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Glocalizing Integrated STEM: Policy Translation and Teacher Perspectives in Urban West Jakarta

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ABSTRACT
This study describes the translation of global policies on integrated STEM into local classroom practices by elementary school teachers in West Jakarta through a glocalization lens. It fills a gap in the literature on non-Western urban contexts where environmental challenges such as flooding shape everyday teaching. A sequential explanatory mixed-methods design was utilized. In the quantitative phase, 94 teachers from six districts completed a 39-item survey that measured STEM knowledge, self-efficacy, barriers, and local relevance. Stratified random sampling was used to ensure district representation. In the qualitative phase, 12 teachers were purposively selected, and semi-structured interviews were conducted and analyzed with reflexive thematic analysis based on glocalization theory. The results show a paradox: teachers strongly believe in the importance of STEM in elementary education (M = 4.68). However, they are not confident in designing integrated lessons (M = 3.42) and applying engineering design (M = 3.38). Teachers in flood-prone districts (Cengkareng and Kalideres) gave higher marks to the community relevance of STEM than teachers in more developed areas, demonstrating how contextual adaptation is driven by local environmental challenges. Qualitative analysis revealed teachers' active glocalization through the integration of local flooding, waste management, traditional markets, and community recycling into STEM lessons. Collaborative Networks Build Confidence: Teachers who worked with peers regularly (weekly or biweekly) expressed greater self-efficacy and persistence. Curriculum constraints (M = 4.21) and limited preparation time (M = 4.18) were the main barriers. The study concludes that three systemic interventions are needed for sustainable STEM integration. These include reforming pre-service curricula to include interdisciplinary STEM design, allocating infrastructure grants to resource-constrained, flood-prone districts, and replacing one-shot workshops with sustained school-based coaching and professional learning communities. Meaningful reform must place teachers as active agents of glocalization.

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■ INTRODUCTION

STEM education has become a policy priority across the world, closely linked with economic growth, technological advancement, and national competitiveness. Governments from the US to Singapore and from Finland to South Africa have launched integrated STEM initiatives to prepare students for the complex, interdisciplinary problem-solving needed in the 21st century. Typically, these reforms are not offered as suggestions but as models to be followed by all, supported by international comparisons and global performance indicators including PISA and TIMSS (Yi et al., 2024). The problem is, what works in one education system does not necessarily translate to another. However, the transnational flow of STEM policies, however well-intentioned, does not necessarily ensure their relevance or efficacy when introduced into very different classroom contexts, particularly in the densely populated urban areas of the Global South.

When global reform agendas hit local school systems, they encounter particular cultural norms, long institutional histories, and material conditions that can either support or inhibit meaningful change. This interaction is particularly challenging in densely populated urban areas such as West Jakarta, where schools often operate under very difficult circumstances: limited physical infrastructure, limited access to quality professional development, and a very uneven distribution of resources across neighborhoods. Choose any public elementary school in Kalideres or Cengkareng; the principal might be a real STEM lover. However, the science tools are limited to a couple of old thermometers, a globe with peeling paint, and perhaps one computer for thirty-five students. The idea that STEM implementation is a simple policy adoption is missing the point entirely in such contexts (Gaab & Duggan, 2024). What really occurs is a messy, creative, and often maddening reinterpretation shaped by the day-to-day realities of the classroom and the instantaneous decisions teachers make.

This process can be well understood through the concept of glocalization. Glocalization is not about global and local forces as opponents in a zero-sum game but about how global ideas are reconstructed by everyday local practice (Roudometof, 2016). Alternatively, a curriculum guide for STEM written in Boston or London does not land in West Jakarta as a sacred text to be followed to the letter. Educational reforms, such as integrated STEM, do not travel unaltered; they are negotiated, adapted, contested and sometimes fundamentally transformed along the way. Teachers are central to this translation work – they are the ones who, in the end, decide what a policy expectation really looks like when thirty children are looking back at them on a Tuesday morning.

So what do we really know from existing research about integrated STEM in elementary schools? Quite a lot, but mostly from the well-resourced educational systems. Research indicates that interdisciplinary and project-based STEM subject matter may enhance collaboration, critical thinking, and basic technological literacy (Sumarni et al., 2025; Pérez Torres et al., 2024). Teachers in countries such as Finland, Australia, and parts of the United States have documented that engineering design challenges and community-based investigations are used to make abstract concepts stick (Filipe et al., 2024; Cordaro et al., 2025). However, most of this evidence comes from contexts where infrastructure is reasonably reliable, class sizes are manageable, and teachers have regular access to professional learning. Nevertheless, little attention has been paid to how these same approaches play out in crowded urban Southeast Asian settings, where socioeconomic disparities are stark, where flooding and waste management are not just topics in a curriculum but weekly realities, and where a teacher may have thirty-five students and exactly one working computer. This gap is not simply academic; it has direct implications for policy and practice.

In the Indonesian context, the challenges are even sharper. Integrated STEM is often defined by interdisciplinary learning, project-based inquiry, and real-world problem solving, all of which sound good in theory. However, almost none of the evidence available today is grounded in the urban Indonesian classroom where socioeconomic disparities are not abstract statistics but daily constraints. Environmental pressures as varied as repeated floods, overflowing waste disposal sites, and polluted neighborhood canals are not just textbook examples; they are everyday influences on what can be taught on any given day. We know surprisingly little about how global STEM models work in places such as West Jakarta, and this lack of evidence leaves policymakers flying blind. When we look across the literature, a curious pattern emerges. STEM policy, urban education, and teacher beliefs research, researchers tend to work in silos and rarely talk to each other. As a result, we have surprisingly little knowledge of how global STEM agendas are actually translated inside urban schools from the perspective of the people doing the translating: teachers themselves (Bertrand & Namukasa, 2023).

This study discusses three major gaps: the limited number of empirical studies on STEM policy translation in non-Western urban settings; the little-understood role of teacher agency in glocalizing global reforms; and the lack of attention to the impact of local environmental challenges (such as flooding) on teachers' STEM perceptions and practices. If we do not examine how educators interpret, resist, or creatively adapt integrated STEM through a glocalization lens, the entire dynamics of global-local interaction remain under-explored, and our policy recommendations risk being irrelevant. This study addresses these gaps by examining the translation of integrated STEM policies in urban West Jakarta through the lens of elementary teachers. The study is guided by the following research questions:

1. How do teachers understand and interpret global STEM reform narratives?
2. What adaptations, resistances, or creative adjustments do they make to fit these reforms to local environmental and cultural conditions?
3. What are the challenges and opportunities they experience in trying to implement integrated STEM day-to-day?

Applying thematic analysis guided by glocalization theory (Imaduddin et al., 2025), we position teachers as active agents rather than passive recipients of policy, and whose everyday decisions determine what STEM education is. Drawing on teachers' voices, this article offers a more grounded and context-sensitive understanding of STEM reform (Cordaro et al., 2025). Our basic argument is straightforward: sustainable innovation in urban education depends not only on global policy alignment but also on real local interpretation – and that means listening hard to the teachers on the ground.

■ METHOD

Research Design and Approach

This study employed a mixed-methods explanatory sequential design to examine how elementary school teachers in West Jakarta translate integrated STEM policies into their classroom practices. The quantitative phase involved collecting survey data from 94 teachers across six districts, measuring their perceptions, confidence levels, and implementation strategies regarding integrated STEM education. This initial phase established broad patterns in teacher perspectives that warranted deeper qualitative exploration.

The qualitative phase subsequently explored these quantitative findings through semi-structured interviews and thematic analysis, drawing upon the glocalization framework (Imaduddin et al., 2025). This framework recognizes that global STEM education principles must be adapted to local contexts, incorporating teachers' cultural knowledge and community-specific challenges. The thematic analysis specifically examined how teachers navigated the tension between international STEM standards and the realities of their West Jakarta classrooms.

The integration of both phases followed a convergent triangulation approach, wherein statistical patterns were enriched by thematic insights into the contextual factors shaping teacher perspectives. This methodological choice aligned with the Social-Ecological Systems perspective (A. Alam & Mohanty, 2024), acknowledging that effective STEM integration requires understanding the complex interplay between global policies, local teacher agency, and community-specific challenges. The design ultimately positioned teachers as active agents in the glocalization process rather than passive recipients of external reforms.

This study reveals that elementary school teachers in West Jakarta actively function as glocalization agents who adapt integrated STEM policies to their specific classroom contexts rather than simply implementing external mandates. The mixed-methods approach captured both the breadth of teacher perspectives across 94 respondents and the depth of their experiences navigating the tension between global STEM principles and local educational realities. Teachers' confidence levels, resource access, and perceptions of STEM relevance to students' urban daily lives emerged as critical factors shaping successful policy translation. These findings underscore that meaningful STEM integration in diverse Indonesian educational landscapes requires professional development programs that prioritize teacher agency and contextual adaptation alongside traditional content knowledge.

Theoretical Framework

This study is based on the premise that STEM education is not separate from the complex social and ecological systems in which teachers and students live and work. (Alam & Mohanty, 2024). Alam et al. (2025) argued that meaningful STEM integration is contingent upon understanding the relationship between teachers, communities, and environments, as classroom practices are inevitably reflective of the broader community values and environmental contexts. The Social-Ecological Systems perspective conceptualizes teachers as embedded agents rather than isolated instructors, whose pedagogical decisions are informed by local resources, cultural norms, and community challenges. This foundational lens recognizes that effective STEM education must be responsive to the entire ecosystem around each school, not treating classrooms as closed systems.

This ecological understanding then informs our application of the glocalization framework as outlined by Imaduddin et al. (2025). Their work is specifically on water literacy in science education for sustainability, but the core logic of glocalization, that global ideas need to be reshaped by local practice, applies directly to our context. Water-related environmental issues are a natural entry point for integrated STEM lessons, as West Jakarta's elementary schools suffer from recurring flooding, polluted canals, and water management problems. So, although Imaduddin et al. were concerned with water literacy, their perspective of glocalization can be applied to our study, in which teachers adapt global STEM principles to local flood risks and community water problems. This approach recognizes that global educational reforms cannot be simply imported or imposed but must be adapted to the local school contexts. In West Jakarta, teachers are actively negotiating between international STEM standards and their students' daily realities, including urban environmental challenges such as seasonal flooding. Through the lens of glocalization, local educators are seen as important translators who adapt global principles, especially those related to environmental sustainability, into contextually relevant classroom practices.

The framework also includes the idea that sustainable program transformation over time is driven by long-term teacher collaboration (as documented in the PULSE Midwest and Great Plains Regional Network study, Allen et al., 2025). Collaborative engagement allows educators to build collective capacity so that they can confront challenges, pool resources, and adapt their approaches over time. This collaborative aspect is directly related to the real-world project-based learning approach (Naseer et al., 2025), in which real-world problems are embedded into classrooms to give students immediately relevant STEM experiences. Together, these interconnected elements form a comprehensive theoretical foundation for understanding how teachers in West Jakarta translate integrated STEM policies into locally meaningful educational practices.

The study's findings indicate that teachers in elementary schools in West Jakarta are not passive recipients of external mandates, but instead act as crucial glocalization agents by actively localizing global STEM principles to their particular classroom contexts. The social-ecological systems perspective highlights how teachers' pedagogical decisions are grounded in local resources, cultural norms, and community challenges that reach far beyond the walls of schools. Long-term collaboration among educators is a key driver for sustainable program transformation, enabling teachers to collectively navigate challenges and develop STEM approaches that are meaningful in context (Cordaro et al., 2025). Real-world project-based learning ultimately provides the pedagogical bridge between theoretical frameworks and students' lived experiences, ensuring that integrated STEM education is relevant responsive to local community needs.

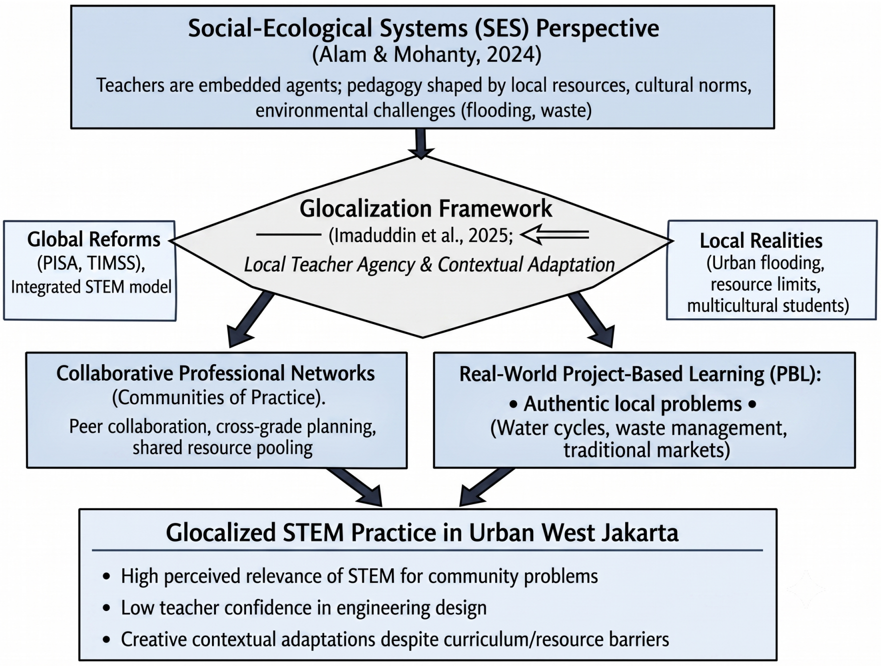

Figure 1. Theoretical framework

Study Context and Participants

This study was conducted in West Jakarta, a densely populated urban area where global and local Indonesian cultural traditions intersect to produce educational practices and teachers' perspectives. The area is divided into six administrative districts, namely Cengkareng, Grogol Petamburan, Kalideres, Kebon Jeruk, Kembangan and Palmerah, with different socioeconomic conditions and community characteristics. However, not all six districts provided an adequate number of respondents for comparative analysis at the district level. As will be explained in the sampling section, only four districts (Cengkareng, Kalideres, Grogol Petamburan, and Palmerah) had sufficient survey respondents ($n \geq 10$ per district) to produce stable mean estimates for cross-district comparison. The other two districts (Kebon Jeruk and Kembangan) had very small subsamples ($n = 5$ and $n = 4$, respectively) and were thus excluded from the disaggregated analysis in Table 3 and the bar charts. However, their data are still included in the overall descriptive statistics (e.g., overall mean scores for the total sample of 94 teachers). The approach is transparent and avoids the problem of making misleading comparisons based on very small subsample sizes.

The population of the research was all the elementary school teachers in 6 sub-districts of West Jakarta. There were some 370 elementary school teachers in the public schools in the districts of Cengkareng, Grogol Petamburan, Kalideres, Kebon Jeruk, Kembangan and Palmerah in the 2025/2026 academic year, the data from the West Jakarta Education Authority showed. The population distribution per district was as follows: Cengkareng (68 teachers), Grogol Petamburan (72), Kalideres (65), Kebon Jeruk (28), Kembangan (26), and Palmerah (111). Using proportional stratified random sampling, we aimed to draw approximately 18% of the population from each district. This gave target samples of 17 for Cengkareng, 18 for Grogol Petamburan, 16 for Kalideres, 7 for Kebon Jeruk, 7 for Kembangan, and 28 for Palmerah (total target 93). The actual achieved samples were 18, 19, 17, 5, 4, and 31, respectively. The low response rates in Kebon Jeruk and Kembangan (5 instead of 7, and 4 instead of 7) resulted in subsamples too small for stable district-level comparisons. Therefore, these two districts were excluded from disaggregated analyses (Table 3), but their data remain included in the overall sample statistics (N = 94).

Initially, the Slovin formula was considered for determining an adequate sample size; however, as a 10% margin of error is generally deemed too large for rigorous educational research, a more conservative approach was adopted. The minimum sample size was initially estimated using Krejcie and Morgan's (1970) table, which suggested approximately 186 respondents for a population of 370 teachers (95% confidence level, 5% margin of error). Subsequently, due to constraints regarding resources and access, a power analysis was conducted using G*Power software (Faul et al., 2009). This analysis indicated a minimum requirement of 80 participants for a descriptive study with a medium effect size (d = 0.5). To balance statistical adequacy with practical feasibility, and to account for potential attrition, 100 teachers were invited to participate. Of these, 94 completed the survey, yielding a 94% response rate. Although this sample size falls below the Krejcie and Morgan recommendation, it exceeds the GPower minimum and is considered adequate for descriptive statistical analysis and exploratory mixed-methods research. Furthermore, a stratified random sampling technique was employed to proportionally represent the number of teachers per district. Consequently, the 94 respondents provided sufficient variation for the subsequent qualitative thematic analysis within the explanatory sequential design. The participating educators were distributed across various grade levels and schools characterized by differing resource availability, administrative support structures, and community engagement patterns. Reflecting the challenges reported by Cordaro et al. (2025), many of these urban teachers faced limited professional development opportunities for STEM integration and the necessity of balancing content coverage with inquiry-based practices. Ultimately, their experiences yielded valuable insights into the implementation of global STEM education policies within Indonesia's complex urban educational landscape.

Consistent with the social-ecological systems view expressed by Pérez Torres et al. (2024), these teachers did not work in isolation, but in interrelated networks of colleagues, school administrators, students' families, and community organizations. Their perceptions of integrated STEM were formed by formal training. However, it was also shaped through everyday interactions with students dealing with real-world issues of urban flooding, waste management, and environmental health, consistent with the project-based learning approaches proposed by Naseer (2025). Thus, the study sample comprised teachers whose professional identities and pedagogical decisions reflected the complex negotiations between global educational discourses and the local, situated realities of communities in West Jakarta. This was consistent with the glocalization framework, in which participants were treated as engaged actors in the translation of international STEM principles into locally relevant classroom practices.

In the case of West Jakarta, the teachers in this study were negotiating the complex intersection of global STEM movements and the urgent environmental and social realities of their urban communities. The 94 participating educators represent a range of districts and school settings, providing rich insights into how local factors shape the capacity for STEM implementation. Their perspectives were embedded in interrelated networks of colleagues, families, and community organizations, in keeping with social-ecological systems thinking. These findings indicate that West Jakarta teachers are significant glocalization agents who transform international STEM principles into local meaningful practices that correspond to their students' authentic needs.

For the qualitative phase, purposive sampling was used to recruit participants for semi-structured interviews from the 94 survey respondents. Selection criteria were created to capture maximum variation in teacher views and included: (a) teaching experience (novice, 2–5 years; mid-career, 6–10 years; veteran, >10 years), (b) grade level taught (lower grades, 1–3; upper grades, 4–6), and (c) prior STEM training background (teachers who had previously participated in at least one professional development program focused on STEM and teachers who had no prior professional development training focused on STEM). Based on these criteria, twelve teachers purposively selected for interview.

Initially, the objective was to include at least two teachers from each of the six districts. However, the recruitment of interview participants from the Kebon Jeruk and Kembangan districts was precluded by logistical challenges and low response rates. Consequently, the qualitative findings predominantly reflect the perspectives of teachers in the remaining four districts: Cengkareng, Kalideres, Grogol Petamburan, and Palmerah. While the quantitative survey was completed by educators across all six districts, the district-level descriptive analysis (Table 3) includes only the four districts with an adequate number of respondents ($n \geq 10$ per district) to ensure meaningful mean comparisons. Data from Kebon Jeruk ($n = 5$) and Kembangan ($n = 4$) were incorporated into the overall descriptive statistics but were excluded from the district-specific breakdowns due to their small subsample sizes. This purposeful sampling approach aligns with the explanatory sequential design, enabling the qualitative phase to target information-rich cases capable of providing deep insights into the quantitative patterns identified in the survey. Furthermore, a district-based stratified random sampling technique was utilized for the quantitative survey; within each stratum, teachers were randomly selected without the application of additional purposive criteria to maximize the generalizability of the descriptive findings.

Figure 2. West jakarta map
(Source: https://pa-jakartabarat.go.id/wilayah-yurisdiksi/)

Instrumentation and Data Collection

The survey instrument was composed of 39 items developed to measure multiple dimensions of teachers' perspectives of integrated STEM education in their West Jakarta classrooms. These items were adapted

Figure 1. Digital reading environment used in the six-week reading cycle

from validated scales from previous studies, such as the Predictors of Scientific Civic Engagement Survey developed by Alam, and the competency frameworks for sustainability education described by Cordaro (A. Alam & Mohanty, 2024; Cordaro et al., 2025). The instrument included items on teachers' understanding of STEM concepts (8 items), their confidence in using integrated approaches (7 items), the barriers they faced (6 items), their perceptions of the relevance of STEM to the daily lives of students (8 items), demographic information (6 items), and open-ended reflections on glocalization practices (4 items). Table 1 lists a total of 39 items. Five items used a five-point Likert scale.

The survey questions were classified into four sections, corresponding to the focus on glocalization and social-ecological systems thinking in the theoretical framework. The initial section collected demographic information about the teachers' background, such as years of experience, grade levels taught, and the districts where their schools are located. The second section assessed teachers' self-efficacy in STEM instruction based on the science identity and self-efficacy constructs that Alvarez-Berrios and Haynes identified as important predictors of students' success in STEM fields (Alvarez-Berrios & Haynes, 2023). The third section examined teachers' perceptions of barriers to STEM integration. This is consistent with Tomkova's (2025) findings that teachers face challenges with implementing inquiry-based approaches without sufficient preparation and support (Tomková, 2025).

Data were collected over 3 months from December 2025 to February 2026. Surveys were distributed to teachers in all six districts of West Jakarta through the school-based coordinators. Teachers completed the surveys either on paper during a faculty meeting or on an online platform that was easily accessible to all participants. This dual-mode approach increased participation rates and accommodated teachers' differing access to technology and internet connectivity across school settings. The data collection process was voluntary and confidential, and the explanations given were clear about how the data would be used for research purposes to understand and improve STEM education in West Jakarta.

The survey design included aspects of Avci et al.'s (2025) study concerning STEM educators' views on the integration of educational technology, specifically how questions probed teachers' motivations and obstacles. Questions about teachers' professional development experiences and their participation in peer learning networks reflected Allen's findings on the importance of long-term teacher collaboration in program change (Allen et al., 2025). The instrument also included open-ended questions in which teachers described, in their own words, how they adapted STEM concepts to address local community issues, directly operationalizing the glocalization framework developed by Imaduddin (Imaduddin et al., 2025). These qualitative responses provided rich contextual data to supplement the quantitative measures and enabled a deeper thematic analysis of teachers' glocalization practices.

The full survey instrument comprised 39 items across six sections, measuring teachers' STEM knowledge, confidence, perceived barriers, and views on local relevance. These items were adapted from multiple validated sources, including A. Alam & Mohanty (2024) and Cordaro et al. (2025). Data collection was conducted over three months across all six districts in West Jakarta and yielded comprehensive responses from 94 elementary school teachers using paper and online formats. The dual-mode approach ensured maximum participation and accounted for varying levels

Table 1. Survey instrument structure and content

Section	Focus Area	Number of Items	Source/Reference
A	Demographic Information	6	Adapted from Dresser et al. (2025)
B	STEM Content Knowledge and Understanding	8	Cordaro et al. (2025); Tomkova (2025)
C	Self-efficacy and Confidence in STEM Teaching	7	Alvarez-Berrios & Haynes (2024); Alam et al. (2024)
D	Perceived Barriers to STEM Integration	6	Acvi et al. (2025); Naseer et al. (2025)
E	STEM Relevance to Local Context and Community	8	Imaduddin et al. (2025); Alam et al. (2025)
F	Open-Ended Reflections on Glocalization Practices	4	Developed for this study

of technology access across school contexts. Open-ended questions provided rich qualitative data that directly operationalized the glocalization framework by asking teachers to describe their adaptations of STEM concepts to local community needs. Quantitative analysis used descriptive statistics to summarize teachers' responses to the survey items. Means were calculated to indicate average perceptions, and standard deviations to show response variability. These descriptive results were then visualized using bar charts to compare patterns across the six districts of West Jakarta. The complete survey instrument, including all items, is provided in supplementary files.

Ethical Considerations

The research was approved by the Research Ethics Committee of State University of Surabaya. All 94 teachers who participated in the study gave informed consent before data were collected. Teachers were told that participation was voluntary, that they could withdraw at any time, and that their responses would be treated confidentially. Surveys and interviews were conducted without collecting identifying information. All data were stored securely and were used for research purposes only.

Data Analysis Procedures

Descriptive statistics commenced the quantitative analysis, summarising teachers' responses to the 35 Likert-scale survey items (Sections B through E). The four open-ended items (Section F) were set aside for qualitative thematic analysis. Results revealed patterns in teachers' STEM content knowledge, confidence, and most common barriers to integrated instruction. The study used approaches similar to those of Altuwaiji in modeling structural equations for factors affecting career choices in STEM, but the study focused on descriptive patterns, not causal modeling (Altuwaijri et al., 2025). The mean scores and standard deviations provided a clear picture of the collective view of the 94 teachers about integrated STEM education in the six districts of West Jakarta.

The analysis also considered variation in teacher responses by demographic variables such as years of experience, grade levels taught, and district location. The comparison was based on Tomková's findings about the influence of teaching experience on the implementation of STEM, knowing that teachers who are just starting and those who have been in the game for a while may have different ideas and challenges (Tomková, 2025). Data also showed that compared to their peers in other areas, teachers in districts with more environmental challenges, like repeated flooding, were more likely to rate STEM as more relevant to students' lives. The patterns observed at the district level were consistent with the social-ecological systems perspective proposed by Alam, illustrating how local environmental settings influence teachers' perceptions and practices (A. Alam & Mohanty, 2024).

The qualitative analysis was performed using reflexive thematic analysis according to Braun and Clarke's guidelines and coding procedures adapted from Avci (2025). We used NVivo 14 not just as a storage tool but also for its query functions. Specifically, we created thematic nodes, coded interview transcripts line by line, and then ran Matrix Coding Queries to examine how frequently each theme appeared across districts. This allowed us to systematically compare, for example, how often teachers in Cengkareng brought up flooding compared to those in Palmerah. Consistent with the reflexive thematic analysis approach (Braun & Clarke, 2006), we did not calculate inter-coder reliability. Instead, we held regular meetings to compare our interpretations, discuss disagreements, and refine the codebook through consensus. The primary researcher then coded the remaining responses, with ongoing peer debriefing sessions to maintain reflexivity. The final codebook with definitions and example quotes for each theme is included in Appendix A. The coding process was iterative and consisted of several rounds, including weekly meetings among researchers to discuss emerging patterns and refine interpretations. The collaborative approach enhanced the findings, both increasing the trustworthiness of the findings and honoring the reflexive, interpretive nature of qualitative inquiry.

A convergent triangulation method was used to combine the quantitative and qualitative results. To make this integration explicit and transparent, we developed joint-display tables (Fetters et al., 2013) that place the descriptive statistics from SPSS (e.g., mean scores for STEM relevance by district) next to the corresponding thematic codes from NVivo (e.g., quotes about flooding and water cycles). For example, the higher mean scores in Cengkareng and Kalideres directly correlated with teachers' open-ended comments about using the Angke River floods as a teaching context. This visual matching enabled us to visualize convergence, divergence, and expansion across strands of data. We also developed a mixed-methods matrix that linked each quantitative survey item to the qualitative codes that explained or contradicted it. The qualitative themes were not simply color; they added explanatory depth. For example, they explained why teachers in flood-prone districts felt STEM was more relevant (because they saw immediate, tangible problems in their communities). This integrated analysis finally framed the findings in the broader glocalization framework.

Descriptive statistics showed that teachers in all six districts of West Jakarta had different views of STEM integration. Teachers in the districts with environmental problems gave higher scores to the relevance of STEM integration than the other districts. The comparative analysis revealed that variables such as years of teaching experience and district location influenced teachers' confidence and challenges in implementing integrated instruction. Reflexive thematic analysis of open-ended responses revealed glocalization strategies used by teachers, such as adaptation of STEM concepts to local flooding and waste management issues. The convergence of quantitative patterns and qualitative themes ultimately illustrated how teachers in West Jakarta actively translated global STEM principles into locally meaningful educational practices.

Integration and Validation

Quantitative and qualitative findings were integrated using a convergent triangulation approach that systematically compared statistical patterns with thematic insights from teachers' written reflections. This methodology aligned with the postpositivist approach described by Cordaro, recognizing that different data sources can balance the drawbacks of each research method (Cordaro et al., 2025). For example, the quantitative patterns indicated that teachers in flood-prone districts rated STEM relevance higher, and qualitative responses explained this pattern by specifically referencing the use of water cycle concepts to address local flooding concerns. This convergence reinforced the credibility of both data strands and illuminated the glocalization processes that teachers employed in their daily practice. An example of such a joint-display table is presented in Table 2 (see Integration and Validation subsection), where quantitative mean scores for STEM local relevance are directly compared with qualitative themes and quotes from each district."

Table 2. Joint display: quantitative means and qualitative themes for STEM local relevance

District	Quantitative Finding (Mean Score for STEM Local Relevance)	Qualitative Finding (Thematic Code & Example Quote)
Cengkareng (flood-prone)	M = 4.65 (SD = 0.52)	Glocalization Practices: *"I use the annual flooding of the Angke River to teach about water cycles, measurement, and community mapping."*
Kalideres (flood-prone)	M = 4.58 (SD = 0.55)	Community & Student Relevance: *"STEM becomes tangible when we connect it to waste management in our neighborhood. Students see the point immediately."*
Grogol Petamburan (developed)	M = 3.98 (SD = 0.71)	Barriers – Resource Limitations: *"My school lacks basic science equipment. I often purchase materials with my own money."* (*Tema yang berbeda, tidak secara langsung menyebut relevansi lokal*)
Palmerah (developed)	M = 4.02 (SD = 0.68)	Neutral/No explicit glocalization theme

To enhance the credibility of qualitative interpretations, member checking procedures were employed, wherein participating teachers were asked to review preliminary findings and verify their accuracy. These validation sessions involved five teachers from different districts discussing whether the themes identified accurately reflected their experiences and perspectives on integrated STEM education. Their feedback confirmed the key findings but added nuanced details of how teachers adapted STEM concepts to address specific community challenges such as waste management and urban environmental health. This process was in line with the principles of participatory organizational change as described by Van den Beemt, where teachers were active participants in the research process, rather than passive

Figure 2. Individual pretest-posttest score distribution

objects of study (van den Beemt et al., 2023).

Peer debriefing sessions with fellow researchers also helped validate the findings, as they critically examined the emerging themes and offered alternative interpretations. The coding frameworks and thematic analyses were reviewed by three colleagues with expertise in STEM education, qualitative methods, and Indonesian educational contexts, and their constructive feedback shaped the final interpretations. These sessions were informed by the collaborative approaches discussed in the PULSE network study, with the added understanding that multiple perspectives enhance the rigor of qualitative inquiry (Allen et al., 2025). The debriefing process helped ensure the findings were authentic teacher voices while also situated in the broader theoretical framework of glocalization.

Ultimately, the integration process reframed teachers as important glocalization actors, making their daily practices into practices that answered real community needs through the translation of international STEM principles. This interpretation aligned with the findings of Spyropoulou et al. regarding STEM educators' development of expertise through self-directed learning and peer support networks, recognizing that professional growth emerges from situated practice rather than isolated training (Spyropoulou & Kameas, 2024). The validated findings showed that West Jakarta teachers did not simply implement external STEM mandates. However, they actively reshaped them to fit the lived experiences of their students, including environmental challenges and community-specific knowledge. This finding reinforced the theoretical framework of the study, demonstrating how glocalization operates in tangible terms in the complex urban educational context of Indonesia.

In particular, convergent triangulation indicated that teachers in flood-prone districts rated STEM relevance higher. Qualitative responses articulated this pattern with specific references to using water cycle concepts to investigate local flooding issues (Imaduddin et al., 2025). Member checking with participating teachers confirmed the core findings and provided nuanced details about adaptations for waste management and urban environmental health challenges. Peer debriefing with colleagues possessing STEM education and Indonesian context expertise refined the interpretations and ensured they reflected authentic teacher voices. The integration process ultimately demonstrated that West Jakarta teachers function as active glocalization agents who reshape global STEM principles into locally meaningful practices that respond to their students' daily realities.

Data Availability

The complete survey instrument (35 items) is provided in Appendix B. To protect participant confidentiality, the raw survey responses and interview transcripts cannot be publicly shared. However, an anonymized dataset (excluding any identifying information) and full examples of interview excerpts supporting each theme are available from the corresponding author upon reasonable request. The thematic analysis codebook with illustrative quotes is presented in Appendix A.

■ RESULTS AND DISCUSSIONS

Descriptive Statistics of Teacher Perspectives

The analysis of survey data from 94 elementary school teachers in West Jakarta showed that, generally, teachers had positive attitudes toward integrated STEM education in all dimensions measured. Teachers' mean scores were highest on items related to their belief in the importance of STEM for elementary education ($M = 4.68$, $SD = 0.51$) and their perception that STEM makes learning more meaningful for students ($M = 4.62$, $SD = 0.55$). Lowest mean scores for the full sample ($N = 94$) were found for the items related to teachers' confidence in designing STEM activities ($M = 3.42$, $SD = 0.89$) and perceived ability to integrate multiple subject areas into cohesive STEM lessons ($M = 3.51$, $SD = 0.92$). The full sample means include teachers from all six districts, including Kebon Jeruk ($n = 5$) and Kembangan ($n = 4$), whose data are not separately presented in the district-level breakdown (Table 3) due to small subsample sizes. Responses of teachers to all 39 items have moderate variability with standard deviations ranging from .48 to .94 and can be further explored qualitatively.

Review of the answers of teachers by district--which included only the four districts with sufficient respondents (Cengkareng, Kalideres, Grogol Petamburan, and Palmerah, each with $n \geq 10$)--revealed significant differences consistent with local environmental and socioeconomic conditions. The other two districts (Kebon Jeruk and Kembangan) had too few respondents ($n = 5$ and $n = 4$, respectively) to provide stable district-level mean estimates, and their data were only included in the overall sample statistics. Teachers in Cengkareng ($M = 4.65$, $SD = 0.52$) and Kalideres ($M = 4.58$, $SD = 0.55$) gave the relevance of STEM to community problem solving a higher rating than their counterparts in Grogol Petamburan (M = 3.98, SD = 0.71) and Palmerah (M = 4.02, SD = 0.68). Female teachers (77.66% of the sample) reported slightly higher scores than their male colleagues on items measuring collaboration and student-centered learning. Years of teaching experience showed a modest positive correlation with self-efficacy scores ($r = 0.29$, $p = 0.02$). As presented in Table 5, a one-way ANOVA revealed significant differences across teaching experience groups for both openness to STEM innovation ($F(2, 91) = 4.87$, $p = 0.010$) and implementation anxiety ($F(2, 91) = 6.15$, $p = 0.003$). Post-hoc comparisons using Tukey HSD indicated that novice teachers (2–5 years) scored significantly higher on openness compared to veterans (>10 years, $p = 0.009$). Novice teachers reported significantly higher anxiety than both mid-career (6–10 years, $p = 0.018$) and veteran teachers ($p = 0.002$).

Table 3. Mean scores (SD) for key STEM perception items by district

District	STEM Importance	STEM Meaningful	Confidence Design	Integration Ability
Cengkareng	4.72 (0.48)	4.68 (0.52)	3.55 (0.85)	3.62 (0.88)
Kalideres	4.68 (0.51)	4.65 (0.54)	3.48 (0.87)	3.58 (0.90)
Grogol Petamburan	4.45 (0.62)	4.42 (0.65)	3.28 (0.92)	3.35 (0.95)
Palmerah	4.42 (0.64)	4.38 (0.67)	3.25 (0.94)	3.30 (0.96)

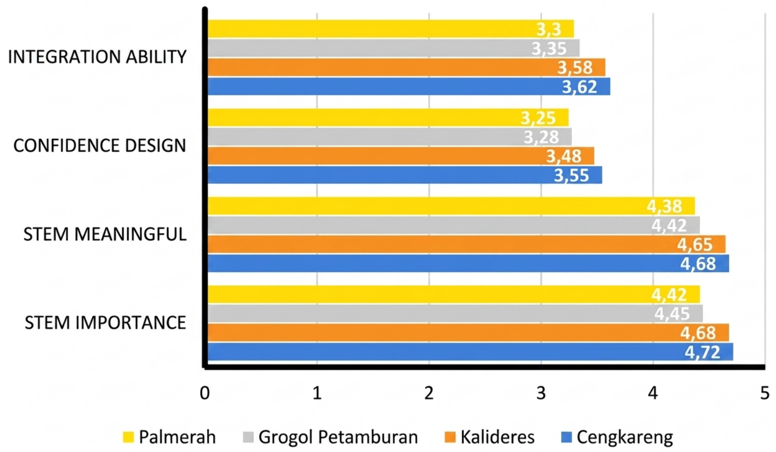

Figure 3. Mean scores of four STEM perception indicators by district

This study found that teachers in West Jakarta strongly believe in the importance of STEM for elementary education, but they lack confidence in designing and implementing integrated STEM activities. The district-level analysis revealed that teachers from flood-prone areas rated the relevance of STEM to the community significantly higher than teachers from more developed districts. Women teachers scored marginally higher on variables related to collaboration, and years of experience were moderately positively correlated with self-efficacy. Taken together, the findings suggest that teacher perceptions are influenced by individual and local environmental factors, highlighting the significance of contextually responsive professional development models (Cook et al., 2025).

Teacher Perspectives by District and Demographic Factors

Analysis of the perceptions of teachers from six administrative districts in West Jakarta showed significant differences that are correlated with local environmental and socioeconomic factors. Teachers in districts of Cengkareng and Kalideres... were more likely to give a higher rating of the relevance of STEM to community problem-solving than their counterparts in the more developed districts such as Grogol Petamburan and Palmerah. This trend is consistent with the social-ecological systems view as described by Stouthart, suggesting that the environmental challenges and resource constraints within teachers' communities influence their pedagogical perceptions (Stouthart et al., 2023). Teachers in these flood-prone districts also reported higher mean scores on items measuring the importance of connecting classroom learning to students' daily life experiences.

Self-efficacy scores were modestly positively correlated with years of teaching experience, suggesting that veteran teachers become more confident in their ability to implement integrated STEM approaches over time (Ariza & Olatunde-Aiyedun, 2024). Teachers with less than five years of classroom experience were more open to innovative pedagogies in STEM. However, they were also significantly more anxious about barriers to implementation, especially in terms of curriculum and access to materials (Bertrand & Namukasa, 2023). Female teachers (n = 73, 77.66%) had slightly higher descriptive mean scores on items measuring collaboration and student-centered learning than their male colleagues (n = 21). Given the large imbalance in sample sizes between female (n = 73) and male (n = 21) teachers, a non-parametric Mann-Whitney U test was used instead of an independent samples t-test. The result showed no statistically significant difference in collaboration and student-centered learning scores between the two groups (U = 637, p = 0.24). Full gender comparisons are shown in Table 4, with means, standard deviations, and t-tests for all the relevant survey items. These demographic patterns are consistent with Durrani and Kataeva's finding that teacher characteristics might influence pedagogical approaches, although the effect of gender was minimal in our sample (Durrani & Kataeva, 2025).

Teachers in the flood-prone Cengkareng and Kalideres districts had higher community relevance scores for STEM than teachers in more developed areas, which might suggest a link between local environmental challenges and teacher perceptions, and thus the relationship between local environmental conditions and pedagogical perceptions. Years of teaching experience showed a mild positive correlation with self-efficacy, indicating that confidence builds slowly over time with accumulated classroom practice. As shown in Table 5, novice teachers (2–5 years) were significantly more open to innovative STEM pedagogies than veteran teachers (>10 years). Also, they reported significantly higher implementation anxiety than both mid-career and veteran teachers. This pattern aligns with Cheng and Carolyn Yang's (2023) observation that novice teachers are more receptive to innovation but also more anxious about barriers (Cheng & Carolyn Yang, 2023). Female teachers scored slightly higher on collaboration measures, suggesting that gender may be a factor in teachers' orientations toward student-centered STEM approaches.

Table 4. Comparison of collaboration and student-centered learning scores by gender

Gender	n	Mean	SD	Mann-Whitney U	p-value
Female	73	4.15	0.62	637	0.24
Male	21	4.02	0.71		

Teacher Confidence and Self-Efficacy in STEM Integration

Analysis of the seven survey items measuring teacher self-efficacy (see Table B3 in Appendix B) revealed a significant gap between teachers' beliefs about the value of STEM and their confidence in implementing integrated approaches. Teachers had the highest confidence in their ability to facilitate student collaboration during STEM activities (Item C4: M = 4.28, SD = 0.67) and to manage classroom discussions about open-ended problems (Item C2: M = 4.19, SD = 0.71). In contrast, the respondents reported considerably lower confidence in their ability to embed engineering design principles into their instruction (Item C3: M = 3.38, SD = 0.88) and in their ability to create authentic STEM activities that meaningfully connect multiple disciplines (Item C1: M = 3.42, SD = 0.89). These findings align with Filipe's integrated STEM teacher identity model, which differentiates between teachers' general pedagogical confidence and their domain-specific self-efficacy in facilitating authentic, inquiry-driven STEM learning (Filipe et al., 2024).

Teachers' comments during the semi-structured interviews provided deeper insight into the sources of their low self-efficacy for STEM implementation. The teachers interviewed (67%, or eight of the twelve) stated that their teacher preparation programs focused on single-subject instruction and provided little experience with interdisciplinary curriculum design or project-based facilitation strategies. Another teacher shared that they felt unprepared to support students in investigations with multiple correct solutions, pointing to the tension between traditional teaching practices and the open-ended nature of authentic STEM problems. This pattern is in line with Sun and Saleh's (2024) finding that the strategies used in pre-service training significantly affect teachers' confidence in their subsequent teaching and their perception of the usefulness of innovative pedagogies. Teachers who reported regular collaboration with colleagues across subject areas had significantly higher self-efficacy scores, suggesting that professional learning communities may be critical supports for the development of STEM teaching confidence.

Teachers reported high self-efficacy for facilitating collaboration and classroom discussions, but significantly lower self-efficacy for engineering activity design and incorporating multiple disciplines. In written comments, pre-service preparation in interdisciplinary approaches was suggested as a significant contributor to this confidence gap. Teachers who consistently collaborated across subject areas with colleagues had significantly higher self-efficacy scores, showing the benefit of professional learning communities. These findings highlight the importance of targeted professional development that increases STEM-specific teaching confidence through collaborative, practice-based learning experiences.

Perceived Barriers to STEM Implementation

The biggest barriers for teachers to implement integrated STEM approaches in their classrooms were curriculum constraints and lack of preparation time. Figure 4 presents a diverging stacked bar chart that visualizes the full distribution of teacher responses for each barrier. The chart clearly shows that for D1 (national curriculum constraints) and D2 (limited preparation time), more than 70% of teachers chose "agree" or "strongly agree", with very few teachers selecting "disagree" or "strongly disagree". In contrast, barriers such as lack of support from principals or colleagues (D5) showed a more balanced distribution, with a notable proportion of teachers remaining neutral or disagreeing. This visualization reveals polarization that is not apparent from mean scores alone. The pressure to cover the prescribed content of the national curriculum meant that many teachers felt they could not spend sufficient time on interdisciplinary projects that might cross the boundaries of traditional subjects. Some respondents noted the constraints of rigid semester schedules and required end-of-term exams as further limiting their ability to engage students in sustained, inquiry-based investigations. These findings align with research by Tomková in Slovakia, who found that time constraints and pressure from the curriculum were important barriers to implementing innovative pedagogies in STEM, despite teachers' recognition of the value of this approach (Tomková, 2025).

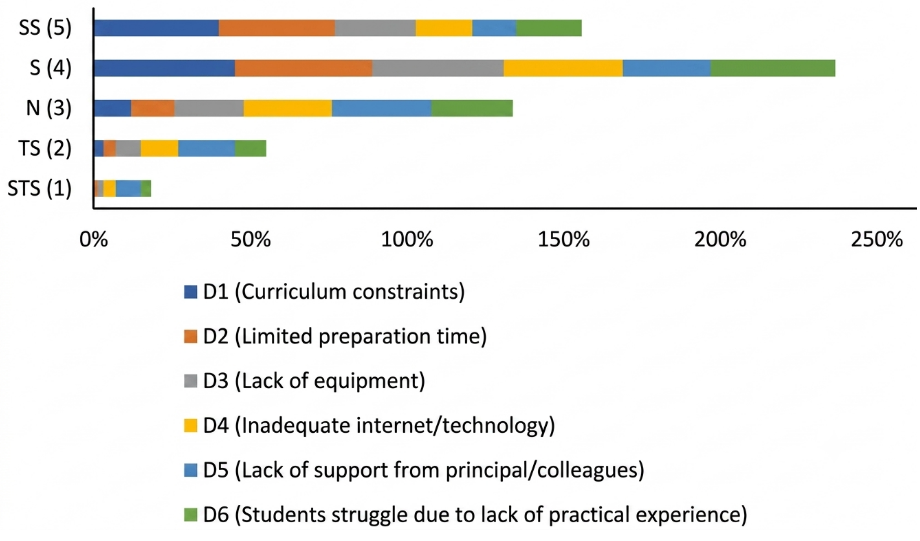

Figure 4. Teacher responses to STEM implementation barriers (diverging stacked bar chart)

Another frequently reported challenge was limited access to materials, equipment, and technology resources, particularly for teachers in schools serving lower-income communities in West Jakarta. Some respondents reported that their schools lack basic science tools, such as microscopes, measuring devices, or even reliable internet access for technology-integrated STEM activities. This pattern of resource disparity aligns with the broader pattern documented by Willson et al. in their study of ecological forecasting education, where students at under-resourced institutions experience systematic barriers to high-quality STEM learning opportunities (Willson et al., 2023). The teachers in the districts of Cengkareng and Kalideres reported the most severe resource limitations. It can be assumed that the schools located in environmentally vulnerable areas also face economic disadvantages that further compound their implementation challenges. One respondent

Table 5. One-Way ANOVA results comparing teaching experience groups on openness to innovation and implementation anxietyi

Variable	Teaching Experience	n	Mean	SD	F	df	p	Post-hoc (Tukey)
Openness to STEM Innovation	*Novice* (2–5 years)	32	4.32	0.58	4.87	2, 91	0.010	*Novice > Veteran**
	Mid-Career (6–10 years)	35	4.10	0.63				
	Veteran (>10 years)	27	3.94	0.69				
Implementation Anxiety	Novice (2–5 years)	32	3.88	0.71	6.15	2, 91	0.003	Novice > Mid-Career, *Novice > Veteran*
	Mid-Career (6–10 years)	35	3.46	0.68				
	Veteran (>10 years)	27	3.31	0.74				

noted that she often uses her own money to buy materials, which is not sustainable and not fair across the district.

Curriculum constraints and limited preparation time were the most important barriers to STEM implementation, and reflect the tension between prescribed content coverage and flexible, inquiry-based approaches (Falloon, 2024). Schools that lack resources had teachers who faced extra problems because they did not have the same materials, equipment, and access to technology as their counterparts in wealthier schools. The districts of Cengkareng and Kalideres reported the strongest constraints on resources, indicating that environmental vulnerability and economic disadvantage are occurring together. These findings suggest the crucial importance of systemic policy interventions focusing on curriculum flexibility, equitable resource distribution, and professional support as interconnected components of STEM implementation.

Teachers' Glocalization Practices in STEM Education

Qualitative analysis of open-ended responses showed that teachers actively modified principles of global STEM education to suit the needs of the local community and students' experiences in West Jakarta. Many teachers mentioned local environmental issues such as seasonal flooding, waste management challenges in densely populated urban neighborhoods, and air pollution from nearby industrial areas as topics to be integrated into their STEM lessons. A teacher in Cengkareng described how she uses the annual flooding of the Angke River to teach about water cycles, measurement, and community mapping, bringing abstract scientific concepts to life for her students. This practice is an example of the glocalization framework proposed by Chappell, where educators are significant translators who turn global principles into classroom practices with contextual meaning (Chappell et al., 2025).

Teachers from schools with culturally diverse populations said they adjusted examples and activities to reflect the different backgrounds of their students, showing sensitivity to the multicultural nature of West Jakarta's population. Several respondents indicated familiarity with introducing STEM concepts relating to economics, environmental science, and health in the context of traditional market activities, neighborhood recycling initiatives, and local food production practices. For example, a teacher in Palmerah invites parents from various ethnic backgrounds to talk about traditional practices such as food preservation or herbal medicine, which students investigate through scientific inquiry. These adaptations are consistent with the culturally sustaining pedagogies documented by Manteaw and Enu that acknowledge that meaningful STEM learning comes from classroom practices that respect and build upon students' lived experiences and community knowledge (Manteaw & Enu, 2025). In Kebon Jeruk, teachers said they developed projects based on the area's urban farming initiatives, linking plant biology, data collection, and community nutrition in ways that resonated with students whose families were involved in the gardens.

The greatest challenges to implementing STEM were curriculum and time for preparation. These responses reflect the tension between curriculum coverage and flexible, inquiry-based approaches. The lack of materials, equipment, and access to technology presented other hurdles to teachers in under-resourced schools that their wealthier counterparts did not experience. The highest levels of resource limitations were reported in the Cengkareng and Kalideres districts, indicating that environmental vulnerability is associated with economic disadvantage. The findings point to an urgent need for systemic policy interventions that consider curriculum flexibility, equitable distribution of resources, and professional support as interrelated aspects of STEM implementation.

The Role of Collaboration and Professional Networks

Teachers who reported regular collaboration with colleagues across grade levels and subject areas scored higher on measures of STEM implementation confidence and perceived success in their classrooms. Professional learning communities within schools appeared to provide valuable spaces for sharing resources, troubleshooting challenges, and developing integrated STEM activities across disciplinary boundaries (AbdulRab, 2023). Several respondents indicated that support from school principals, who actively encouraged innovative teaching approaches and time for collaborative planning during otherwise crowded weekly schedules, was important.

These findings align with the research of Atmojo et al. (2025) on communities of practice, which showed that long-term teacher collaboration is an important mechanism in sustaining program transformation and developing collective capacity to work through implementation challenges. Teachers who indicated low levels of collegial support as measured by (a) a score of 4 or 5 on survey item D5 (“Lack of support from principal or colleagues”) or (b) during interviews, that they had no regular collaboration with peers (less than once a month) more frequently described feeling isolated in their efforts to implement STEM. Teachers said they were not sure if their practices were best or met curriculum expectations. One respondent from a school with few collaborative structures said that she often gives up on potentially good STEM activities because she does not have colleagues with whom to troubleshoot implementation challenges or refine her approaches. In contrast, teachers in schools with professional learning communities in place (defined as schools where teachers participated in weekly or bi-weekly collaborative planning sessions) reported not only increased confidence but also greater perseverance in coping with constraints of limited resources and time. This pattern echoes Azzam and Charles’ research that STEM educators develop expertise through self-directed learning and peer support networks, recognizing that professional growth emerges from the situated practice and collaborative reflection of professional learning rather than isolated training alone (Azzam & Charles, 2025). Cengkareng teachers described how their collaboration across grades enabled them to identify STEM ideas and skills that could be integrated into the elementary curriculum, so that students were exposed to increasingly complex concepts as they progressed through grade levels.

Teacher-Identified Needs for Professional Development

When asked to identify their professional development priorities, teachers most often requested training focused on practical strategies for integrating STEM across multiple subjects at the same time, rather than theoretical presentations about STEM education principles. Respondents stressed the need for concrete examples of lesson plans, activity templates, and assessment tools that they could adapt easily to their own classroom contexts with minimal modification. Many teachers said that previous professional development workshops were too abstract, leaving them feeling inspired but unsure how to put new ideas into practice within the constraints of their resources and curriculum demands. This finding is consistent with Millán and Arango's (2015) research on collaborative professional development, which found that teachers learn best through hands-on, school-based sessions that directly support the creation and delivery of interactive, inquiry-driven STEM lessons (Millán & Arango, 2025).

Additionally, teachers expressed a desire to observe successful STEM approaches in action in the classrooms of their colleagues and to receive continuous coaching and feedback on their own teaching practices. Some respondents said that one-off workshops may be useful for initial exposure, but not for sustained support to develop confidence in complex pedagogical approaches such as interdisciplinary project design. Instructional coaches who can model STEM lessons, co-teach challenging units, and provide constructive feedback were highlighted by teachers as important during the early stages of implementation. This preference for ongoing, practice-based support is consistent with Tang’s findings that experiential feedback strategies such as authentic practice and formative feedback have a mixed impact on teachers’ perceived ease of use and perceived usefulness of innovative pedagogies (M. Tang et al., 2025). Teachers from Kalideres said that workshops should address the limited resources in their schools and provide guidance on how to conduct STEM activities with few materials, a concern consistent with the equity dimensions raised by Chiriacescu in their analysis of educational access in communities with different resource levels (Chiriacescu et al., 2023).

■ CONCLUSION

The findings of this study reveal that elementary school teachers in West Jakarta are actively playing the role of glocalization agents by adapting global principles of STEM education into locally relevant classroom practices that address environmental issues in their communities and their students' cultural context. The differences in teachers' views at the district level suggest that perceptions of pedagogy may be associated with local environmental factors. Descriptive comparisons suggest that teachers in flood-prone areas rated the community relevance of STEM higher than their counterparts in more developed districts. These findings support Spinney's social-ecological systems perspective, emphasizing that teachers' professional decisions are not separable from the communities and environments surrounding their schools (Spinney, 2023). Hence, the study offers empirical support for the glocalization framework developed by Imaduddin et al., which shows how international educational reforms are negotiated, adapted, and transformed through local teacher agency and contextual practice (Imaduddin et al., 2025).

The significant discrepancy between teachers' high perception of the importance of STEM and their low confidence in implementation illustrates an underdeveloped STEM learner identity, attributed to insufficient pre-service preparation in interdisciplinary approaches. Teachers demonstrated a strong professional identity through commitment to student-centered, collaborative learning. However, limited exposure to engineering design principles and project-based facilitation strategies limited their ability to guide students through authentic, inquiry-based investigations. This pattern is consistent with Tang's model of integrated STEM teacher identity, which distinguishes teachers' general pedagogical confidence from their domain-specific self-efficacy in facilitating complex STEM learning (X. Tang et al., 2023). These findings suggest that teachers need not only pedagogical training but also opportunities to experience STEM learning in their own learning as they guide their students through similar processes. This is in line with Hanum's emphasis on experiential feedback strategies in teacher preparation (Hanum, 2025).

Collaborative professional networks were important supports for building STEM teaching confidence, enabling teachers to collaboratively navigate implementation barriers that isolated educators found insurmountable. Teachers who engaged in regular professional learning communities showed significantly higher levels of confidence and persistence in navigating curriculum constraints and resource limitations, supporting Yang's research on communities of practice as engines of sustainable program change (Yang et al., 2025). The desire for professional development that provides practical, immediately useful resources rather than theoretical presentations reflects a nuanced understanding of teachers' own learning needs, consistent with Kessler's research on collaborative, school-based professional development (Kessler et al., 2024). Each key finding points to a specific systemic intervention that policymakers in Indonesia can act upon. First, the consistently low self-efficacy scores for engineering design (mean 3.38) and for interdisciplinary integration (mean 3.51), even among veteran teachers, indicate a clear gap in pre-service preparation.

Therefore, we recommend that Indonesian Teacher Training Universities (LPTK) review their elementary education curriculum by including at least one mandatory course on integrated STEM design and one practice teaching module where pre-service teachers co-facilitate a community-based STEM project. Second, our finding that teachers in Cengkareng and Kalideres, the two most resource-constrained and flood-prone districts, reported the most severe shortages of basic science equipment such as microscopes, measurement tools, and reliable internet, suggests that a one-size-fits-all policy will not work. We recommend that the Ministry of Education provide a focused STEM infrastructure grant to public elementary schools in these two districts, focusing on portable, low-cost kits for water quality testing and waste measurement that relate directly to local flooding and environmental issues. Third, teachers in all districts strongly rejected one-shot theoretical workshops and requested sustained practice-embedded coaching. We thus recommend that district education offices abandon short-term training contracts and instead fund school-based STEM teacher learning communities that meet biweekly for a full academic year, led by a trained facilitator from the same district. Such communities would co-develop lesson plans using only locally available materials such as recycled containers and traditional market scales, as teachers in Kalideres explicitly requested. Every recommendation is tied to a specific empirical finding, from district-level mean differences to direct quotes on material shortages. We provide a roadmap that is both evidence-based and actionable for Indonesian education policymakers at the national, provincial, and district levels. Collectively, these findings show that successful STEM integration depends on teachers being seen as active agents in the glocalization process, rather than passive receivers of external reforms.

While our mixed methods design has advantages, there are several limitations to be aware of when interpreting the findings. First, although the sample of 94 teachers from six districts in West Jakarta was adequate for descriptive analysis and qualitative exploration, it is relatively small for making broad statistical generalizations to all elementary teachers across Indonesia or even to other urban areas in the country. Stratified random sampling was used to ensure proportional district representation, but the sample only represents one region within the greater Jakarta metropolitan area. Second, the study focused only on public elementary schools in West Jakarta, so the findings may not fully represent the experiences of teachers in private schools, secondary schools, or rural or peri-urban schools. Third, the cross-sectional nature of the survey data (collected over three months) provides a snapshot of teacher perspectives at a single point in time, without capturing how these perspectives might evolve as teachers gain more experience with STEM integration or as school conditions change. Future research should thus include larger and more diverse samples across multiple Indonesian provinces, use longitudinal designs to explore changes in teacher confidence and practice over time, and compare glocalization processes across different types of schools (e.g., public versus private, urban versus rural). In recognizing these limitations, we do not weaken our conclusions, but instead provide a more transparent and nuanced perspective on the scope and limits of our claims.

■ DECLARATION OF AI TOOLS

In writing this manuscript, I made limited use of DeepSeek, ChatGPT, and Quillbot for language refinement, paraphrasing, and initial brainstorming. All AI generated outputs were critically reviewed, substantially revised, and incorporated into my own writing. I take full responsibility for the accuracy and originality of the final text. No confidential or unpublished data were processed by these tools.

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