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Elementary school teacher's perceptions of stem-based performance assessment across urban and rural contexts

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ABSTRACT

This study aims to analyze elementary school teacher's perceptions of the use of This study investigates elementary teacher's perceptions of STEM based performance assessment and examines how these perceptions vary between urban and rural school settings. The study adopts a descriptive mixed methods design in which quantitative survey findings serve as the main source of analysis and qualitative input is used to clarify contextual differences across geographical locations. A total of 52 teachers completed a 12 item questionnaire measuring awareness, familiarity, and fluency, followed by short interviews with a purposive sample to explore the reasons behind emerging patterns. The results show that all three aspects fall within the high category, indicating that teachers view STEM based performance assessment as valuable for supporting critical thinking, creativity, collaboration, and problem solving. Fluency receives the highest mean score, suggesting that many teachers feel reasonably confident implementing STEM assessment, although the qualitative data reveal gaps in rubric design and project based assessment skills. The comparison across locations shows that rural teachers consistently report higher perceptions than urban teachers. Rural teachers describe more contextual and community oriented experiences, while urban teachers highlight administrative barriers and limited access to technical training. The findings underscore the need for professional development that is sensitive to geographical conditions and supports teachers in designing authentic, integrated STEM performance assessments.

INTRODUCTION

In the era of globalization and technological advancement, 21st-century education is expected to produce individuals who not only possess academic knowledge but also have skills relevant to contemporary demands (Osiesi & Blignaut, 2025 ; Guerra-Macías & Tobón, 2025). These include citizenship, critical thinking, collaboration, creativity, communication, character, and STEM-related competencies (Yang et al., 2025). These skills are crucial to prepare students for an ever-evolving global landscape. Therefore, education must incorporate both practical and theoretical learning approaches, one of which is STEM-based education (Science, Technology, Engineering, and Mathematics). The STEM approach helps students apply core concepts from each STEM discipline to real-life situations, enabling them to communicate, collaborate, think critically, and foster creativity in line with 21st-century demands (Cheng & Weatherly, 2025; Ammar et al., 2024).

In this context, STEM-based performance assessment becomes a vital instrument, as it evaluates not only student's theoretical understanding but also their practical skills in solving

problems, conducting experiments, and applying technology in daily life (Han et al., 2024; Chang et al., 2021). This type of assessment enables students to demonstrate their ability to address contextual problems that are relevant to real-world challenges. Student skill assessments must be authentic, meaning they should reflect actual conditions and situations (Hong et al., 2025; Peddle et al., 2025). One way to realize authentic assessment is through the use of rubrics, which provide measurable, structured, and transparent criteria (Mesny et al., 2026; Mesny et al., 2026). Consequently, rubric-based assessment allows teachers to objectively and contextually evaluate student's competencies, particularly in implementing the STEM approach.

Although STEM-based performance assessment has significant potential to improve education quality, its implementation in Indonesia, especially at the primary school level, still faces numerous challenges (Arlinwibowo et al., 2023; Sihombing et al., 2024). One major challenge lies in teacher's perceptions of the assessment itself, which influences their readiness to engage with and implement the STEM curriculum. Teachers who possess knowledge and skills to implement STEM activities tend to have higher self-efficacy toward this type of instruction (DeCoito & Myszkal, 2018). Teacher's positive perceptions of STEM significantly affect the sustainable implementation of STEM education and form a critical foundation for teacher's professional development (Thi To Khuyen et al., 2020). Conversely, teachers with limited understanding often face difficulties in designing and conducting assessments aligned with integrated STEM principles.

Moreover, teacher's perceptions of STEM-based assessments are influenced by contextual factors such as school infrastructure, training availability, and access to supporting resources (Kurup et al., 2019). In Indonesia, differences between urban and rural areas, such as those found in Tasikmalaya City and Tasikmalaya Regency, offer an important perspective on how geographical and infrastructural disparities impact the implementation of STEM-based assessments. Tasikmalaya City, as an urban area, has more adequate access to technology and facilities compared to the more rural Tasikmalaya Regency. Educational infrastructure in urban areas also tends to better support technology-based learning (Wajnah et al., 2025). Geographic factors further play a key role in shaping teacher readiness, as teachers in rural areas often face obstacles such as limited geographical access and minimal supervision, which can affect their professional development, including in assessment practices (Persada et al., 2025; Yar & Shaheedzooy, 2023). However, infrastructure limitations are not always the primary barrier, as teachers in rural areas frequently demonstrate adaptability and creativity in utilizing local resources for contextual learning. Although many primary school teachers face infrastructural and training limitations, most still show positive attitudes toward STEM and recognize the importance of early STEM implementation (Samara & Kotsis, 2023).

In addition to technical and accessibility issues, another challenge is the pedagogical understanding possessed by teachers. In this regard, the concept of TPACK (Technological Pedagogical Content Knowledge) is highly relevant, as teachers must be able to integrate content knowledge, pedagogy, and technology when designing effective assessments. Saubern et al., (2020) emphasize that quality teaching with technology requires more than just technical proficiency; it demands the teacher's ability to align technology with instructional strategies and subject matter content. Without a sound understanding of TPACK, the implementation of STEM-based assessments may fall short, as teachers might use technology in isolation from its pedagogical or content context. Therefore, a comprehensive understanding of this approach is

essential to produce assessments that are not only rigorous but also enhance student's critical thinking and problem-solving skills in an integrated and contextual manner.

Although STEM-based performance assessment has been widely discussed in various educational settings, most existing studies have focused on instrument development, the influence of assessment on learning outcomes, or its implementation at the secondary and higher education levels. Research that specifically examines elementary school teacher's perceptions within different geographical contexts, particularly comparisons between urban and rural environments remains limited. Yet, disparities in technology access, availability of learning facilities, and training opportunities can substantially affect teacher's preparedness and understanding in implementing integrated STEM performance assessments effectively.

Several studies have attempted to explore STEM-based performance assessment, but most were conducted in middle schools or universities. Research that directly involves elementary teachers is still scarce. Existing publications discuss rubric development for STEM assessment or report how STEM learning affects student outcomes, but give little attention to teacher's real classroom experiences in designing and applying performance assessments. The issue becomes more complex when comparing school contexts because access to technology, training, and instructional facilities is not always equal. Scholars such as Kurup and colleagues argue that the learning environment surrounding teachers shapes their confidence and readiness to adopt STEM assessment practices. This suggests that teachers in different geographical contexts may interpret the same policy or framework differently, and such contrasts have not been thoroughly explored at the elementary school level.

Based on this background, the present study aims to answer two main research questions. First, it investigates elementary school teacher's perceptions of STEM-based performance assessment across three aspects: awareness, familiarity, and fluency in classroom practice. Second, it examines how these perceptions differ between teachers working in urban and rural school settings. Through these two focal points, the study seeks to provide a more comprehensive understanding of teacher's readiness to implement STEM performance assessments and to offer empirical foundations for designing training programs and policies that are sensitive to diverse school contexts.

METHOD

This study employed a descriptive mixed-methods design. The quantitative strand served as the primary source of analysis, while qualitative input was incorporated to illuminate contextual variations across different geographical settings (Sugiyono, 2023). A descriptive survey approach was used to capture a broad picture of elementary teacher's perceptions of STEM-based performance assessment, with qualitative insights added to deepen the interpretation of emerging patterns. The quantitative component was structured to identify perception trends across three indicator awareness, familiarity, and fluency (Chaya, 2023; Papagiannopoulou, 2024). The qualitative component helped clarify the contextual reasons behind those patterns. This design enabled the research to document general tendencies while still attending to the realities in which teachers carry out assessment practices (Leavy, 2022).

The study involved 52 elementary school teachers who participated voluntarily. The participants represented schools situated in geographically varied environments, and convenience sampling was chosen because it aligned with the accessibility constraints during the research period (Golzar et al., 2022). To strengthen the interpretation of both quantitative and qualitative findings, demographic information such as school location, teaching experience, and school type was collected in Table 1.

Table 1. Participant Demographics

Category	Subcategory	n	%
School Location	Urban	26	50.0
	Rural	26	50.0
Teaching Experience	< 5 years	12	23.1
	5–10 years	18	34.6
	> 10 years	22	42.3
School Type	Public	31	59.6
	Private	21	40.4

Data were collected through a Likert-scale questionnaire followed by a set of brief open-ended questions. The questionnaire consisted of 12 items that assessed teacher's perceptions across three aspects: awareness (their recognition of the importance of STEM-based performance assessment), familiarity (their understanding of STEM concepts in relation to assessment), and fluency (their confidence and ability to apply STEM-based assessment in practice). Each aspect contained four items rated on a 1–5 scale. The instrument's content validity was reviewed by two experts in elementary education, and the open-ended items invited teachers to describe the challenges, opportunities, and support they needed when implementing STEM-based performance (Roebianto et al., 2023). The structure of the questionnaire is presented in Table 2.

Table 2. Questionnaire Structure by Aspect

Aspect	Number of items	Sample item
Awareness	4	Recognition of the importance and relevance of STEM-based performance assessment in elementary education.
Familiarity	4	Understanding of STEM concepts and how they relate to classroom assessment practices.
Fluency	4	Level of confidence and ability to apply STEM-based performance assessment in instructional settings.

The questionnaire was distributed in both online and printed formats. After the quantitative responses were collected, 6–8 teachers were selected for brief follow-up interviews using purposive criteria based on school location and teaching experience. The interviews served to confirm and clarify the questionnaire findings and to explore contextual factors that shaped teacher's perceptions. Before participating, teachers received information about the study's purpose and confidentiality procedures, and no personal identifying data were collected (Drolet et al., 2023).

The quantitative data were analyzed descriptively by calculating mean scores for each item and each perception aspect. Perception categories (low, medium, high) were established using predetermined score ranges, and their distribution was compared across urban and rural schools.

The quantitative findings were also visualized through graphs to show geographical patterns in teacher's perceptions. Qualitative responses from the open-ended items and interviews were analyzed thematically. Codes were developed from recurring ideas and then organized into themes related to challenges, opportunities, and support needs. These themes enriched the interpretation of the quantitative results and helped explain variations observed across different geographical contexts (Squires, 2023).

RESULTS

An overview of teacher's perceptions of STEM-based performance assessment can be seen through the mean scores of the three measured aspects. The calculations show that all three aspects fall within the high category, indicating that most teachers hold positive views regarding the use of STEM-based performance assessment in primary schools. A summary of the total scores for the three aspects is presented in Table 3.

Table 3. Overall Perception Scores Across Three Aspects

Aspect	Mean Total	Category
Awareness	3.70	High
Familiarity	3.72	High
Fluency	3.84	High

Table 3 shows that fluency received the highest mean score, followed by familiarity and awareness. This pattern suggests that teachers feel relatively confident in applying elements of STEM-based assessment, while their conceptual understanding and recognition of STEM's role still require strengthening. Although all three aspects fall within the high category, the score differences offer an initial indication of areas that warrant deeper exploration in the discussion.

To further examine how geographical context shapes teacher's perceptions, the analysis continued by separating mean scores based on school location. The comparison between teachers working in urban and rural settings is presented in Table 4.

Table 4. Comparison of Perception Scores by School Location

Aspect	Urban Mean	Rural Mean	Difference
Awareness	3.56	3.84	+0.28
Familiarity	3.61	3.84	+0.23
Fluency	3.69	3.98	+0.29

The figures in Table 4 show that teachers in rural areas consistently report higher scores across all aspects. The widest gap appears in the fluency aspect. This pattern indicates that rural teachers express stronger confidence in applying STEM based performance assessment compared to teachers in urban schools. After examining the mean differences across locations, the next step was to observe how perception categories are distributed within each setting. This distribution helps reveal the level of teacher perception in a more detailed manner. The category distribution is presented in Table 5.

Table 5. Distribution of Perception Categories by Location (%)

Aspect	Urban Low	Urban Med	Urban High	Rural Low	Rural Med	Rural High
Awareness	0%	58%	42%	0%	38%	62%
Familiarity	0%	52%	48%	0%	36%	64%
Fluency	0%	45%	55%	0%	28%	72%

Table 5 shows that most teachers in both settings fall within the medium and high categories for every aspect. None of the responses fall in the low category, which aligns with the overall mean scores that fall within the mid to upper range. To provide a clearer overview of the overall tendency, the total means were then arranged from the highest to the lowest. The order is displayed in Figure 1.

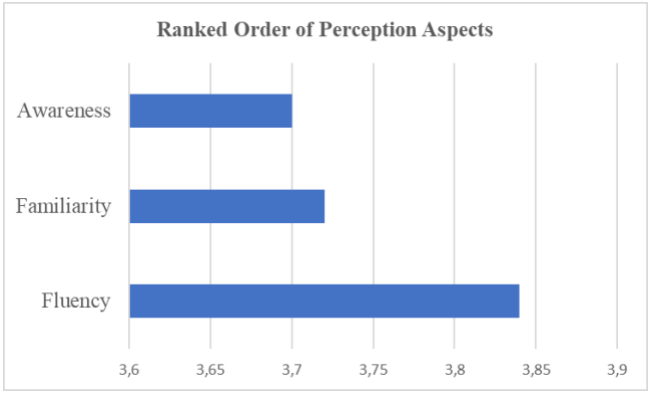

Figure 1. Ranked Order of Perception Aspects

Figure 1 shows that fluency holds the highest position, followed by familiarity and awareness. The order offers an overview of the aspect with the strongest tendency and the aspect that may need further reinforcement in teacher perception. The quantitative patterns are then explored more deeply through qualitative findings to understand the context behind these results.

After observing the ranked means for each aspect, the analysis continued by comparing perception scores between teachers in urban and rural settings. This comparison helps determine whether the patterns in the ranked aspects remain consistent when the data is viewed by location. The visual comparison is presented in Figure 2.

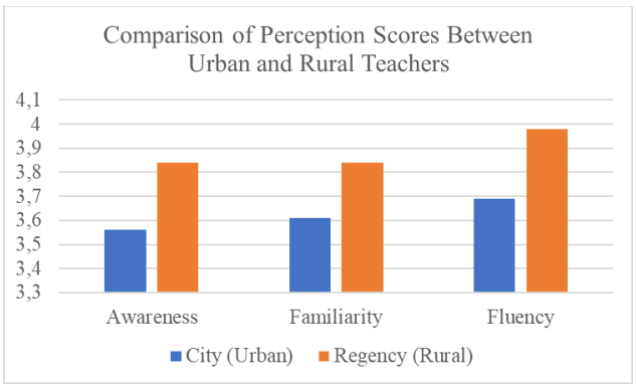

Figure 2. Comparison of Perception Scores Between Urban and Rural Teachers

Figure 2 shows that rural teachers score higher on every aspect when compared with teachers in urban schools. The visual provides a clearer picture of the differences that appeared in the previous tables. The next stage of analysis draws on qualitative findings to add contextual explanation to these patterns. Interviews were conducted with a group of teachers selected through purposive criteria to explore the reasons behind the tendencies observed across the three aspects. The qualitative input offers additional insight into how teachers understand, become familiar with, and apply STEM based performance assessment in their instructional practice.

Table 6. Summary of Follow-Up Interview Themes

Teacher Code	Experience	Findings			Notes
		Awareness	**Familiarity**	**Fluency**	
U1	4 years	Aware of the importance of STEM but sees it as general and still theoretical	Understands the basic ideas of STEM yet feels unsure about the accuracy of the interpretation	Not confident creating an integrative rubric	Reports that no specific training is available at the school
U2	8 years	Considers STEM important for building student creativity	Familiar with the terminology but unsure how to connect the idea of engineering	Has tried applying STEM but only in small project tasks	Mentions limited time as the main obstacle
U3	12 years	Has known about STEM for a long time but says it has not become a priority	Understands the concepts but often makes mistakes when combining the fields	Not consistent in using performance rubrics	States that teachers need ready to use rubric examples
R1	6 years	Connects STEM with contextual activities such as work in the rice field environment	Knows STEM components through frequent participation in local workshops	Fairly confident designing project assessments	Uses local materials for simple project tasks
R2	15 years	Highly aware of STEM and its impact on life skills	Understands integrative concepts well, especially the link between science and engineering	Confident designing performance tasks based on real problems	Often uses village resources as learning materials
R3	10 years	Believes STEM is relevant to student needs in rural settings	Familiar with the concepts but still needs guidance in the technology component	Applies STEM quite smoothly although the rubric still needs refinement	Notes that limited facilities encourage creativity
U4	5 years	Aware of STEM but says STEM assessment is still quite new	Understands the ideas but is unsure about how performance assessment should work	Does not yet feel ready to apply STEM assessment fully	Notes that school policy communication is minimal

The interview findings in Table 6 indicate that teachers in both settings show a reasonable level of awareness and understanding of STEM, although their fluency in applying it varies. Teachers in rural schools describe more contextual experiences when developing project-based tasks and assessments, while those in urban schools tend to highlight their need for training, technical guidance, and stronger support from the school. The qualitative data reinforces the earlier quantitative patterns and offers a clearer picture of the factors that shape teacher perception of STEM based performance assessment.

DISCUSSION

The findings show that teacher's perceptions of STEM based performance assessment fall within the high category across the three aspects awareness, familiarity, and fluency. This indicates that teachers hold a positive view of assessment approaches that evaluate student's critical thinking, creativity, collaboration, and problem solving in authentic ways (Akiri et al., 2021; Jingbo & Ying, 2023; Pullu & Gömleksiz, 2021). The pattern aligns with the view that teacher beliefs play a central role in shaping the adoption of instructional and assessment innovations (Kyza & Georgiou, 2025). Previous work also notes that teachers who hold positive perceptions of STEM tend to be more prepared to integrate interdisciplinary approaches and performance-based assessment into classroom practice (Chen et al., 2025). Awareness being slightly lower than familiarity and fluency suggests a gap between teachers recognizing the importance of STEM and understanding how it influences assessment design (Lin et al., 2022). Strengthening teacher's conceptual grounding through structured professional development can help shift their knowledge from declarative to applied, enabling them to design performance assessments that are coherent with the needs of 21st century learning.

Teacher's familiarity with STEM reflects a solid understanding of the basic concepts and their connection to assessment, although much of this knowledge remains conceptual rather than translated into practice. This pattern is consistent with Gardner et al., (2019) who found that many teachers are familiar with STEM terminology but struggle to operationalize it in integrated assessment tasks. Berry et al., (2025) emphasize that deeper familiarity requires teachers to draw on both content and pedagogy in ways that support authentic and contextual performance assessment. Challenges in rubric development, project organization, and assessment of collaboration and problem solving highlight the need for stronger pedagogical support. The TPACK framework (Mishra & Koehler, 2006; Saili & Taat, 2023) reinforces this point by showing that effective STEM assessment depends on a teacher's ability to blend content, pedagogy, and technology. Without this pedagogical grounding, familiarity often remains superficial and insufficient for constructing comprehensive assessment indicators. Practice based training, rubric development workshops, and collaborative teacher forums can strengthen familiarity and help teachers refine the way they design STEM based assessments.

Teacher's fluency emerged as the highest of the three aspects, indicating a relatively strong level of confidence in implementing STEM based performance assessment (Liu & Lian, 2026). The interviews show that this confidence does not always reflect technical or pedagogical readiness. Several teachers still struggle with developing integrative rubrics or maintaining consistency in project-based assessment. Myyrya et al., (2022) notes that teacher self efficacy does not always correspond to well developed assessment design skills. Vlachopoulos & Makri, (2024) also points out that authentic assessment requires opportunities for students to apply ideas in real contexts, which demands a strong command of assessment design. Mayantao & Tantiado, (2024) found that teacher's confidence in using technology is shaped by their hands on experience, suggesting that fluency improves through repeated practice, professional mentoring, and exposure to adaptable rubric examples. These findings indicate that high fluency benefits from ongoing technical and pedagogical support so that confidence aligns with actual implementation skills.

The second research question, which compares urban and rural teachers, reveals an unexpected pattern. Teachers in rural schools reported higher scores across all three aspects,

challenging the common assumption that better infrastructure in urban schools leads to stronger readiness for STEM assessment. Research on rural education suggests that limited facilities often encourage teachers to be more adaptive, creative, and contextual in using their surroundings as learning resources (Holmes et al., 2021). The interview data support this view. Rural teachers tend to connect STEM activities with nature-based tasks, local wisdom, and community practices, while urban teachers point more frequently to structural constraints such as administrative workload and limited training opportunities. This aligns with literature that highlights the contribution of local wisdom and community-based approaches in supporting STEM teaching and assessment in rural settings (Herliani et al., 2021). These geographical, social, and pedagogical factors help explain why rural teachers show higher fluency even with fewer physical resources.

The differences between urban and rural teachers indicate that teacher capacity building should not rely on a uniform model. Urban teachers benefit from structured technical assistance, access to clearer assessment guidelines, and stronger support for technology integration and project management. Rural teachers need greater access to formal training, digital resources, and consistent mentoring (Kusin, 2022). Earlier studies also demonstrate that positive perceptions alone do not ensure successful implementation unless supported by school policy, allocated time for project work, and coordinated efforts among teachers (Chafouleas et al., 2021). Capacity building programs that acknowledge geographical realities and local needs can strengthen teacher's ability to design and implement STEM based performance assessment in meaningful and sustainable ways. These findings offer direction for policymakers, teacher training institutions, and primary schools in designing professional development that is contextually grounded and responsive to classroom realities (Arnab et al., 2025).

CONCLUSION

The study shows that elementary teacher's perceptions of STEM based performance assessment fall within the high category across the three indicators awareness, familiarity, and fluency. Teachers recognize the value of assessing students through authentic tasks that highlight critical thinking, creativity, collaboration, and problem solving. The comparison between urban and rural contexts reveals a consistent pattern in which rural teachers report higher scores on all indicators. Rural teachers tend to view STEM assessment as closely connected to contextual learning and community -based experience, while urban teachers describe challenges linked to administrative demands and limited technical training. The combination of these findings provides a clear picture of how teacher's perceptions are shaped by their instructional environment and how geographical conditions influence their readiness to apply STEM based performance assessment. This research was conducted with a relatively small sample and relied on descriptive analysis, which limits the extent to which broader generalizations can be made. Even so, the study offers practical contributions for strengthening teacher preparation, especially in designing performance assessments that integrate STEM principles. The findings can inform policy development, guide teacher training programs, and support schools in creating assessment practices that respond to local conditions. Future studies may expand the sample, incorporate inferential techniques, or explore how specific school level factors influence teacher's perceptions and implementation practices. Such research can deepen understanding of how STEM based assessment develops

across diverse educational settings and contribute to more equitable approaches in primary education.

REFERENCES

Akiri, E., Tor, H. M., & Dori, Y. J. (2021). Teaching and Assessment Methods: STEM Teachers' Perceptions and Implementation. *Eurasia Journal of Mathematics, Science and Technology Education*, *17*(6).

Ammar, M., Al-Thani, N. J., & Ahmad, Z. (2024). Role of pedagogical approaches in fostering innovation among K-12 students in STEM education. *Social Sciences & Humanities Open*, *9*, 100839.

Arlinwibowo, J., Retnawati, H., Pradani, R. G., & Fatima, G. N. (2023). STEM implementation issues in Indonesia: Identifying the problems source and its implications. *The Qualitative Report*, *28*(8), 2213–2229.

Arnab, S., Masters, A., Purnomo, R. A., Mahon, D., & Minoi, J.-L. (2025). Playful and frugal learning design: A value-based approach to inclusive and sustainable STEM education. *Social Sciences & Humanities Open*, *12*, 101923. https://doi.org/https://doi.org/10.1016/j.ssaho.2025.101923

Berry, A., Carpendale, J., & Mulhall, P. (2025). Understanding Secondary Inservice Teachers' Perceptions and Practices of Implementing Integrated STEM Education. *Education Sciences*, *15*(2), 255.

Chafouleas, S. M., Iovino, E. A., & Stokes, H. E. (2021). Engaging a Whole Child , School , and Community Lens in Positive Education to Advance Equity in Schools. *Frontiers in Psychology*, *12*(December), 1–11. https://doi.org/10.3389/fpsyg.2021.758788

Chang, D., Hwang, G.-J., Chang, S.-C., & Wang, S.-Y. (2021). Promoting students' cross-disciplinary performance and higher order thinking: A peer assessment-facilitated STEM approach in a mathematics course. *Educational Technology Research and Development*, *69*(6), 3281–3306.

Chaya, H. (2023). Investigating Teachers ' Perceptions of STEM Education in Private Elementary Schools in Abu Dhabi. *Journal of Education and Learning*, *12*(2), 60–78. https://doi.org/10.5539/jel.v12n2p60

Chen, M., Guo, C., Tseng, L., Chiu, M., & Weng, H. (2025). Understanding Teachers' Interdisciplinary Role Perceptions: Scale Development and Importance–Performance Analysis. *Psychology in the Schools*.

Cheng, C., & Weatherly, K. I. C. H. (2025). Navigating the Double-Edged Sword: A Meta-analysis of the Effect of Digital Games on 21st Century Skills. *Educational Research Review*, 100710.

DeCoito, I., & Myszkal, P. (2018). Connecting science instruction and teachers' self-efficacy and beliefs in STEM education. *Journal of Science Teacher Education*, *29*(6), 485–503.

Drolet, M.-J., Rose-Derouin, E., Leblanc, J.-C., Ruest, M., & Williams-Jones, B. (2023). Ethical issues in research: Perceptions of researchers, research ethics board members and research ethics experts. *Journal of Academic Ethics*, *21*(2), 269–292.

Gardner, K., Glassmeyer, D., & Worthy, R. (2019). Impacts of STEM professional development on teachers' knowledge, self-efficacy, and practice. *Frontiers in Education*, *4*, 26.

Golzar, J., Noor, S., & Tajik, O. (2022). Convenience sampling. *International Journal of Education & Language Studies*, *1*(2), 72–77.

Guerra-Macías, Y., & Tobón, S. (2025). Development of transversal skills in higher education programs in conjunction with online learning: relationship between learning strategies, project-based pedagogical practices, e-learning platforms, and academic performance. *Heliyon*, *11*(2).

Han, Z., So, W. W. M., & Wan, Z. H. (2024). Challenges in assessing students' STEM-based problem solving. *Ways of Thinking in STEM-Based Problem Solving*, 250–262.

Herliani, E., Karyana, S., & Nulhakim, L. (2021). Implementation of STEM Local Context in Indonesia Dr. Elly Herliani 1 , Septian Karyana, M.Si 2 , Lukman Nulhakim, M.Pd 3. *SEAQIS Journal of Science Education (SciEd)*, *1*(1), 6–17.

Holmes, K., Mackenzie, E., Berger, N., & Walker, M. (2021). Linking K-12 STEM Pedagogy to Local Contexts : A Scoping Review of Bene fi ts and Limitations. *Frontiers in Education*, *6*(August), 1–10. https://doi.org/10.3389/feduc.2021.693808

Hong, S., Eom, T., & Moon, J. (2025). Virtual reality simulation to foster authentic learning in pre-service teacher education: A systematic literature review. *Educational Research Review*, 100743.

Jingbo, H., & Ying, L. (2023). Holistic language learning: implementing authentic assessment to cultivate 4c skills in Chinese university English course. *Advances in Educational Technology and Psychology*, *7*, 126–130.

Kurup, P. M., Li, X., Powell, G., & Brown, M. (2019). Building future primary teachers' capacity in STEM: based on a platform of beliefs, understandings and intentions. *International Journal of STEM Education*, *6*(1), 10.

Kusin, S. M. (2022). Teachers' Teaching Capability in Urban and Rural Areas: A Comparative Study. *International Journal Of Multidisciplinary: Applied Business And Education Research*, *3*(11), 2432–2439. https://doi.org/10.11594/ijmaber.03.11.26

Kyza, E. A., & Georgiou, Y. (2025). Teachers' psychological ownership as a lens for understanding the adoption of pedagogical innovations: A situated perspective. *Learning in Context*, *2*(1), 100011. https://doi.org/https://doi.org/10.1016/j.lecon.2025.100011

Leavy, P. (2022). *Research design: Quantitative, qualitative, mixed methods, arts-based, and community-based participatory research approaches*. Guilford publications.

Lin, P.-Y., Chai, C. S., Di, W., & Wang, X. (2022). Modeling Chinese teachers' efficacies for the teaching of integrated STEM with interdisciplinary communication and epistemic fluency. *Frontiers in Psychology*, *13*, 908421.

Liu, W., & Lian, Z. (2026). Navigating open-ended STEM challenges under uncertainty: A mixed-method experimental study on grit, delay of gratification, and emotion regulation in problem-based learning. *Learning and Motivation*, *93*, 102223. https://doi.org/https://doi.org/10.1016/j.lmot.2025.102223

Mayantao, R., & Tantiado, R. C. (2024). Teachers ' Utilization of Digital Tools and Confidence in Technology. *INTERNATIONAL JOURNAL OF MULTIDISCIPLINARY RESEARCH AND ANALYSIS*, *07*(05), 1945–1952. https://doi.org/10.47191/ijmra/v7-i05-16

Mesny, A., Roberge-Maltais, I., & Galy, A. (2026). Innovative assessment and grading practices in higher education: a critical exploration for management educators. *The International Journal of Management Education*, *24*(1), 101307.

Mishra, P., & Koehler, M. J. (2006). Technological Pedagogical Content Knowledge: A Framework for Teacher Knowledge. *Teachers College Record: The Voice of Scholarship in Education*, *108*(6), 1017–1054. https://doi.org/10.1177/016146810610800610

Myyrya, L., Karaharju-Suvantob, T., Virtalac, A.-M. K., Raekalliod, M. R., Salminene, O., Vesalainenf, M., & Nevg, A. (2022). How self-efficacy beliefs are related to assessment practices : A study of experienced university teachers. *Assessment & Evaluation in Higher Education*, *47*(1), 155–168. https://doi.org/https://doi.org/10.1080/02602938.2021.1887812

Osiesi, M. P., & Blignaut, S. (2025). Impact of the teacher education curriculum on the development of 21st-Century skills: Pre-service teachers' perceptions. *Social Sciences & Humanities Open*, *11*, 101317.

Papagiannopoulou, T. (2024). Teachers ' Attitudes Towards STEM Education : Exploring the Role of Their Readiness via a Structural Equation Model. *European Journal of Investigation in Helath, Psychology, and Education*, 2850–2864.

Peddle, M., Jackson, M., Searby, A., & Alexander, L. (2025). Influence of simulation on the knowledge, skills, and confidence of entry-to-practice nursing students to recognise and respond to occupational violence and aggression: A scoping review. *Nurse Education Today*, 106939.

Persada, Y. I. P., Oktarianto, M. L., Wibowo, S., & Ai, K. (2025). The influence of technological skills and geographical conditions on elementary school teachers' readiness for implementing DL. *Jurnal Bidang Pendidikan Dasar*, *9*(2), 178–185.

Pullu, E. K., & Gömleksiz, M. N. (2021). Authentic teaching tasks for academic success, attitude, problem solving, and creative thinking skills. *Discourse and Communication for Sustainable Education*, *12*(2), 108–123.

Roebianto, A., Savitri, S. I., Aulia, I., Suciyana, A., & Mubarokah, L. (2023). Content validity: Definition and procedure of content validation in psychological research. *Testing, Psychometrics, Methodology in Applied Psychology (TPM)*, *30*(1), 5–18.

Saili, J., & Taat, M. S. (2023). *Enhancing the Creativity of Islamic Education Teaching through the TPACK Approach : A Conceptual Review*. *12*(4), 1503–1517. https://doi.org/10.6007/IJARPED/v12-i4/20311

Samara, V., & Kotsis, K. T. (2023). Primary school teachers' perceptions of using STEM in the classroom attitudes, obstacles, and suggestions: A literature review. *Contemporary Mathematics and Science Education*, *4*(2), ep23018.

Saubern, R., Henderson, M., Heinrich, E., & Redmond, P. (2020). TPACK–time to reboot? *Australasian Journal of Educational Technology*, *36*(3), 1–9.

Sihombing, R. A., Muslim, M., Rahman, T., & Winarno, N. (2024). Enhancing Quality Education in Indonesia: A Literature Review of STEM-ESD Landscape Contributions. *Journal of Science Learning*, *7*(3), 213–226.

Squires, V. (2023). Thematic analysis. In *Varieties of qualitative research methods: Selected contextual perspectives* (pp. 463–468). Springer.

Sugiyono. (2023). Metode Penelitian Kuantitatif Kualitatif dan R&D. In Sutopo (Ed.), *Sustainability (Switzerland)* (5th ed., Vol. 11, Issue 1). ALFABETA. http://scioteca.caf.com/bitstream/handle/123456789/1091/RED2017-Eng-8ene.pdf?sequence=12&isAllowed=y%0Ahttp://dx.doi.org/10.1016/j.regsciurbeco.2008.06.005%0Ahttps://www.researchgate.net/publication/305320484_SISTEM_PEMBETUNGAN_TERPUSAT_STRATEGI_MELESTARI

Thi To Khuyen, N., Van Bien, N., Lin, P.-L., Lin, J., & Chang, C.-Y. (2020). Measuring teachers' perceptions to sustain STEM education development. *Sustainability*, *12*(4), 1531.

Vlachopoulos, D., & Makri, A. (2024). A systematic literature review on authentic assessment in

higher education: Best practices for the development of 21st century skills, and policy considerations. *Studies in Educational Evaluation*, *83*, 101425. https://doi.org/https://doi.org/10.1016/j.stueduc.2024.101425

Wajnah, W., Kusmawan, U., Arifin, S., Muhammadiyah, M. ud, & Arsyad, M. (2025). Technology-Based Learning Innovation in Community Service: Impact on Improving Education Access in Remote Areas. *Journal Of Human And Education (JAHE)*, *5*(2), 137–144.

Yang, W., Liang, L., Xiang, S., & Yeter, I. H. (2025). Making a Makerspace in early childhood education: Effects on children's STEM thinking skills and emotional development. *Thinking Skills and Creativity*, *56*, 101754.

Yar, F. G. M., & Shaheedzooy, M. I. (2023). The role of environmental and geographical factors in the education process. *Journal of World Science*, *2*(12), 2017–2099.