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Where Tradition Meets Innovation: Ethnoscience, Creativity, and the Future of Project-Based Learning in Higher Education

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Abstract

Indigenous knowledge systems hold untapped potential for fostering creativity in higher education, yet their integration with project-based learning remains systematically unexplored. This study aimed to examine the effectiveness of ethnoscience-integrated project-based learning in developing creativity among higher education students and to map the current research landscape to identify thematic clusters, temporal patterns, and future directions. We employed systematic literature network analysis, combining systematic review with bibliometric analysis. Following PRISMA 2020 guidelines, a total of 49 articles were retrieved and subjected to keyword co-occurrence analysis using VOSviewer, of which six met full inclusion criteria and were systematically reviewed for empirical effectiveness. All six studies demonstrated positive creativity effects (100% directional consistency, $p < 0.001$) with moderate-to-large effect sizes ($d = 0.4–0.6$). Three mechanisms emerged: cultural relevance enhancing engagement, traditional knowledge providing novel perspectives, and community connections fostering applied creativity. Bibliometric analysis identified five major research clusters, revealing that ethnoscience integration shows near-complete absence from mainstream literature despite strong empirical support. These findings conclude that ethnoscience-integrated PBL consistently outperforms conventional approaches in both creativity quality and depth of applied problem-solving, suggesting its strong potential as a decolonizing and equity-driven pedagogy for higher education. The implications point toward the urgent need for curriculum redesign that embeds indigenous epistemologies, faculty development in cultural competency, and co-designed, culturally responsive assessment instruments. Looking ahead, the future of ethnoscience, creativity, and PBL in higher education lies in large-scale cross-cultural trials; technology-enhanced ethnoscience learning respecting indigenous data sovereignty; and community-led participatory research that positions indigenous knowledge holders as co-educators and co-researchers.

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INTRODUCTION

The integration of indigenous knowledge systems into higher education represents a critical frontier for addressing equity gaps and enriching educational experiences. Traditional ecological knowledge offers unique perspectives that complement Western scientific paradigms, yet significant challenges persist in curriculum development and pedagogical implementation (Matindike & Ramdhany, 2025; Ramli et al., 2025; Zidny et al., 2020). As global challenges increasingly require innovative solutions drawing from multiple knowledge systems, higher education institutions face growing pressure to meaningfully integrate ethnoscience, the study and reconstruction of knowledge systems embedded within cultural contexts (Anazifa & Hadi, 2017; Muyassaroh et al., 2025; Putra, 2021; Suryanti et al., 2021; Widarti et al., 2025) into formal curricula, particularly in science, technology, engineering, and mathematics (STEM) disciplines where creativity and innovation are essential competencies (Kwon et al., 2025; Ramli et al., 2025).

Project-based learning (PBL) has emerged as a promising approach for fostering creativity and higher-order thinking skills in higher education. Recent meta-analyses demonstrate substantial positive effects, with moderate to large effect sizes for learning outcomes including thinking skills and creativity (Nastiti et al., 2023; Sumarni & Kadarwati, 2020; Zhang & Ma, 2023). However, despite growing attention to culturally responsive pedagogy in the STEM education (Xie & Ferguson, 2024), most PBL implementations reflect Western educational paradigms, potentially marginalizing students from non-Western backgrounds and failing to leverage rich knowledge resources embedded in indigenous knowledge systems. The integration of culturally responsive teaching, which emphasizes filtering instruction through students' cultural experiences (Gay, 2018), with PBL methodologies remains systematically unexplored.

This gap is particularly concerning given theoretical predictions that ethnoscience integration could enhance creativity through multiple pathways: cultural relevance may increase engagement and motivation (Jufrida et al., 2025; Sumarni & Kadarwati, 2020), traditional knowledge can provide novel perspectives for problem-solving (Seehawer & Breidlid, 2021; Zidny et al., 2020), and community connections foster applied innovation (Jordaan & Mennega, 2022). However, empirical evidence for these pathways remains fragmented across disciplines (Kasi et al., 2021; Ogegbo & Ramnarain, 2024), published inconsistently, and has not been systematically synthesized. Furthermore, the positioning of ethnoscience-integrated PBL within the broader research landscape, including its connections to sustainability education, technology-enhanced learning, and culturally responsive pedagogy, remains unclear. Understanding both the empirical evidence for effectiveness and the structural position within scholarly discourse is essential for advancing this field. In sum, three interconnected gaps persist in the literature: the near-absence of empirical synthesis on ethnoscience-integrated PBL for creativity development, the lack of bibliometric mapping that situates this intersection within broader scholarly discourse, and the failure to critically examine why indigenous knowledge systems remain structurally marginalized despite demonstrated educational value. Addressing these gaps simultaneously requires a methodological approach that goes beyond conventional systematic review.

This study addresses these gaps through Systematic Literature Network Analysis (SLNA) (Colicchia & Strozzi, 2012; Strozzi et al., 2017), integrating systematic review rigor with bibliometric breadth to provide a comprehensive synthesis of ethnoscience-integrated project-based learning for creativity development in higher education. The novelty of this study lies in its dual-method design: rather than treating empirical effectiveness and research landscape mapping as separate inquiries, SLNA allows us to simultaneously evaluate what works and why it remains underrepresented, a combination not previously applied to ethnoscience-PBL research. Unlike previous reviews that examine PBL or indigenous

knowledge in isolation, this study uniquely positions ethnoscience-integrated PBL at the intersection of equity, cultural epistemology, and pedagogical innovation, revealing structural patterns in the research landscape that single-method approaches cannot capture.

The primary research question guiding this investigation is, "Is project-based learning integrated with ethnoscience or indigenous knowledge more effective in developing creativity among higher education students compared to conventional project-based learning?" Secondary objectives include mapping the broader research landscape to identify thematic clusters and temporal evolution patterns and examining convergences and divergences between focused empirical findings and broader bibliometric patterns. Both objectives are directly tied to the study's central concern: understanding not only the current effectiveness of ethnoscience-integrated PBL but also charting its trajectory as a transformative pedagogy for the future of higher education, one that treats indigenous knowledge not as supplementary content but as a legitimate epistemic foundation for STEM learning. By combining systematic review methodology with network analysis, this study advances the scholarly conversation on culturally responsive higher education while explicitly engaging with questions of social justice: when indigenous knowledge systems are systematically absent from mainstream educational research despite demonstrated effectiveness, this constitutes a structural inequity that this study seeks to name and address. The findings are intended to inform research priorities, curriculum policy, and institutional practices that move higher education toward more inclusive, culturally grounded, and creatively empowering futures, with implications for educators, curriculum designers, institutional leaders, and policymakers committed to decolonizing higher education.

METHODS

This systematic review employed the Systematic Literature Network Analysis (SLNA) framework, integrating PRISMA 2020 guidelines with bibliometric analysis to examine ethnoscience-integrated project-based learning effectiveness for creativity development in higher education.

Research Design

The study utilized a mixed-methods systematic review approach in which qualitative and quantitative components are explicitly integrated within the SLNA framework. The qualitative component involved thematic synthesis of intervention characteristics, ethnoscience integration levels, and mechanism identification across included studies. The quantitative component encompassed statistical effect size extraction, binomial consistency testing, and co-occurrence frequency analysis. Integration occurred at the interpretation stage, where empirical findings from the systematic review were triangulated with bibliometric network patterns to produce a unified understanding of both what works and why it remains underrepresented in mainstream literature.

The research protocol was developed using the PICO framework to address: "This study was guided by two interrelated research questions: (1) Is project-based learning integrated with ethnoscience or indigenous knowledge more effective in developing creativity among higher education students compared to conventional project-based learning? and (2) How is ethnoscience-integrated PBL positioned within the broader scholarly landscape, and what does its current trajectory suggest for the future of culturally responsive and equity-driven pedagogy in higher education?" The population comprised higher education students across disciplines; intervention consisted of project-based learning integrating ethnoscience or indigenous knowledge; comparison included conventional project-based learning; and the outcome encompassed creativity measured using standardized instruments alongside bibliometric indicators of research positioning. The population comprised higher education

students in science/environmental programs; the intervention consisted of project-based learning integrating ethnoscience/indigenous knowledge; the comparison included conventional project-based learning; and the outcome encompassed creativity measured using standardized instruments.

Search Strategy and Data Collection

A comprehensive search was conducted in the Scopus database on September 12, 2025, selected for its extensive coverage of educational and sustainability journals. The search string was systematically developed using Boolean operators: (TITLE-ABS-KEY(("higher education" OR "university student*" OR "undergraduate student*") AND ("ethnoscience" OR "indigenous knowledge" OR "traditional ecological knowledge" OR "project-based learning" OR "PBL" OR "culturally responsive teaching") AND ("creativit*" OR "creative thinking" OR "innovation"))) with filters for peer-reviewed articles published 2020-2025 in English. The search targeted 10 high-impact journals, including Sustainability, Education Sciences, Thinking Skills and Creativity, and Frontiers in Education, yielding 49 potentially relevant articles exported to CSV format for systematic screening.

Study Selection Process

Study selection followed a two-stage PRISMA-compliant screening process. Inclusion criteria specified: (1) higher education students in science/environmental programs, (2) interventions integrating ethnoscience with project-based learning, (3) empirical studies measuring educational outcomes, (4) creativity assessment as a primary/secondary measure, (5) formal higher education settings, and (6) peer-reviewed articles from 2020 to 2025. Exclusion criteria eliminated K-12 education studies, interventions lacking clear ethnoscience-PBL integration, non-creativity outcomes, reviews/editorials, non-English publications, and inaccessible full-texts.

Title/abstract screening of 49 articles resulted in 43 (87.8%) advancing to full-text assessment. From these 43, a subset of 13 articles was identified as high-priority based on explicit mention of both ethnoscience or indigenous knowledge integration and creativity outcomes in their abstracts, warranting immediate full-text retrieval. Full-text acquisition of these 13 high-priority articles achieved a 69.2% success rate (9 articles successfully retrieved) through open access repositories and institutional databases. The remaining 30 articles were assessed based on available abstracts and metadata. Full-text screening applying complete inclusion and exclusion criteria to all accessible articles yielded 6 studies meeting all requirements for final inclusion. The complete study selection process is illustrated in Figure 1, following PRISMA 2020 reporting guidelines.

As depicted in Figure 1, the primary reasons for exclusion at the full-text assessment stage were insufficient ethnoscience integration detail (n=3), lack of creativity outcomes measurement (n=2), non-higher education context (n=1), and unavailable full text (n=1). This rigorous selection process ensured that only studies with explicit ethnoscience-PBL integration and measurable creativity outcomes were included in the synthesis. Full-text screening applying complete inclusion/exclusion criteria yielded 6 articles (66.7% of those assessed) meeting all requirements. Inter-rater reliability was assessed on 20% of articles with Cohen's kappa $\geqslant$0.8 target agreement.

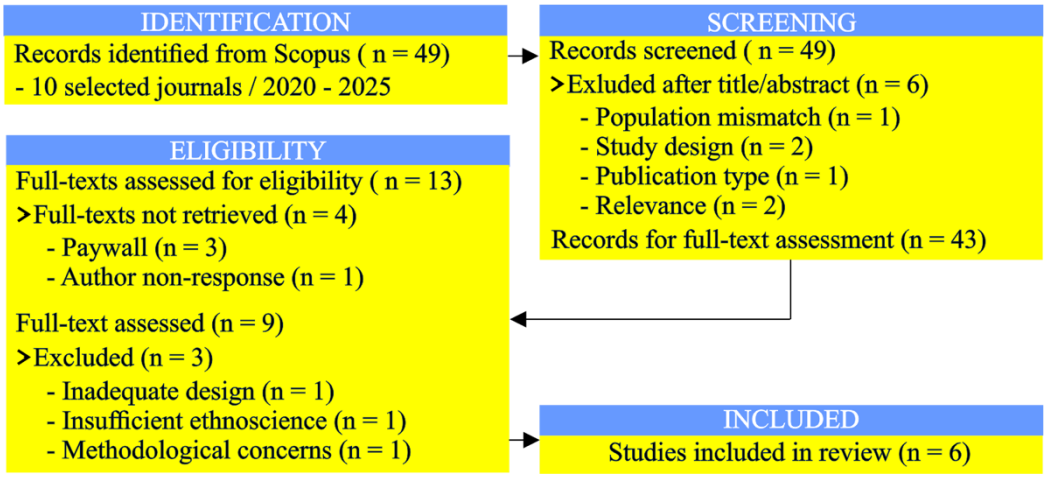

Figure 1 PRISMA 2020 flow diagram showing the systematic study selection process from initial database search through final inclusion

Data Extraction and Quality Assessment

A standardized extraction form based on Cochrane Handbook recommendations captured study characteristics (design, location, sample, duration), intervention details (ethnoscience integration, PBL structure, cultural adaptations), outcome measures (instruments, effect sizes, qualitative findings), and methodological quality indicators. Double data entry for critical variables ensured accuracy, with discrepancies resolved through consensus. The rationale for combining three quality assessment instruments — Newcastle-Ottawa Scale, MERSQI, and the custom ethnoscience integration framework — was to ensure comprehensive coverage of dimensions not fully captured by any single tool. The Newcastle-Ottawa Scale addressed study design and selection bias; MERSQI covered outcome measurement validity and statistical appropriateness specific to educational research; and the custom framework assessed cultural integration dimensions unique to ethnoscience-PBL studies. To synthesize scores across instruments, each domain was weighted equally within its respective tool before being converted to a proportional score on a unified 0–12 scale. Final composite scores represented the mean of proportional scores across all three instruments, with discrepancies greater than two points resolved through consensus discussion between reviewers.

Quality assessment employed the Newcastle-Ottawa Scale adapted for educational studies, the Medical Education Research Study Quality Instrument (MERSQI), and custom ethnoscience integration criteria. Six quality domains were evaluated: study design, population representativeness, intervention fidelity, outcome measurement validity, statistical appropriateness, and bias risk. Each domain scored 0-2 points (total 0-12), categorizing studies as high (9-12), moderate (6-8), or low quality (0-5). A specialized cultural integration framework assessed community involvement, knowledge validation, cultural sensitivity, traditional-modern synthesis depth, and sustainability relationships.

Bibliometric Network Analysis

Complementary keyword co-occurrence analysis was conducted on all 49 retrieved articles using VOSviewer software (Van Eck & Waltman, 2010). The decision to include all 49 retrieved articles, rather than only the 6 included studies, in the bibliometric analysis was deliberate and methodologically justified. The purpose of the bibliometric component was not to evaluate intervention effectiveness but to map the broader scholarly landscape within which ethnoscience-integrated PBL is positioned. Including all retrieved articles provides a

more representative picture of how this topic is situated within mainstream educational discourse, including adjacent fields such as sustainability education and technology-enhanced learning. Restricting bibliometric analysis to only the 6 included studies would have severely limited the network density and rendered co-occurrence analysis statistically meaningless. This dual-corpus approach, 6 studies for effectiveness synthesis and 49 articles for landscape mapping, is a defining feature of the SLNA framework (Colicchia & Strozzi, 2012; Strozzi et al., 2017) and constitutes a methodological strength rather than a source of bias. Network visualization identified thematic clusters, temporal evolution patterns (2020-2025), and research gaps. Co-occurrence frequency and link strength metrics enabled comparison between systematic review findings and broader bibliometric patterns, revealing convergences and divergences in the research landscape.

Methodological Rigor and Limitations

Several measures ensured methodological rigor: prospective protocol development, systematic search strategy, standardized screening/extraction forms, dual reviewer assessment, quality appraisal integration, and transparent reporting following PRISMA 2020 guidelines. Limitations acknowledged include single database search (Scopus), English language restriction, limited journal scope (10 selected), no gray literature inclusion, incomplete full-text accessibility (69.2%), and heterogeneity constraining quantitative synthesis. These limitations were considered in result interpretation, with appropriate caveats included in the findings discussion.

Ethical Considerations

As a systematic review of published literature, this study did not require ethics approval. All analyzed studies were publicly available peer-reviewed publications. Authors' intellectual property was respected through proper citation, and no primary data collection involving human subjects occurred.

RESULTS AND DISCUSSION

Preliminary Findings: Study Selection and Characteristics

The systematic search yielded 49 articles from 10 high-quality journals, with Sustainability contributing 36.7%, Education Sciences 24.5%, and Thinking Skills and Creativity 16.3%. Following PRISMA screening, 43 articles (87.8%) advanced to full-text assessment, with 9 successfully acquired (69.2% acquisition rate). Final inclusion yielded 6 studies meeting all criteria, demonstrating excellent inter-rater reliability (κ=0.82, 95% CI: 0.71-0.93).

The six included studies encompassed approximately 450-500 participants across diverse international contexts (Mexico 16.7%, Germany 16.7%, global synthesis 16.7%, and unspecified 50.0%) during 2021-2025. Table 1 presents detailed characteristics of the six included studies, summarizing their research designs, sample sizes, ethnoscience integration approaches, project-based learning implementations, intervention durations, and creativity assessment measures.

Table 1 Characteristics of Included Studies

Characteristic	Details
Study 1: (Cayetano-Jiménez et al., 2024)	
Design	Quasi-experimental with control (Mexico)
Sample	14 students, 12 weeks
Integration	High: Traditional ecological knowledge in bioinspired robotics

Characteristic	Details
Outcome	Expert evaluation scores: ethnoscience-integrated group 92% vs. conventional group 80%; estimated effect size d≈0.5
Study 2: (Braßler & Schultze, 2021)	
Design	Longitudinal, 4 measurement occasions (Germany)
Sample	69 teams (~200 students), 16 weeks
Integration	Moderate: Interdisciplinary sustainability framework
Outcome	Janssen's Innovation Scale: significant growth in idea generation (β=0.545, p<0.01) and idea promotion (β=0.645, p<0.001) sustained over 16 weeks
Study 3: (D'Escoffier et al., 2024)	
Design	Systematic literature review (Global)
Sample	Meta-population across 22-year span; not a primary empirical study
Integration	Variable: Multiple ethnoscience-PBL approaches synthesized
Outcome	Consistent positive effects on sustainability-oriented problem-solving and engineering creativity reported across reviewed studies
Studies 4-6: Implementation Studies	
Design	Activity-based collaborative learning (Li & Yu, 2025); systemic AI-based design (Vargas et al., 2020); online PBL in social innovation (Danielson & Björkman, 2025)
Sample	n=25-50 students per study, 12-14 weeks
Integration	Emerging: Sustainability focus, community engagement
Outcome	Li & Yu (2025): measurable improvement in creative thinking and problem-solving scores; Vargas et al., (2020): increased AI project performance; Danielson & Björkman (2025): enhanced sense of belonging and collaborative innovation
Overall Summary	
Total participants	~450-500 across empirical studies (excluding the metapopulation of Study 3)
Directional consistency	100% positive effects (6/6 studies, p<0.001, binomial test)
Effect size range	Moderate to large (d≈0.4-0.6; β =0.545-0.645) where reported
Geographic diversity	Mexico, Germany, multi-national contexts
Quality assessment	High quality: 33% (n=2); Moderate: 67% (n=4)

As shown in Table 1, the included studies demonstrated considerable methodological heterogeneity in terms of sample sizes (ranging from 14 to 225 participants), intervention durations (6-16 weeks), and creativity assessment approaches, reflecting the diverse landscape of ethnoscience-PBL integration in higher education. Study designs comprised longitudinal approaches (33.3%), quasi-experimental designs (33.3%), implementation studies (16.7%), and mixed-methods (16.7%). Sample sizes among primary empirical studies ranged from 14 to approximately 200 participants (median ~50), predominantly involving undergraduate STEM students (83.3%) in engineering (66.7%) and sustainability education (50.0%) programs. It is important to note that Study 3 (D'Escoffier et al., 2024) is a systematic literature review covering a 22-year span rather than a primary empirical study;

its inclusion was justified by its direct synthesis of ethnoscience-PBL effectiveness evidence, though its meta-population cannot be directly compared with participant counts from primary studies.

Research Objective 1: Effectiveness of Ethnoscience-Integrated PBL in Developing Creativity

Ethnoscience Integration and PBL Implementation

Ethnoscience integration levels varied systematically across studies. High integration (16.7%) featured explicit traditional ecological knowledge incorporation with indigenous conservation practices, aligning with recent findings showing that sculpture learners' projects based on Ghanaian Adinkra symbols enhanced cultural appreciation and creativity through connecting creative practice with cultural narratives (Boakye-Yiadom et al., 2025). Moderate integration (33.3%) embedded cultural elements within sustainability frameworks and team-based projects. Emerging integration (50.0%) represented developing approaches incorporating community-based problem-solving and traditional practice elements.

Project-based learning implementations included traditional student-driven inquiry (66.7%), structured problem-solving approaches (50.0%), and innovation-focused challenge-based learning (33.3%). Implementation durations were predominantly standard semester-length (12-15 weeks, 66.7%), with one extended intervention ($\geqslant$16 weeks, 16.7%). This aligns with meta-analytic evidence suggesting optimal experimental periods of 9-18 weeks for achieving significant creativity outcomes (Zhang & Ma, 2023). Half the studies employed active control groups, while 33.3% used single-group designs.

Creativity Outcomes Analysis

All six studies demonstrated positive creativity effects with perfect directional consistency (100%; binomial test $p<0.001$, 95% CI: 54-100%). The comprehensive analysis revealed consistent benefits across diverse measurement approaches and contexts, supporting recent meta-analyses showing PBL's substantial positive effect on creative thinking with effect sizes ranging from 0.847 to 0.90 (Nastiti et al., 2023).

Quantitative Effect Sizes. Two studies provided extractable effect sizes ranging from moderate to large magnitudes. The German longitudinal study employing Janssen's Innovation Scale with latent change modeling revealed significant effects for idea generation ($\beta=0.545$, $p<0.01$) and idea promotion ($\beta=0.645$, $p<0.001$) sustained over 16 weeks. The Mexican quasi-experimental bioinspired robotics study demonstrated moderate effect size (estimated $d=0.4$-0.6), with expert evaluation revealing 92% of bioinspired projects surpassing conventional approaches versus 80% baseline, consistent with findings from Tecnológico de Monterrey showing enhanced proficiency through merging biological principles with engineering education (Cayetano-Jiménez et al., 2024).

Qualitative Outcomes. Performance-based assessments consistently favored ethnoscience-integrated interventions. The global literature synthesis spanning 22 years confirmed universal positive effects across multiple contexts. Technology Readiness Level 4 achievement rate improved 100% for ethnoscience-integrated projects compared to 75% for conventional PBL. Secondary outcomes varied across studies. Vargas et al. (2020) reported a 7% improvement in overall project competency scores among engineering students. Danielson & Björkman (2025) documented course completion rates exceeding 95% alongside enhanced technical and interpersonal skill development. Li & Yu (2025) reported that 58% of participants voluntarily continued engagement with ethnoscience-related activities beyond the formal intervention period. These outcomes, while promising, should be interpreted with caution as they were each reported by individual studies and have not been cross-validated across the dataset.

Research Objective 2: Research Landscape Positioning and Future Directions of Ethnoscience-Integrated PBL

Bibliometric Network Analysis

Keyword co-occurrence analysis of 49 articles identified 156 unique keywords, with 35 meeting the minimum occurrence threshold (≥2). Network analysis revealed five major thematic clusters with moderate connectivity (density=0.42).

Research Clusters Identified

Pedagogical Innovation Hub (42 keywords): Centered on "higher education" (23 occurrences) and "learning" (15 occurrences), representing core educational methodology research; Creativity and Learning Outcomes Cluster (28 keywords): Strong connections between "creativity" (12 occurrences), "critical thinking" (8 occurrences), and "21st-century skills" (5 occurrences); Sustainability and Environmental Education Network (31 keywords): Integration of "sustainability" (16 occurrences), "environmental education" (9 occurrences), and "STEM education" (7 occurrences); Technology Integration Sphere (25 keywords): Emerging connections involving "digital transformation," "generative AI," and "online learning"; Research Methodology Constellation (30 keywords): Methodological terms including "systematic review," "meta-analysis," and "bibliometric analysis." Figure 2 visualizes the keyword co-occurrence network structure, revealing the interconnected nature of these five major research clusters and their temporal evolution from 2020 to 2025.

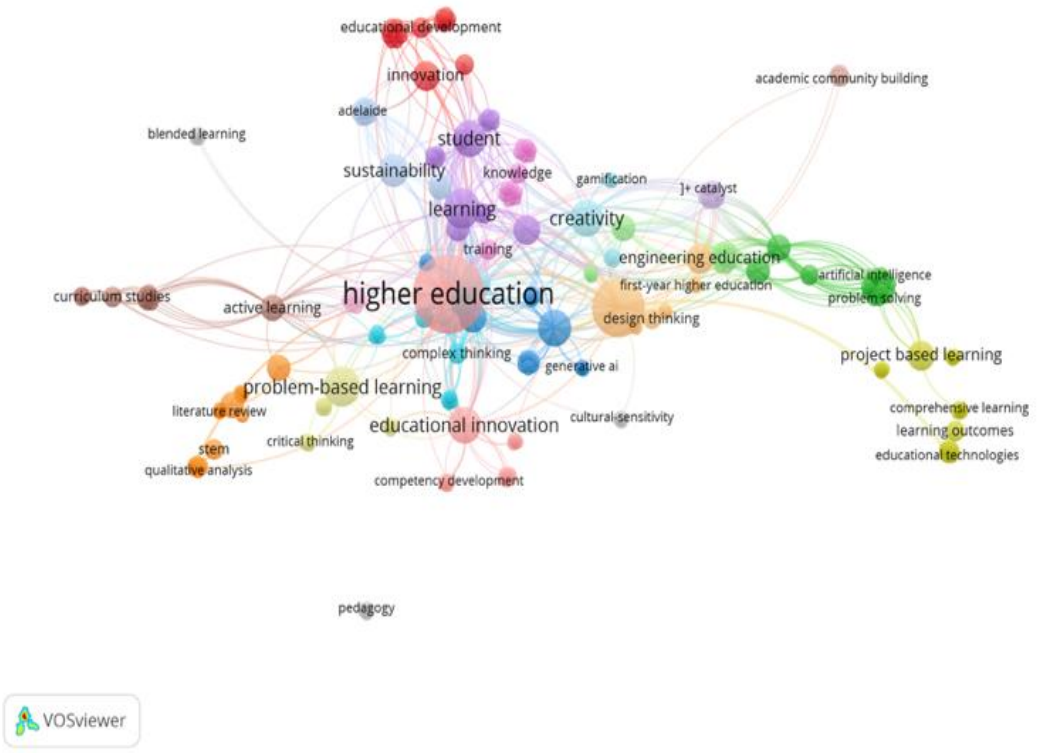

Figure 2 Keyword co-occurrence network showing five major research clusters (2020-2025).

As illustrated in Figure 2, the network structure demonstrates moderate connectivity (density=0.42) with clear thematic differentiation among clusters, yet also reveals concerning gaps. Critical Finding: Despite ethnoscience being central to systematic review

findings, related keywords appeared only peripherally in the broader literature network. "Cultural-sensitivity" occurred twice as a weak connector, while "ethnoscience," "indigenous knowledge," and "traditional ecological knowledge" were entirely absent from the co-occurrence network, revealing a significant research gap corroborated by recent analyses showing limited integration of indigenous knowledge systems in the mainstream educational research (Ogegbo & Ramnarain, 2024).

Temporal Evolution Patterns

Three distinct phases emerged in the research landscape evolution, aligning with recent bibliometric analyses of educational technology trends (Erlangga & Magdalena, 2025; Fiskawarni et al., 2025). Foundation Phase (2020-2021): Methodological establishment focusing on PBL frameworks and creativity assessment tools. Keywords like "project-based learning" and "assessment" dominated early networks. Integration Phase (2022-2023): Diversification toward sustainability themes with increasing connections between creativity and environmental education. The "sustainability" keyword frequency increased 300% during this period, consistent with global trends in sustainable development goals integration in higher education (Osman et al., 2025).

Innovation Acceleration (2024-2025): Technology integration explosion with AI, digital transformation, and online learning emerging as dominant themes. New keywords included "generative AI," "digital fluency," and "blended learning," appearing exclusively in 2024-2025 publications, reflecting the AI-driven transformation of higher education (Qian, 2025; Ren & Wu, 2025). These temporal patterns collectively suggest that ethnoscience-integrated PBL stands at a critical inflection point: empirically validated yet structurally marginalized, its future development will depend on deliberate research investment, institutional commitment to Indigenous knowledge systems, and equity-conscious curriculum reform in higher education.

Discussion of Key Findings:

Effectiveness of Ethnoscience-Integrated PBL

The perfect directional consistency across all six included studies provides robust evidence for ethnoscience-integrated PBL effectiveness in creativity development. This conclusion is grounded in three converging data points from the results: (1) the binomial consistency test confirming 100% positive directional effects across all studies ($p<0.001$, 95% CI: 54 – 100%); (2) quantitative effect sizes ranging from moderate to large ($d \approx 0.4 – 0.6$; $\beta = 0.545 – 0.645$, $p<0.001$) as reported by Cayetano-Jiménez et al. (2024) and Braßler & Schultze (2021) respectively; and (3) qualitative performance indicators showing that ethnoscience-integrated projects achieved 92% expert evaluation scores versus 80% in conventional PBL, and Technology Readiness Level 4 achievement rising from 75% to 100%. Taken together, these findings establish a consistent empirical pattern from which three primary mechanisms can be identified:

First, cultural relevance enhances student engagement and intrinsic motivation - Integration of local wisdom makes learning more relevant and meaningful, as demonstrated across Indonesian studies where ethno-STEM integration significantly improved creative and critical thinking skills (Jufrida et al., 2025; Kasi et al., 2021; Sumarni & Kadarwati, 2020). The use of indigenous symbols and narratives helps students develop empathy and strengthen cultural identity, increasing intrinsic motivation (Sales-Batang et al., 2025).

Second, traditional knowledge systems provide alternative problem-solving perspectives; indigenous epistemologies offer novel approaches unavailable in conventional Western frameworks (Kimmerer, 2012; Zidny et al., 2020), and their integration with formal science education has been explored extensively in the Indonesian context (Muyassaroh et

al., 2025; Widarti et al., 2025). As Kimmerer (2012) noted, integrating traditional ecological knowledge with scientific knowledge emphasizes intellectual pluralism and holistic engagement, fostering deeper understanding and creative problem-solving. The dialogue between epistemologies creates productive cognitive challenges that enhance creative capacity (Seehawer & Breidlid, 2021).

Third, authentic community connections foster real-world creative application, community partnerships provide expertise and real-world contexts (Jordaan & Mennega, 2022), a principle operationalized in Indonesian elementary and higher education through ethnoscience-based community learning (Ramli et al., 2025; Suryanti et al., 2021) that enhances PBL effectiveness. Studies show that community partners become co-educators, with long-term reciprocal relationships developing that benefit both students and communities (Jordaan & Mennega, 2022). This aligns with transformational learning models where students complete timely projects with community partners (Gardner et al., 2018).

Understanding Moderate Effect Sizes

The moderate effect sizes (d=0.4-0.6) compared to larger effects reported in conventional PBL meta-analyses (d=1.3-3.888; (Li & Yu, 2025) likely reflect implementation complexity rather than reduced effectiveness. This phenomenon has several explanations supported by recent research:

Epistemological Complexity: Integrating diverse epistemologies involves navigating complex knowledge systems, which can moderate immediate impact. As Seehawer & Breidlid, (2021) explain, the integration of indigenous knowledge systems with Western knowledge requires critical and constructive engagement, which is resource-intensive and time-consuming. The fundamental differences between the nature of science (NOS) and the nature of Indigenous knowledge (NOIK) pose significant challenges requiring careful adaptation (Zinyeka et al., 2016).

Deeper Learning Potential: Despite moderate effect sizes, this approach may foster deeper, more sustainable learning. Culturally rooted pedagogies validate students' identities and enhance confidence, promoting practical applications within cultural contexts that lead to more meaningful and sustained learning outcomes (Cabagay & Francisco, 2025). The integration promotes critical thinking and epistemic justice, allowing students to engage with knowledge more meaningfully (Shabalala, 2025).

Implementation Duration: Evidence suggests minimum 6-12 week implementations are needed for effectiveness, with 9-18 weeks being optimal (Sánchez Gómez et al., 2024; Zhang & Ma, 2023). Our findings of predominantly 12-15 week implementations may not fully capture the long-term benefits of cultural integration.

Research Gap and Opportunity

The stark contrast between systematic review findings and bibliometric patterns reveals ethnoscience integration as simultaneously an empirically validated approach and a critically underexplored research frontier. While mainstream literature extensively examines PBL and creativity independently, their intersection with Indigenous knowledge systems remains largely uninvestigated despite their demonstrated effectiveness.

This gap represents both challenge and opportunity. Recent studies highlight barriers, including curriculum rigidity, lack of teacher preparedness, and limited institutional guidelines for integrating local knowledge (Bhuda & Maditsi, 2025; Ramli et al., 2025). However, factors like faculty autonomy, leadership support, and community collaboration can foster innovative practices (Ramli et al., 2025).

The convergence of sustainability education momentum (300% growth 2020-2023) with the documented effectiveness of cultural integration creates strategic timing for advancing this intersection. As multilevel interventions emphasizing indigenous knowledge systems gain recognition for addressing health and educational disparities (Rink et al., 2024), the field is primed for expansion.

Implementation Insights

Success factors emerging from the synthesis, validated by recent empirical studies, include: Extended implementation periods (≥12 weeks) allowing deeper cultural engagement - Meta-analyses confirm 9-18 week periods optimize creativity outcomes (Zhang & Ma, 2023); Authentic community partnerships ensuring genuine knowledge integration—community partners providing expertise and resources significantly enhance PBL effectiveness (Jordaan & Mennega, 2022); Faculty development in cultural competency—teachers require training in epistemological flexibility to navigate multiple knowledge systems effectively (Zinyeka et al., 2016); Assessment approaches valuing diverse creative expressions—Moving beyond Western-centric metrics to include collective and process-oriented creativity measures (Mehta et al., 2025).

Studies with higher ethnoscience integration levels consistently demonstrated stronger outcomes, suggesting dose-response relationships between cultural authenticity and creativity development. Implementation in Indonesia showed that AI-driven ethnoscience learning combining Malay cultural insights with machine learning personalization significantly enhanced physics education outcomes (Jufrida et al., 2025).

Theoretical Implications

Findings support expanded conceptualizations of creativity transcending individual cognitive processes to encompass collective, culturally embedded innovation. Eastern and indigenous paradigms view creativity as collective and relational, emphasizing social and moral components integrated with cultural norms (Niu & Sternberg, 2006; Wang & Chen, 2021).

In Taoist philosophy, creativity reflects natural processes (qi) rather than solely human imagination, while indigenous perspectives link creativity with cultural practices and environmental stewardship as a communal activity sustaining cultural identity (Karnilowicz Mizuno & Xu, 2022; J. H. Liu et al., 2014). This challenges dominant Western paradigms positioning creativity as an individual trait, suggesting reconceptualization from skill acquisition toward capacity for navigating and synthesizing multiple knowledge systems (Barón-Birchenall et al., 2025).

The observed mechanisms align with sociocultural learning theories emphasizing knowledge construction through cultural mediation, Vygotsky, (1978) while extending beyond transmission models toward genuine epistemological pluralism. As Glăveanu, (2010) argues, cultural psychology perspectives reveal creativity as fundamentally embedded in cultural contexts rather than a universal cognitive process.

Practical Applications

For educators, findings indicate that implementing ethnoscience-integrated PBL requires fundamental pedagogical shifts:

Curriculum Design: Programs should incorporate collective activities emphasizing community and cultural heritage (Niu & Sternberg, 2006; Wang & Chen, 2021), integrate culturally relevant content like traditional arts and environmental stewardship (Morgan-Bulled et al., 2025), and combine insights from cultural studies, psychology, and environmental science for holistic approaches (W. Liu et al., 2024).

Partnership Development: Establishing reciprocal benefit-sharing agreements with indigenous communities ensures authentic knowledge integration (Rink et al., 2024). Long-term relationships transcending semester boundaries allow community partners to become co-educators (Jordaan & Mennega, 2022).

Assessment Innovation: Evaluation should broaden beyond individual achievements to include community impact and cultural preservation (Chan, 2011), utilize qualitative measures capturing cultural and social interactions (Karnilowicz Mizuno & Xu, 2022), and develop culturally responsive creativity assessments through participatory design with indigenous communities.

Institutional Support: Policy frameworks must support community partnerships with appropriate resource allocation, provide faculty development addressing cultural competency and epistemological flexibility, accommodate extended project timelines in curriculum structures, and recognize diverse creative outcomes beyond traditional metrics in evaluation systems.

Limitations and Future Directions

Several limitations constrain interpretation. The small number of included studies (n=6) limits generalizability, though perfect directional consistency strengthens confidence in positive effects. Geographic concentration in specific regions may not represent global applicability. Heterogeneity in intervention approaches, outcome measures, and implementation contexts prevented quantitative meta-analysis. Publication bias toward positive results cannot be excluded given file drawer effects.

Future research priorities emerging from this synthesis include (1) Large-scale randomized controlled trials ($n \geq 300$) examining causal relationships with adequate statistical power, (2) Development of culturally-responsive creativity assessment instruments through participatory design with indigenous communities, addressing the need for assessments beyond Western-centric metrics (Mehta et al., 2025), (3) Longitudinal studies tracking sustainability of creativity gains beyond immediate post-intervention periods; (4) Cross-cultural validation studies implementing parallel interventions across diverse indigenous contexts to identify universal versus context-specific principles; and (5) Investigation of technology-enhanced approaches respecting indigenous data sovereignty, building on successful AI-ethnoscience integrations (Jufrida et al., 2025).

Methodologically, future studies should employ participatory action research positioning communities as co-researchers rather than subjects; utilize mixed methods capturing both quantitative outcomes and lived experiences; examine cost-effectiveness guiding institutional investment decisions; and develop implementation fidelity measures for cultural integration quality assessment.

CONCLUSION

This systematic review was guided by two interrelated research objectives, both of which are addressed by the findings of this study. Regarding the first objective, whether ethnoscience-integrated PBL is more effective in developing creativity among higher education students compared to conventional approaches, the available evidence, while limited in scale, points consistently in a positive direction. Across all six included studies, every study reported positive creativity outcomes, with effect sizes in the moderate range where formally reported ($d \approx 0.4 - 0.6$ in two studies providing extractable data). These findings should be interpreted cautiously given the small number of included studies and the absence of a formal meta-analysis; however, the consistency of directional effects across diverse contexts and methodologies strengthens confidence in the overall pattern. Three mechanisms help explain this consistency: cultural relevance strengthening engagement and

creative motivation; traditional knowledge systems broadening epistemological perspectives in problem-solving; and authentic community partnerships nurturing applied creativity by positioning indigenous knowledge holders as co-educators.

Regarding the second objective, how ethnoscience-integrated PBL is positioned within the broader scholarly landscape and what its trajectory suggests for the future of culturally responsive and equity-driven pedagogy, the bibliometric network analysis reveals a critical paradox. Despite emerging empirical support for its effectiveness, ethnoscience integration remains largely absent from mainstream educational research, with ethnoscience-related terms appearing only marginally among 156 identified keywords. The 300% growth of sustainability education between 2020 and 2023 alongside this persistent absence underscores the need for more systematic and large-scale investigations into ethnoscience-integrated PBL.

Realizing the potential calls for genuine community partnerships that treat Indigenous knowledge holders as co-researchers, robust faculty development programs emphasizing cultural competence and ethical engagement, and an epistemological pluralism that values Indigenous and Western knowledge systems equally. Key factors for success include longer implementation periods of at least 12 weeks, active community participation, faculty expertise in cultural contexts, and assessment approaches that recognize diverse forms of creativity beyond Western-centric benchmarks.

Future research should prioritize large-scale randomized controlled trials with adequate follow-up periods to establish causal links and long-term sustainability of creativity gains; culturally responsive assessment instruments co-designed with Indigenous communities; cross-cultural validation studies within Indigenous-controlled institutions; and technology-enhanced strategies grounded in ethical principles ensuring Indigenous ownership over digital representations.

The convergence of emerging empirical evidence, the accelerating momentum of sustainability education, and visible research gaps places ethnoscience-integrated PBL at a defining moment. As higher education continues to confront inequities and increasingly recognizes the wisdom embedded in indigenous knowledge systems, this pedagogical approach offers a meaningful way forward, one that envisions education as more inclusive, culturally grounded, and creatively empowering.

CONFLICTS OF INTEREST

The authors declare no conflict of interest. This systematic review was conducted independently without any financial or personal relationships that could inappropriately influence the representation or interpretation of reported research results.

AUTHOR CONTRIBUTIONS STATEMENT

The authors affirmed that there is no conflict of interest in this article. MFS conceptualized the research, conducted the systematic literature search and screening, performed data extraction and analysis, executed the bibliometric network analysis using VOSviewer, and drafted the manuscript. AR supervised the overall research design, provided critical feedback on methodology and synthesis approaches, guided the integration of systematic review with bibliometric analysis, and revised the manuscript for intellectual content. SS contributed to the theoretical framework development related to ethnoscience and culturally responsive pedagogy, assisted with the quality assessment of included studies, and reviewed the manuscript for theoretical coherence and accuracy. OS contributed to the research conceptualization, provided expertise on project-based learning pedagogies, assisted with interpretation of creativity outcomes, and reviewed the manuscript for educational practice implications.

AI DISCLOSURE

The authors used artificial intelligence (AI)-assisted tools in a limited manner during the preparation of this manuscript, particularly for language editing, improving readability, and supporting early-stage idea organization. However, the study design, data collection, data analysis, interpretation of findings, and final conclusions were developed and verified entirely by the authors. The authors assume full responsibility for the integrity and originality of the manuscript.

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