Available online at: https://jurnal-fkip.ut.ac.id/index.php/ijrse/issue/archive
International Journal of Research in STEM Education (IJRSE)
ISSN 2721-2904 (online)
Volume 7 Number 1 (2025): 162 - 168

Advancing STEM Education through Inquiry, Equity, and Cultural Relevance: Insights from Diverse Educational Contexts

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Abstract

This editorial introduces the first issue of *International Journal of Research in STEM Education* (IJRSE) for 2025, presenting a diverse collection of nine articles, including empirical studies, conceptual analyses, and case-based research. The contributions span across seven countries—Korea, Namibia, the Philippines, Indonesia, Nigeria, Mexico, and Taiwan—representing four continents and fifteen institutions. This issue exemplifies a shared global commitment to address key challenges in STEM education through culturally grounded innovation, interdisciplinary pedagogy, and inclusive policy perspectives. Themes emerging from the articles include inquiry-based and project-based strategies, indigenous knowledge integration, differentiated instruction, equity in science learning, and STEM professional development. Together, these studies chart critical pathways for advancing quality, relevance, and access in STEM education, providing insights that are both context-specific and globally resonant.

Keywords: *STEM pedagogy, interdisciplinary learning, inquiry-based education, educational equity, global perspectives*

INTRODUCTION

The global landscape of STEM education is experiencing transformative shifts, driven by technological advancement, evolving learner needs, and demands for inclusive and context-relevant learning. This editorial issue captures that momentum, showcasing studies across diverse cultural and geographic settings—including Korea, Namibia, the Philippines, Indonesia, Nigeria, Mexico, and Taiwan—that reflect a growing global consensus on the importance of contextualized and equity-driven STEM pedagogy (Ogegeb & Lin, 2024; Sholeuddin, 2024; Etotoku, 2024; González et al., 2024).

Four critical themes emerge across the articles in this issue. First, localized STEM practice emphasizes the integration of ethnoscience and indigenous knowledge systems to enhance conceptual understanding while preserving cultural identity (Kim, 2024; Shovolo, 2024). Second, inquiry-based and critical thinking approaches are reevaluated through frameworks that align assessment and delivery with students' learning processes, supporting higher-order reasoning (Ogegeb & Lin, 2024; Sholeuddin, 2024). Third, pedagogical innovation and teacher perspectives are explored through spatial and cognitive dimensions that influence learning, particularly in technical and science instruction (Etotoku, 2024; Davidson, 2024). Lastly, equity, inclusion, and social relevance are discussed in relation to how STEM education can promote civic engagement and address societal challenges (González et al., 2024).

This editorial review highlights how current research addresses the challenges and possibilities of advancing STEM education through inquiry, equity, and cultural relevance. It focuses on the intersections of practice and policy that support transformative STEM learning environments within and across global contexts.

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DOI: https://doi.org/10.33830/ijrse.v7i1.1840
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EXPANDING ACCESS AND RELEVANCE THROUGH LOCALIZED STEM PRACTICE

Expanding access and relevance through localized STEM practice requires aligning STEM education with the cultural, social, and environmental realities of local communities. By doing so, STEM learning becomes more meaningful and engaging for students, especially those in underserved or marginalized areas. This approach emphasizes the integration of indigenous knowledge systems and context-specific content to enhance conceptual understanding while preserving cultural identity. For example, Kim (2024) demonstrates through his paper that the potential of a hybrid model that combines flipped classrooms and project-based learning grounded in ethnoscience to improve student literacy and identity, while Shovolo (2024) in his paper uses student-generated concept maps to foster inquiry in life sciences classrooms in Namibia.

One key element in localized STEM practices is community-driven science, which invites local participation in defining research agendas and generating knowledge. Ballard et al. (2023) highlight how this participatory model can democratize science and address long-standing equity issues, as exemplified by the Flint water crisis. Such models not only empower communities but also promote justice-oriented education that values lived experiences and local expertise. Embedding cultural and historical narratives into science instruction strengthens the relevance of STEM for learners, particularly in communities historically excluded from scientific discourse.

Localized pathways also target specific populations, such as military veterans, to expand STEM access in tailored ways. Rand-Fleming (2023) describes how regionally focused STEM pipelines for veterans reduce barriers to employment and foster a sense of belonging by connecting personal experiences with local STEM career opportunities. Similarly, programs like CCERS STEM + C link underrepresented students to environmental issues in their own communities—such as the restoration of New York Harbor—thereby expanding their STEM identities and making learning more immediate and personal (Birney & McNamara, 2022). Kaggwa et al. (2023) further show how inclusive STEM outreach programs in Missouri improve access for students from under resourced schools, increasing both interest and representation in STEM fields.

Despite their promise, localized STEM practices must contend with systemic challenges such as limited resources, inconsistent teacher training, and institutional inertia. In resource-constrained environments, Nawaz et al. (2023) advocate for innovative, low-cost strategies and sustained professional development to ensure scalability and sustainability. Hirst-Bernhardt & Almasi (2022) underscore the urgency of extending science access to elementary learners, a group often overlooked in national priorities. Their research calls for tapping into young learners' natural curiosity through integrated, high-quality science instruction. Collectively, these studies reveal that while localized approaches are not without obstacles, they hold considerable potential for transforming STEM education into a more inclusive, equitable, and culturally responsive endeavor.

RETHINKING INQUIRY-BASED AND CRITICAL THINKING APPROACHES

Inquiry-based learning (IBL) and critical thinking approaches have received increasing attention in STEM education research for their potential to cultivate higher-order cognitive skills. These pedagogical strategies prioritize student-driven inquiry, problem formulation, evidence-based reasoning, and reflective thinking. While their theoretical underpinnings align with constructivist learning theories, their practical implementation varies across disciplines, educational levels, and cultural contexts. The contributions in this IJRSE issue highlight both the promise and complexity of integrating these approaches meaningfully into classroom practice.

A key insight into IBL's effectiveness is presented by Antonio and Prudente (2023), whose meta-analysis reveals a substantial impact of IBL on higher-order thinking skills in science education, with a

strong effect size (g = 0.893). Their findings confirm that IBL enhances analytical reasoning, interpretation, and problem-solving across various levels of education, though they also note a lack of emphasis on technology integration within these pedagogical models. In early childhood settings, Kausar et al. (2024) affirm the value of IBL in promoting student engagement, collaboration, and inquiry, while also acknowledging implementation barriers such as limited teacher readiness and access to resources.

When comparing instructional strategies, Dwijayanti et al. (2020) found that both problem-based and inquiry-based approaches enhance critical thinking, though the problem-based method showed slightly stronger statistical results. These differences may reflect the structured nature of problem-solving tasks, which often provide clearer pathways to logical reasoning. In higher education, Shofiah et al. (2024) show that collaborative inquiry-based writing assignments in Indonesian language courses support students' development of argumentation and reflective thinking. Similarly, Wale and Bishaw (2020) demonstrate that IBL fosters metacognitive skills—including analysis, evaluation, and self-regulation—in English as a Foreign Language (EFL) classroom.

Despite these promising outcomes, several challenges temper the enthusiasm for wide-scale adoption of IBL. Kausar et al. (2024) highlight the tension between open-ended exploration and curriculum mandates in early learning contexts, which can hinder implementation without adequate support. National policy frameworks, such as India's NEP 2020, advocate for inquiry-based and experiential learning as a means of cultivating critical thinking yet translating these ideals into classroom realities remains complex ("NEP 2020," 2023). Further complicating the picture, Gómez and Suárez (2020) found a negative correlation between IBL practices and scientific performance in PISA assessments among Colombian students, even as students reported improved critical thinking perceptions. This suggests a nuanced relationship between inquiry practices, learner motivation, and academic performance.

Taken together, these findings indicate that while IBL and critical thinking approaches have demonstrated cognitive benefits, their effectiveness is highly context dependent. Successful implementation requires attention to instructional design, teacher preparation, and the alignment of assessments with learning goals. Moreover, the tension between fostering inquiry and meeting standardized testing requirements underscores the need for balanced instructional strategies that blend direct instruction with inquiry elements. Future research should continue exploring adaptive models that address contextual constraints while preserving the transformative potential of these pedagogies across diverse learning environments.

PAEDAGOGICAL INNOVATION AND TEACHER PERSPECTIVES

Pedagogical innovation is a crucial element in transforming educational practices, with teachers playing a pivotal role in this process. Teachers are not only responsible for content delivery but also for fostering holistic student development through innovative practices. This involves a critical and reflective approach to teaching, which can significantly impact educational contexts by addressing various challenges and implementing improvement actions (Loja & Suco, 2021). The essence of pedagogical innovation lies in enriching educational activities with new ideas, content, and technologies, requiring teachers to possess specific skills and a readiness for innovation (Zavalevskyi, 2023).

Teacher's Role in Pedagogical Innovation

- Teachers are central to the implementation of pedagogical innovations, as they are the primary agents of change in the classroom (Loja & Suco, 2021).
- Innovative teachers are characterized by their ability to think systematically, creatively, and constructively, which is essential for adapting to educational reforms (Zavalevskyi, 2023).

- Teachers' perspectives and active involvement are crucial for aligning educational practices with societal needs and challenges ("Influencia de la Perspectiva Docente en la Relación entre Educación y Sociedad", 2024).

Challenges and Facilitators of Innovation

- Factors such as solid teaching teams, a receptive educational community, and teachers' intrinsic motivation can facilitate pedagogical innovation (Lima et al., 2020).
- Conversely, lack of motivation, improvisation, and inadequate planning can hinder the innovation process (Lima et al., 2020).
- Teachers' attitudes towards new pedagogical technologies and their skill levels also significantly impact on the successful application of innovations (Hasanova, 2021).

Impact on Student Learning

- Pedagogical innovations have been shown to increase cognitive activity, reduce negative emotions, and create lasting motivation among students (Hasanova, 2021).
- Meaningful student learning is encouraged through innovative practices that engage students effectively and address contemporary societal challenges ("Influencia de la Perspectiva Docente en la Relación entre Educación y Sociedad", 2024).

While pedagogical innovation is essential for educational transformation, it is not without its challenges. Teachers' attitudes, motivation, and readiness for change play a significant role in the successful implementation of innovative practices. Addressing these challenges requires a supportive educational environment and a focus on developing teachers' skills and attitudes towards innovation.

EQUITY, INCLUSION, AND SOCIAL RELEVANCE

Equity, inclusion, and social relevance are increasingly recognized as foundational principles in education and other sectors, ensuring that policies and practices are responsive to the needs of diverse populations. In STEM education, these principles take on added significance as efforts to democratize knowledge and broaden participation intersect with the challenges of access and representation. Across contexts—ranging from climate adaptation and research to infrastructure and healthcare—equity-centered approaches foster environments in which all individuals can contribute meaningfully and benefit from shared progress (Husmann & Peng, 2022; Chinapaw & Anselma, 2023).

In the realm of environmental planning, equity and inclusion are critical for ensuring socially responsive outcomes. Ma (2022) emphasizes that climate adaptation strategies in smaller American municipalities are more successful when they integrate the perspectives of vulnerable and marginalized groups. By bringing diverse stakeholders into the planning process, these communities not only improve the relevance of their responses but also reinforce justice-oriented adaptation measures that reflect lived experiences and localized needs.

Social justice in education and other institutional settings requires more than token representation. Husmann and Peng (2022) argue that inclusion means welcoming the "whole self" of individuals, rather than expecting conformity to dominant cultural norms. This paradigm shift fosters a genuine appreciation for diverse identities and challenges systemic inequities by reshaping the conditions under which participation and recognition occur. In STEM fields, this means designing learning environments that affirm multiple ways of knowing, thereby promoting deeper engagement and critical citizenship.

Research and innovation also benefit significantly from inclusive practices. Chinapaw and Anselma (2023) critique the dominance of WEIRD perspectives—Western, Educated, Industrialized,

Rich, and Democratic—that have historically skewed the relevance and applicability of scientific inquiry. They call for more pluralistic frameworks in research design and data interpretation to ensure that findings reflect broader human experiences and are socially impactful. This aligns with calls in STEM education to ground curriculum and assessment in diverse cultural and cognitive frameworks.

Beyond education and research, equity and inclusion are central to sectors such as transportation and healthcare. In infrastructure planning, Pagliara et al. (2022) advocate for inclusive decision-making in high-speed rail development to minimize socio-spatial inequalities and promote sustainable growth. In healthcare, Samora (2022) highlights the importance of workforce diversity, noting that culturally competent care improves health outcomes and reduces disparities. These cases illustrate that while progress has been made, sustained attention and action are needed to embed equity and inclusion deeply within institutional structures. Empowering diverse voices to shape policy and practice remains both a challenge and an imperative across all domains.

CONCLUSION

This issue of *IJRSE* reflects a robust and evolving discourse in STEM education, characterized by a growing commitment to innovation, contextual relevance, and educational equity. The nine articles featured in this volume collectively highlight how localized pedagogies, inquiry-driven methods, teacher agency, and inclusive practices are shaping the next generation of STEM learning. While challenges such as resource disparities, assessment alignment, and systemic biases persist, the research presented here offers promising pathways and grounded strategies for transformative change.

As STEM education continues to respond to global shifts—technological, ecological, and sociopolitical—the contributions in this issue affirm the importance of fostering interdisciplinary collaboration and culturally responsive teaching. Moving forward, the *International Journal of Research in STEM Education* remains committed to supporting diverse voices and evidence-based practices that advance the quality, inclusiveness, and impact of STEM education worldwide.

Acknowledgments

The Editor-in-Chief expresses sincere gratitude to the editorial board members, reviewers, authors, and readers for their continued support and contributions. Your collective efforts are instrumental in shaping the quality and direction of IJRSE. We invite you to engage with the articles in this issue and to contribute to future editions as we continue fostering global collaboration in STEM education.

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