contextualized through the Nyerayo tradition, while Susanta et al. (2025) reported stronger literacy outcomes through digital STEAM-Inquiry learning. Atmojo, Anggriani, et al. (2025) and Prayogi et al. (2023) further showed that culturally responsive and inquiry-oriented learning can strengthen critical thinking alongside scientific understanding.

These findings suggest that scientific literacy functions as a bridge linking STEM knowledge to meaningful decision-making. In Humanistic STEM, scientific literacy is not limited to knowing scientific terminology or recalling concepts. It encompasses the ability to interpret information, evaluate evidence, understand scientific phenomena, apply scientific reasoning, and use knowledge to address personal, social, cultural, and environmental issues. When scientific literacy is situated within local cultural contexts, learners can understand how scientific concepts relate to their own communities and environments.

This expanded understanding also connects STEM education with sustainability. Marcone (2022) argues that interdisciplinary STEM education can contribute to Education for Sustainable Development by helping students examine relationships among scientific, environmental, social, and economic challenges. Hasani et al. (2021) likewise demonstrate that STEM concepts can be integrated into broader elementary learning to contribute to sustainability education. Indigenous environmental learning further shows how cultural knowledge can support environmental sustainability and contextual learning (Ee et al., 2025).

Humanistic STEM therefore has relevance to multiple Sustainable Development Goals. Its commitment to meaningful, inclusive, and culturally responsive learning is consistent with SDG 4 on Quality Education. Incorporating local knowledge and community practices supports objectives associated with SDG 11 on Sustainable Cities and Communities, while environmental inquiry and sustainability-oriented scientific literacy contribute to SDG 12 on Responsible Consumption and Production and SDG 13 on Climate Action (Hasani et al., 2021; Marcone, 2022). Sustainable citizenship consequently emerges as a long-term educational outcome that combines scientific competence with ethical responsibility, cultural awareness, and commitment to community and environmental well-being.

Toward a Humanistic STEM Framework

The synthesis shows that ethnopedagogy, digital learning, scientific literacy, and sustainability are individually well represented in the literature, but they are rarely integrated simultaneously. Ethnoscience research typically focuses on local wisdom and cultural relevance but may pay less attention to digital innovation. Conversely, digital learning research often prioritizes engagement, technology adoption, and effectiveness without explicitly incorporating cultural knowledge. Research on scientific literacy usually emphasizes cognitive outcomes, while sustainability studies may address global challenges without adequately considering indigenous knowledge and local cultural identities (Atmojo, Anggriani, et al., 2025; Hasani et al., 2021; Prayogi et al., 2023; Syahrir et al., 2024b). This fragmentation represents the central conceptual gap identified by the review.

Based on the synthesis, Humanistic STEM Education can therefore be conceptualized through interconnected dimensions involving local wisdom, ethnopedagogy, digital learning, scientific literacy, and sustainable citizenship. Local wisdom provides authentic cultural and environmental contexts, while ethnopedagogy translates these cultural resources into pedagogical practice. Humanistic STEM connects scientific and technological learning with ethical awareness, cultural identity, and social responsibility. Digital storytelling then functions as a technology-supported medium for representing local narratives, scientific concepts, and sustainability challenges in engaging forms. Scientific literacy emerges as an important learning result that supports informed reasoning and action, ultimately contributing to sustainable citizenship.

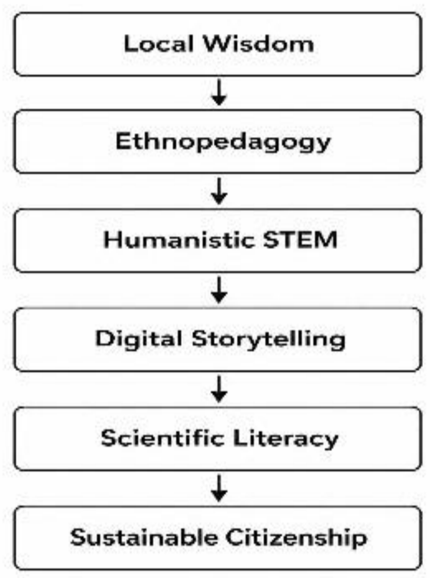

Figure 7. Conceptual Framework of Humanistic STEM Education

This framework represents a shift from Traditional STEM toward Humanistic STEM. Rather than replacing disciplinary competence, it broadens the purposes of STEM education. Scientific knowledge, technology, engineering, and mathematics remain essential, but they are connected to culture, values, ethics, and sustainability. Technology is therefore understood as a means to support meaningful learning rather than as an end product, while culture becomes a central resource for knowledge construction rather than a peripheral addition. The intended outcome similarly moves beyond technical competence toward learners who are scientifically literate, culturally grounded, technologically capable, ethically responsible, and sustainability oriented (Imad et al., 2023; Marcone, 2022).

Proposed Humanistic Ethno-STEM Model for Sustainable Citizenship

Based on the combined systematic review, bibliometric findings, and thematic synthesis, this study proposes a Humanistic Ethno-STEM Model for Sustainable Citizenship consisting of four interconnected components: Input, Process, Output, and Outcome. This model responds directly to the fragmented nature of previous research by integrating cultural responsiveness, technological innovation, scientific literacy, and sustainability into a unified pedagogical structure (Atmojo, Anggriani, et al., 2025; Imad et al., 2023; Marcone, 2022; Patras et al., 2025; Prayogi et al., 2023).

The Input component consists of local wisdom and cultural values. Indigenous knowledge, community traditions, environmental practices, folklore, and everyday cultural experiences provide authentic contexts for STEM learning. Values such as cooperation, respect, empathy, responsibility, environmental stewardship, and community participation provide the ethical foundation for learning. Evidence indicates that integrating such resources can strengthen engagement, cultural literacy, and conceptual understanding (Atmojo, Anggriani, et al., 2025; Ee et al., 2025; Mahlianurrahman et al., 2023a; Patras et al., 2025).

The Process component combines inquiry-based learning, STEM integration, and digital storytelling. Inquiry encourages learners to formulate questions, investigate authentic phenomena, collect and evaluate evidence, and construct explanations, thereby supporting scientific reasoning and critical thinking (Atmojo, Anggriani, et al., 2025; Prayogi et al., 2023). STEM integration enables students to connect science, technology, engineering, and mathematics when solving contextual problems (Hasani et al., 2021; Suryanti et al., 2024; Syahrir et al., 2024b). Digital storytelling complements these processes by transforming scientific and cultural content into multimedia narratives, animations, and interactive experiences that can strengthen engagement and contextual meaning (Isnaniah et al., 2025; Prayogi et al., 2023; Susanta et al., 2025).

The Output component comprises scientific literacy, critical thinking, and cultural awareness. Scientific literacy enables students to understand concepts, interpret evidence, and make informed decisions (Mahlianurrahman et al., 2023a; Suryanti et al., 2024). Critical thinking supports analysis, evaluation, problem solving, and reasoned judgment (Atmojo, Anggriani, et al., 2025; Prayogi et al., 2023). Cultural awareness enables learners to appreciate local knowledge, cultural diversity, community values, and different ways of understanding the world (Aprilia et al., 2025; Atmojo, Anggriani, et al., 2025). These outcomes represent the cognitive, affective, and sociocultural dimensions of Humanistic STEM Education.

The final Outcome is sustainable citizenship. Sustainable citizens are expected to combine scientific literacy, critical thinking, cultural awareness, technological competence, ethical responsibility, and commitment to sustainability (Imad et al., 2023; Marcone, 2022). They should be capable of using scientific knowledge to make informed decisions while remaining sensitive to community needs, cultural heritage, and environmental consequences (Ee et al., 2025; Hasani et al., 2021). Through this progression, learners are positioned not merely as consumers of scientific and technological knowledge but as active participants capable of balancing innovation with cultural preservation, environmental stewardship, and social well-being.

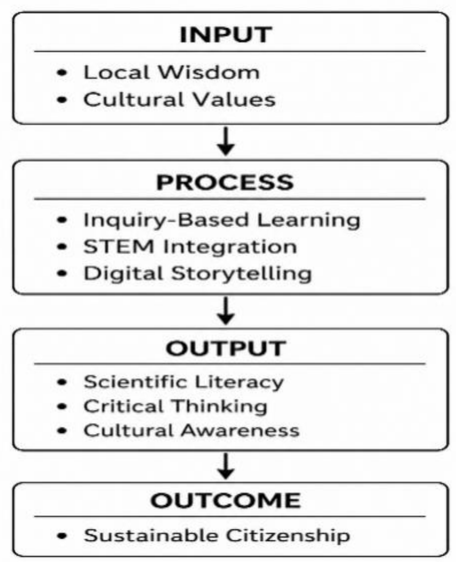

Figure 8. Proposed Humanistic Ethno-STEM Model for Sustainable Citizenship

Overall, the findings demonstrate a clear movement toward a more integrated form of STEM education in which scientific and technological competencies coexist with cultural relevance, human values, digital innovation, and sustainability. The proposed Humanistic Ethno-STEM Model synthesizes these dimensions into a coherent educational pathway from culturally grounded inputs, through inquiry-based and digitally supported STEM processes, toward scientific literacy, critical thinking, cultural awareness, and ultimately sustainable citizenship. The model therefore provides a conceptual foundation for future curriculum development, instructional design, and empirical testing in elementary education, particularly in culturally diverse contexts where scientific advancement, local identity, and sustainability must be developed simultaneously.

CONCLUSION

This systematic literature review demonstrates that STEM education is increasingly shifting from a predominantly technology-centered orientation toward a more human-centered, culturally responsive, and sustainability-oriented paradigm. The synthesis of fourteen studies identified five interconnected themes—Humanistic STEM Education, Ethnopedagogy and Local Wisdom, Digital Learning and Multimedia Innovation, Scientific Literacy Development, and Sustainability Education and Future Citizenship—which collectively indicate that meaningful STEM learning should integrate scientific and technological competencies with cultural identity, ethical responsibility, and sustainable development. Based on these findings, this study proposes the Humanistic Ethno-STEM Model for Sustainable Citizenship, which combines local wisdom and cultural values with inquiry-based learning, STEM integration, and digital storytelling to strengthen scientific literacy, critical thinking, cultural awareness, and sustainability competencies. The proposed framework positions culture as a central foundation for knowledge construction rather than a supplementary element of STEM learning, while digital technology functions as a pedagogical tool that supports contextualized and meaningful learning experiences. Ultimately, Humanistic STEM Education offers a holistic pathway for preparing learners who are scientifically literate, technologically capable, culturally grounded, ethically responsible, and able to contribute actively to sustainable communities and an increasingly interconnected global society.

REFERENCE

Abdiyah, L., & Subiyantoro, S. (2021). Penerapan teori konstruktivistik dalam pembelajaran tematik di sekolah dasar. In *ELSE (Elementary School Education Journal) : Jurnal Pendidikan dan Pembelajaran Sekolah Dasar* (Vol. 5, Issue 2, p. 127). Universitas Muhammadiyah Surabaya. https://doi.org/10.30651/else.v5i2.6951

Agisni, A., Novari, D., Leander, G., Prawirawan, B. U., & Pohan, A. H. (2023). The effectiveness of multimedia learning: A study on student learning. *Priviet Social Sciences Journal*, *3*(7), 9–11. https://doi.org/10.55942/pssj.v3i7.215

Ahmed, S. K., Mohammed, R. A., Nashwan, A. J., Ibrahim, R. H., Abdalla, A. Q., M. Ameen, B. M., & Khdhir, R. M. (2025). Using thematic analysis in qualitative research. *Journal of Medicine, Surgery, and Public Health*, *6*(April), 100198. https://doi.org/10.1016/j.glmedi.2025.100198

Amiruddin, M. Z. Bin, Nahadi, N., Anwar, S., Samsudin, A., Suhandi, A., & Aminudin, A. H. (2024). Ethnoscience: A Philosophical Study with Anthropological, Ontological and Axiological Perspectives. *Vidya Karya*, *39*(1), 12. https://doi.org/10.20527/jvk.v39i1.17912

Aprilia, V., Sartika, S. B., & Salim, A. (2025). Contextual Teaching and Learning Based on Ethnoscience in Natural and Social Sciences. *Indonesian Journal of Education Methods Development*, *20*(4), 1–12. https://doi.org/10.21070/ijemd.v20i4.901

Atmojo, Anggriani, Rahmawati, Skotnicka, Wardana, & Anindya. (2025). Bridging stem and culture: the role of ethnoscience in developing critical thinking and cultural literacy. *Jurnal Pendidikan IPA Indonesia*, *14*(2), 251–266. https://doi.org/10.15294/jpii.v14i2.23505

Atmojo, S., Lukitoaji, B., Rahmawati, R., Anggriani, M., & Putri Anindya, A. (2025). Effects of Hybrid STEM Learning on 21st-Century Skills and Character Development in Prospective Elementary Teachers: A Mixed-Methods Study from Indonesia. *Qubahan Academic Journal*, *5*(2), 384–401. https://doi.org/10.48161/qaj.v5n2a1716

Caingcoy, M. (2023). Culturally Responsive Pedagogy. *Diversitas Journal*, *8*(4), 3203–3212. https://doi.org/10.48017/dj.v8i4.2780

Cardwell, K., Quigley, J., Clyne, B., Tyner, B., Carrigan, M., Smith, S., Ryan, M., & O'Neill, M. (2021). Processes for updating guidelines: protocol for a systematic review. *HRB Open Research*, *4*, 116. https://doi.org/10.12688/hrbopenres.13448.1

Chan, S. L., Fung, J. T. C., Wong, M. S., Cheng, C. C. W., Lee, J. J. J., Choi, H. R., Wan, W. H., Withrow, H., Sirirat, S. iad, Tse, W. H., Poon, R. P. W., Lam, C. F., Lam, H. C. Y., Chan, C. K., & Lin, C. C. (2025). Educational technology enhanced interprofessional E-learning for engaging cross-institutional and cross-border healthcare students: A mixed-methods study. *International Journal of Nursing Studies Advances*, *9*(August), 100404. https://doi.org/10.1016/j.ijnsa.2025.100404

Chasokela, D. (2024). Fostering Global Citizenship through ESD in Higher Education: A Study of International Student Mobility and Sustainability Awareness. *Journal of Education* *for Sustainable Development Studies*, *1*(2), 117–133. https://doi.org/10.70232/jesds.v1i2.7

Ee, L. S., Ibrahim, N. H., Surif, J., Abdullah, A. H., & Talib, C. A. (2025). Project-based environmental module for indigenous students in Malaysia. *International Journal of Evaluation and Research in Education*, *14*(3), 2042–2050. https://doi.org/10.11591/ijere.v14i3.32047

Eko Atmojo, S., Dwi Lukitoaji, B., Dyah Rahmawati, R., Dwi Anggriani, M., & Putri Anindya, A. (2025). Effects of Hybrid STEM Learning on 21st-Century Skills and Character Development in Prospective Elementary Teachers: A Mixed-Methods Study from Indonesia. *Qubahan Academic Journal*, *5*(2), 384–401. https://doi.org/10.48161/qaj.v5n2a1716

Groshans, G., Mikhailova, E., Post, C., Schlautman, M., Carbajales-Dale, P., & Payne, K. (2019). Digital story map learning for STEM disciplines. *Education Sciences*, *9*(2), 1–17. https://doi.org/10.3390/educsci9020075

Haryono, D., Subkhan, E., & Widhanarto, G. P. (2017). *21st Century Competencies and Its Implications on Educational Practices*. *118*, 606–610. https://doi.org/10.2991/icset-17.2017.100

Hasani, A., Juansah, D. E., Sari, I. J., & El Islami, R. A. Z. (2021). Conceptual frameworks on how to teach stem concepts in bahasa indonesia subject as integrated learning in grades 1–3 at elementary school in the curriculum 2013 to contribute to sustainability education. *Sustainability (Switzerland)*, *13*(1), 1–15. https://doi.org/10.3390/su13010173

Imad, M., Reder, M., & Rose, M. (2023). Recasting the agreements to re-humanize STEM education. *Frontiers in Education*, *8*(October), 1–21. https://doi.org/10.3389/feduc.2023.1193477

Isnaniah, Marlina, & Ningsih, R. P. (2025). The Effectiveness of an Interactive Augmented Reality E-Book Featuring Local Wisdom of Kalimantan Selatan on English Learning Outcomes; [La efectividad de un libro electrónico interactivo de realidad aumentada que presenta la sabiduría local de Kalimantan. *Salud, Ciencia y Tecnologia*, *5*. https://doi.org/10.56294/saludcyt20252214

Jackson, C., Mohr-Schroeder, M. J., Bush, S. B., Maiorca, C., Roberts, T., Yost, C., & Fowler, A. (2021). Equity-Oriented Conceptual Framework for K-12 STEM literacy. *International Journal of STEM Education*, *8*(1). https://doi.org/10.1186/s40594-021-00294-z

Kayumova, S., & Strom, K. J. (2023). Ontology, Epistemology, and Critical Theory in STEM Education. *Oxford Research Encyclopedia of Education*. https://doi.org/10.1093/acrefore/9780190264093.013.1508

Khery, Y., Sarjan, M., Ahzan, S., Efendi, I., Studi, P., Pendidikan, D., Mataram, U., Nomor, P., Barat, N. T., Studi, P., Kimia, P., Sains, F., Mandalika, P., Nomor, J. P., Barat, N. T., Mataram, U., Nomor, J. P., Barat, T., Studi, P., … Barat, N. T. (2022). *Konseptualisasi literasi sains mengacu pada kerangka sains pisa sejak tahun 2000 Programme for International Student Assessment (PISA) adalah survei tiga tahunan yang diselenggarakan oleh Organisation for Economic Co-operation and Development (OECD) t*. *2*(4), 200–231.

Kostikova, I., Holubnyacha, L., Besarab, T., Moshynska, O., Moroz, T., & Shamaieva, I. (2023). Interactive Mobile Technologies. *International Journal of Interactive Mobile Technologies*, *17*(15), 135–154.

Kumar, R. (2025). Bibliometric Analysis: Comprehensive Insights into Tools, Techniques, Applications, and Solutions for Research Excellence. *Spectrum of Engineering and Management Sciences*, *3*(1), 45–62. https://doi.org/10.31181/sems31202535k

maduddin, M. I., Nikmah, A., Salic-Hairullah, P. M., & Guarin, R. M. (2024). A bibliometric Analysis of the Scientific Production and Thematic Trends of Ethnopedagogy in STEM Education. *Pakistan Journal of Life and Social Sciences (PJLSS)*, *22*(1), 2668–2690. https://doi.org/10.57239/pjlss-2024-22.1.00199

Mahlianurrahman, Lasmawan, I. W., Candiasa, I. M., & Suastra, I. W. (2023a). The Effect of Nyerayo Based SETS Learning on Student’s Scientific Literacy. *Pegem Egitim ve Ogretim Dergisi*, *13*(2), 79–84. https://doi.org/10.47750/pegegog.13.02.10

Mahlianurrahman, Lasmawan, I. W., Candiasa, I. M., & Suastra, I. W. (2023b). The Effect of Nyerayo Based SETS Learning on Student’s Scientific Literacy. *Pegem Egitim ve Ogretim Dergisi*, *13*(2), 79–84. https://doi.org/10.47750/pegegog.13.02.10

Marcone, G. (2022). Humanities and Social Sciences in Relation to Sustainable Development Goals and STEM Education. *Sustainability (Switzerland)*, *14*(6). https://doi.org/10.3390/su14063279

Marosi, N., Avraamidou, L., & Galani, L. (2021). Culturally relevant pedagogies in science education as a response to global migration. *SN Social Sciences*, *1*(6), 1–20. https://doi.org/10.1007/s43545-021-00159-w

Maulidiyah, Y. N. (2017). Elementary education. *Routledge Library Editions: Education in Asia*, *10*(1), 221–225. https://doi.org/10.1177/002248715800900418

Mayer, R. E. (2024). The Past, Present, and Future of the Cognitive Theory of Multimedia Learning. *Educational Psychology Review*, *36*(1), 1–25. https://doi.org/10.1007/s10648-023-09842-1

Meadows, J., Baker, J., & Wendt, S. (2020). Fab Fridays: Fostering Elementary Teacher Candidate Preparation Through Informal STEM Events. In *Journal of STEM Teacher Education* (Vol. 54, Issue 1). Milner Library - Illinois State University. https://doi.org/10.30707/jste54.1/wnsh4279

Nair, D. S. (2025). Improving critical thinking of teacher–trainees through a strength-based program: a positive psychology approach. *Journal of Research in Innovative Teaching and Learning*. https://doi.org/10.1108/JRIT-02-2025-0041

Nakidien, T., Singh, M., & Sayed, Y. (2021). Teachers and Teacher Education: Limitations and Possibilities of Attaining SDG 4 in South Africa. In *Education Sciences* (Vol. 11, Issue 2, p. 66). MDPI AG. https://doi.org/10.3390/educsci11020066

Noraffandy Yahaya & Nur Fazila i Salleh. (2020). *No 主観的健康感を中心とした在宅高齢者における 健康関連指標に関する共分散構造分析Title*. *21*(1), 1–9.

Patras, Y. E., Japar, M., Rahmawati, Y., & Hidayat, R. (2025). Integration of Culturally Responsive Teaching Approach, Local Wisdom, and Gamification in Pancasila Education to Develop Students' Multicultural Competence. *Educational Process: International Journal*, *14*. https://doi.org/10.22521/edupij.2025.14.45

Poojar, B., Ommurugan, B., Adiga, S., Thomas, H., Sori, R. K., Poojar, B., Hodlur, N., Tilak, A., Korde, R., Gandigawad, P., In, M., Sleep, R., Albino, D., Rats, W., Article, O., Schedule, P., Injury, C. C., Sori, R. K., Poojar, B., … Gandigawad, P. (2017). Methodology Used in the Study. *Asian Journal of Pharmaceutical and Clinical Research*, *7*(10), 1–5. https://doi.org/10.4103/jpbs.JPBS

Prayogi, S., Ahzan, S., Indriaturrahmi, Rokhmat, J., & Verawati, N. N. S. P. (2023). Dynamic blend of ethnoscience and inquiry in a digital learning platform (e-learning) for empowering future science educators' critical thinking. *Journal of Education and E-Learning Research*, *10*(4), 819–828. https://doi.org/10.20448/jeelr.v10i4.5233

Purnama, H. I., Wilujeng, I., & Jabar, C. S. A. (2023). Web-based E-learning in Elementary School: A Systematic Literature Review. *International Journal on Informatics Visualization*, *7*(3), 749–759. https://doi.org/10.30630/joiv.7.3.1203

Putri, D. K., Zahro, N., Widodo, W., & Suprapto, N. (2025). Primary teachers' perceptions of deep learning pedagogy in culture-integrated STEM education: A quantitative survey. *Journal on Mathematics Education*, *16*(4), 1331–1346. https://doi.org/10.22342/jme.v16i4.pp1331-1346

Qingna, J. (2021). Supporting Indigenous Students in Science and STEM Education: A Systematic Review. *Education Sciences*, *11*(9), 555–555.

Simbolon, M., Pongkendek, J. J., Henukh, A., & Ronchintaniawati, D. (2025). AI-Driven Sociocultural Interactive Digital Module for Papua: Advancing Educational Technology to Sustainable Development Goals. *International Journal of Learning, Teaching and Educational Research*, *24*(2), 543–559. https://doi.org/10.26803/ijlter.24.2.27

Southerland, S. A., & Settlage, J. (2022). Humanistic science education: Updating our collective consciousness and offering fresh consideration. *Science Education*, *106*(3), 479–481. https://doi.org/10.1002/sce.21715

Sudirman, S., Sutikno, S., Indriyanti, D. R., Sumarni, W., & Rahayuningsi, M. (2025). Integration of Ethnoscience in Natural Science learning: Literacy Study. *Jurnal Penelitian Pendidikan IPA*, *11*(6), 68–77. https://doi.org/10.29303/jppipa.v11i6.9980

Suryanti, S., Nursalim, M., Choirunnisa, N. L., & Yuliana, I. (2024). STEAM-Project-Based Learning: A Catalyst for Elementary School Students' Scientific Literacy Skills. *European Journal of Educational Research*, *13*(1), 1–14. https://doi.org/10.12973/eu-jer.13.1.1

Susanta, A., Susanto, E., Rusnilawati, Sumardi, H., & Ali, S. R. B. (2025). Literacy skills through the use of digital STEAM-inquiry learning modules: A comparative study of urban and rural elementary schools in Indonesia. *Eurasia*

Journal of Mathematics, Science and Technology Education, *21*(4), 1–18. https://doi.org/10.29333/ejmste/16170

Syahrir, S., Pujiriyanto, P., As, M., Nur, F. A. M., & Fitri, S. (2024a). Primary School STEM Education Innovation through ICT Integration for Teacher Competency Development: A Systematic Literature Review. *Jurnal Pendidikan Dan Kebudayaan*, *9*(1), 47–61. https://doi.org/10.24832/jpnk.v9i1.4896

Syahrir, S., Pujiriyanto, P., As, M., Nur, F. A. M., & Fitri, S. (2024b). Primary School STEM Education Innovation through ICT Integration for Teacher Competency Development: A Systematic Literature Review. In *Jurnal Pendidikan dan Kebudayaan* (Vol. 9, Issue 1, pp. 47–61). Badan Standar, Kurikulum, dan Asesmen Pendidikan. https://doi.org/10.24832/jpnk.v9i1.4896

Taber, K. S. (2025). *https://science-education-research.com This is the author's manuscript copy. The version of record is: Taber, K. S. (2025). Mediated learning leading development – the social development theory of Lev Vygotsky. In B. Akpan & T. Kennedy (Eds.),*. 275–292.

Tenney, K., Stringer, B. P., LaTona-Tequida, T., & White, I. (2023). Conceptualizations and Limitations of STEM Literacy across Learning Theories. *Journal of Microbiology & Biology Education*, *24*(1), 1–5. https://doi.org/10.1128/jmbe.00168-22

Willie, M. M., & Africa, S. (n.d.). *A Critical Appraisal of Study Selection and Results Reporting in PRISMA-Based Systematic Reviews*. 1–11.

Yanarateş, E. (2024). The Effects of Digital Literacy Skills on Preschool Science Education. In *Transforming Early Childhood Education: Technology, Sustainability, and Foundational Skills for the 21st Century*. Özgür Yayınları. https://doi.org/10.58830/ozgur.pub534.c2200

Zawacki-Richter, O., Cefa, B., & Bai, J. Y. H. (2025). Towards reproducible systematic reviews in Open, Distance, and Digital Education—An umbrella mapping review. *Review of Education*, *13*(1), 1–32. https://doi.org/10.1002/rev3.70031