

Teachers' need analysis in STEM-Eco-Mathematics learning: Evidence from border elementary schools

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Abstract: The integration of STEM with the environmental context is increasingly important as mathematics education emphasizes authentic, and interdisciplinary learning experiences. However, empirical evidence on the learning needs of elementary school teachers in boarder area is limited. This study examines the needs of teachers in implementing STEM-Eco-Mathematics learning in elementary schools in Bengkayang, an Indonesia-Malaysia border area. Data were collected from 70 elementary school teachers via online questionnaire comprising 20 Likert-scale statements representing five dimension, namely innovative learning modeling, STEM integration, contextual learning, mathematical modeling, and teacher readiness. The data were analyzed using descriptive statistics. The results showed that teachers had a high level of need for implementing STEM-Eco-Mathematics ($M = 3.57$; $SD = 0.52$). The highest needs were found in innovative learning models, STEM integration, and contextual learning while mathematical modeling and teacher readiness received relatively lower scores. Although teachers have recognized the importance of intedisciplinay and context-based mathematics learning, they still need pratical support to apply this approach effectively in everyday learning. These findings emphasize the importance of professional development programs and the development of leaning models that are responsive to the characteristics of border areas to strengthen teachers' capacity to implement STEM-Eco-Mathematics effectively.

Keywords: Border areas, mathematics learning, teacher needs analysis

Abstrak: Integrasi STEM dengan konteks lingkungan semakin penting seiring berkembangnya pembelajaran matematika yang menekankan pengalaman belajar autentik dan bersifat interdisipliner. Meskipun demikian, bukti empiris mengenai kebutuhan pembelajaran guru sekolah dasar di wilayah perbatasan masih terbatas yang pada akhirnya berdampak pada kajian STEM. Berpijak dari hal ini, maka tujuan penelitian ini adalah untuk mengkaji kebutuhan guru dalam mengimplementasikan pembelajaran STEM-Eco-Mathematics di sekolah dasar di Bengkayang, sebagai wilayah perbatasan Indonesia-Malaysia. Data dikumpulkan dari 70 guru sekolah dasar melalui kuesioner daring yang terdiri atas 20 butir pernyataan skala Likert yang mewakili lima dimensi, yaitu model pembelajaran inovatif, integrasi STEM, pembelajaran kontekstual, pemodelan matematika, dan kesiapan guru. Data dianalisis menggunakan statistik deskriptif. Hasil penelitian menunjukkan bahwa guru memiliki tingkat kebutuhan yang tinggi terhadap implementasi STEM-Eco-Mathematics ($M = 3,57$; $SD = 0,52$). Kebutuhan tertinggi terdapat pada aspek model pembelajaran inovatif, integrasi STEM, dan pembelajaran kontekstual, sedangkan pemodelan matematika serta kesiapan guru memperoleh skor yang relatif lebih rendah. Meskipun guru telah menyadari pentingnya pembelajaran matematika yang bersifat interdisipliner dan berbasis konteks, dukungan praktis diperlukan agar pendekatan tersebut dapat diterapkan. Temuan ini menegaskan pentingnya program pengembangan profesional serta pengembangan model pembelajaran yang responsif terhadap karakteristik wilayah perbatasan guna memperkuat kapasitas guru dalam mengimplementasikan STEM-Eco-Mathematics secara efektif.

Kata kunci: Wilayah perbatasan, pembelajaran matematika, analisis kebutuhan guru

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INTRODUCTION

The rise of increasingly complex environmental issues and rapid technological developments makes 21st-century competencies increasingly important. This development also has an impact on mathematics education, as a result of which the demands of mathematics do not only stop at procedural skills but also include analytical reasoning, problem solving, interpretation, and other abilities as targets (Criollo-C et al., 2024). Increasingly complex developments can also be seen in the emergence of the integration of various scientific disciplines.

In the context of education, STEM reflects 21st-century competencies. Various views are presented as clues to how STEM can be learned. Taking one view, STEM can be interpreted as an approach that allows students to connect mathematical competencies with science, technology, and engineering competencies (Falloon et al., 2022; Nugraha et al., 2024). The goal is to equip students with demanding competencies in the current era where digitalization cannot be fulfilled with one competency alone. However, amid the development of the digital era, environmental issues continue to emerge and cannot be ignored. This means the competencies they have should be able to solve the issues that arise, not just developing technology. Issues and technologies that seem to develop in tandem encourage developments in the body of mathematics itself. This change means teaching mathematics content needs to be adjusted; no longer talk about numbers, calculation operations, or formulas. However, how can these theorems and formulas address current issues while keeping pace with the increasingly rapid development of digital technologies (Buriro et al., 2023; Pakpahan & Saragih, 2022; Ruef et al., 2019; Yuldashovich, 2022).

Responding to changes in mathematics content driven by the era's developments and emerging issues, the STEM concept, which integrates ecology into mathematics, can help generate mathematical content that supports the formation of 21st-century competencies. STEM-Eco-Math is a holistic answer in meeting this need. On the other hand, mathematics can serve as a means of developing logical thinking to help solve problems, and STEM is present as a form of integration between science and ecology disciplines to provide answers to environmental issues that arise, especially in the Bengkayang area. This area is often affected by recurring environmental issues, including floods, haze from land burning, and illegal mining. Ecological phenomena can be presented as mathematical models therefore the content and teaching activities are contextual. The formation of this authentic practice is linear with the concept of constructivism and emphasizes meaningfulness, thus another guide that is also linear is the concept of TPACK (Technological Pedagogical Content Knowledge) (Falloon, 2020; Li, 2025).

TPACK is a suitable framework for bringing up the concept of STEM-Eco-Math. Although STEM is not new today, there are still many levels of education that are unfamiliar, one of which is the basic education level. Various challenges certainly arise in implementing STEM, especially when linking it to other concepts such as STEM-Eco-Math. To facilitate its implementation, TPACK can serve as the strategy of choice. The demands of this implementation are not just content mastery but also how to design learning activities that students can pass that include all elements of STEM-Eco-Math. A review of previous studies indicates that many teachers have reported difficulties in developing and implementing STEM without any additions (Septiadevana & Abdullah, 2024; Zainil et al., 2023), while ecological issues cannot be ignored, therefore STEM-Eco-Math will increase this level of

difficulty. On the other hand, teacher competency development programs are rarely given, especially those that focus on STEM, hence the minimal ability of teachers is not a surprise.

This condition is increasingly being seen in various schools along the border, such as in the Bengkayang area. Limited access, infrastructure, geographical conditions, and minimal teacher competency support are also challenges in STEM learning (Saputro et al., 2025). Therefore, understanding what teachers really need is essential. This can be fulfilled through a needs analysis that not only explores teachers' perceptions but also provides opportunities for teachers to develop, in order to professional development program services can be a suitable forum, especially in boosting the development of the necessary competencies (Fatimah et al., 2023; Nguyen & Tran, 2024).

Reviewing the results of previous research that examined STEM-related topics tends to highlight implementation efforts in the classroom (Purwaningsih & Wangid, 2021; Rakhmawati & Mustadi, 2022), this makes research with a focus on STEM-Eco-Math bring new nuances in science and can add new constructions, especially in supporting the development of mathematical competencies in the current era. This research bridges the gap that arises, focusing on identifying teachers' needs in implementing STEM-Eco-Math learning in elementary schools on the Indonesia-Malaysia border. Not only is research on STEM in general important, but a review of how environmental issues relate to mathematics learning through a STEM approach is also warranted. To answer this, the analysis of teachers' needs is carried out by exploring five fundamental dimensions: innovative learning models, STEM integration, contextual learning, mathematical modeling, and teacher readiness. These dimensions are analyzed simultaneously to identify teachers' needs in order to STEM-Eco-Math learning can be developed and implemented.

METHOD

This study uses a quantitative, descriptive approach to identify the needs of elementary school teachers in implementing STEM-Eco-Math in border areas. The research was conducted in Bengkayang, West Kalimantan, as one of the Indonesia-Malaysia border areas. The participants in this study were elementary school teachers selected through purposive sampling, categorized as active classroom teachers, with experience teaching mathematics or thematic subjects, and with willingness and commitment to participate. The total number of respondents in this study was 70 teachers, spread across the central, rural, and remote Bengkayang areas. From the net distribution of respondents, the following are the demographics of respondents shown in Table 1.

Data collection was conducted using an online questionnaire developed based on previous research findings. The questionnaire contains 20 statements on a Likert scale that assess 5 main indicators: innovative learning models, STEM integration, contextual learning, mathematical modeling, and teacher readiness. Each item is assessed with 5 scores, from a score of 1 to 5, with the category of score 1 meaning strongly disagree) to a score of 5, which means strongly agree. A higher score indicates a higher level of identified need. To maintain the instrument's credibility and accuracy, a content validity analysis was conducted with 3 experts.

Table 1. Respondent demographics

No	Category	Quantity	Percentage	
1	Gender	Male	48	68.6 %
		Female	22	31.4%
2	Age	< 30 years old	13	18.6%
		30 – 40 years old	27	38.6%
		41 – 50 years old	21	30%
		> 50 years old	9	12.8%
3	Teaching experience	< 5 years	16	22.9%
		5 – 10 years	20	28.6%
		11 – 20 years	24	34.4%
		> 20 years	10	14.2%
4	Academic qualification	Bachelor’s degree	61	87.1%
		Master’s degree	9	12.9%
5	School location	Downtown	18	25,7%
		Rural area	32	45.7%
		Remote area	20	28.6%

The results of the analysis showed a reliability score of Cronbach's alpha ($\alpha=0.89$), indicating that the instrument's consistency is categorized as good. This indicates that the instrument can be used. Furthermore, the collected data is analyzed descriptively to examine the mean, standard deviation, and percentage distribution, enabling the identification of teacher needs. To facilitate identification, the scoring is categorized into 5 levels, namely very high with a score of 4.21 – 5.00, high category with a score of 3.41 – 4.20, medium category with a score of 2.61 – 3.40, low category with a score of 1.81 – 2.60, and very low category with a score of 1.00 – 1.80 (Lindner & Lindner, 2024). Comparative analysis across the five indicators was conducted to identify priority areas requiring support. Ethical considerations were upheld by ensuring voluntary participation, anonymity, and confidentiality for all respondents, and by using the data solely for research purposes.

RESULTS AND DISCUSSION

This study examined the needs of elementary school teachers in border areas to implement STEM-Eco-Mathematics learning across five critical areas: innovative learning models, STEM integration, contextual learning, mathematical modeling, and teacher readiness. Descriptive statistics were used to calculate teacher needs for each measured indicator. The results are presented in Table 2.

The five STEM-Eco-Mathematics dimensions that were the focus of the measurement consistently indicated that teachers in border areas had a high need for implementation (Table 2). The overall mean score was 3.57 (SD = 0.52). Although all dimensions were classified as "high," the mean scores demonstrate that participants responded differently to each implementation component. The innovative learning model ranked highest (M = 3.63, SD = 0.50), with STEM integration following closely behind (M = 3.62, SD = 0.49). In comparison, teacher readiness achieved the lowest mean score (M = 3.47, SD = 0.55),

although this indicator also remained in the high category. Overall, responses indicated that support is needed for the implementation of STEM-Eco-Mathematics in all aspects, with a particular emphasis on enhancing innovative teaching practices and interdisciplinary mathematics learning.

Table 2. Teachers' needs for implementing STEM-Eco-Mathematics learning

No	Indicator	Mean	SD	Category
1	Need for Innovative Learning Models	3.63	0.50	High
2	Need for STEM Integration	3.62	0.49	High
3	Need for Contextual Learning	3.59	0.51	High
4	Need for Mathematical Modelling	3.56	0.56	High
5	Teacher Readiness	3.47	0.55	High
	Overall Mean	3.57	0.52	High

A comprehensive analysis of the data indicates that the requirements of educators were not uniformly allocated among the five categories. The little difference in average ratings reflects a collective recognition of the significance of STEM-Eco-Mathematics, while also revealing variations in the sorts of assistance considered most crucial. The disparities in standard deviation indicate that the individuals started the research with differing degrees of expertise, professional development opportunities, and classroom environments. These findings highlight the need for professional assistance that is adequately flexible to accommodate the many circumstances of teaching in border schools, rather than focusing on a single aim.

Distribution of teachers' needs across indicators

The first indicator evaluates teachers' need to apply innovative learning to support STEM-Eco-Mathematics integration in elementary schools. The four questions in the questionnaire emphasize new educational approaches that encourage active student engagement, practical pedagogical support, and creative teaching. Descriptive data are presented in Table 3.

The responses summarized in Table 3 suggest that all four items were rated in the high category, as evidenced by the consistent strong demand for innovative approaches to mathematics instruction. The demand for novel mathematics learning models among instructors was underscored by the highest mean score recorded for ILM1 ($M = 3.72$, $SD = 0.45$). In contrast, ILM2 maintained its status as a high-rated variable, despite receiving the lowest mean score ($M = 3.55$, $SD = 0.57$). In general, the indicator mean of 3.63 ($SD = 0.50$) places innovative learning models among the highest priorities for facilitating the implementation of STEM-Eco-Mathematics.

Table 3. Teachers' needs for innovative learning models

Item	Statement	Mean	SD	Category
ILM1	I need new learning models for mathematics	3.72	0.45	High
ILM2	The learning models currently used still need to be improved	3.55	0.57	High
ILM3	I need systematic and practical learning guidelines	3.62	0.49	High
ILM4	I need learning models that can increase students' active participation	3.62	0.49	High
Indicator Mean		3.63	0.50	High

The second indicator assessed the necessity for instructors to incorporate science, technology, engineering, and mathematics into their mathematics instruction. Teachers' expectations regarding interdisciplinary learning, technology integration, practical examples of STEM implementation, and the connection between mathematics and real-world situations were examined through four questionnaire items. Descriptive statistics are illustrated in Table 4.

Table 4. Teachers' needs for STEM integration

Item	Statement	Mean	SD	Category
STEM1	I need mathematics learning that integrates science, technology, engineering, and mathematics (STEM)	3.62	0.49	High
STEM2	I need examples of STEM implementation in mathematics learning	3.48	0.51	High
STEM3	I need guidance on integrating technology into mathematics learning	3.62	0.49	High
STEM4	I believe it is important to relate mathematics to real-world phenomena	3.76	0.44	High
Indicator Mean		3.62	0.48	High

The responses presented in Table 4 suggest that all four items were rated in the high category, indicating that there were consistently positive perceptions of STEM integration.

The mean score for STEM4 was the highest ($M = 3.76$, $SD = 0.44$), indicating that participants firmly acknowledged the significance of connecting mathematics to real-world phenomena. In contrast, STEM2's mean score was the lowest ($M = 3.48$, $SD = 0.51$), despite remaining in the high category. The mean of the overall indicator is 3.62 ($SD = 0.48$), which suggests that teachers consistently expressed the need for additional instructional support and identified STEM integration as a critical component of mathematics education.

The third indicator evaluated the necessity of contextual learning for instructors, with a particular focus on the connection between mathematics and the environment and the daily experiences of students. The integration of environmental data into mathematics instruction, the use of local learning resources, and environment-based learning activities were all addressed by four questionnaire items. Refer to Table 5 for the descriptive statistics.

Table 5. Teachers' needs for contextual learning

Item	Statement	Mean	SD	Category
CL1	I need learning that connects mathematics with students' daily lives	3.72	0.45	High
CL2	I need environment-based learning activities	3.66	0.48	High
CL3	I need learning resources derived from the surrounding environment	3.52	0.57	High
CL4	I need learning activities that utilize environmental data (e.g., temperature, humidity, etc.)	3.34	0.67	Moderate
Indicator Mean		3.56	0.54	High

The responses summarized in Table 5 indicate that three of the four items were rated in the high category, while one item was rated in the moderate category. Teachers' strong demand for learning experiences that integrate mathematics with students' daily activities was underscored by the highest mean score recorded for CL1 ($M = 3.72$, $SD = 0.45$). In contrast, CL4 was the sole item classified as moderate, and it received the lowest mean score ($M = 3.34$, $SD = 0.67$). Despite the fact that the utilization of environmental data in classroom activities appears to necessitate additional support, the overall indicator mean of 3.56 ($SD = 0.54$) indicates that contextual learning continues to be a significant priority.

The fourth indicator concentrated on the necessity of mathematical modeling in STEM-Eco-Mathematics education for instructors. Four questionnaire items explored the use of data, mathematical representations, modelling activities, and guidance for teaching mathematical modelling. The descriptive statistics are presented in Table 6.

Responses presented in Table 6 indicate that all four items were rated within the high category. The highest mean score was obtained for MM3 ($M = 3.69$, $SD = 0.47$), suggesting

that participants placed considerable value on having examples of mathematical modelling activities suitable for elementary school students. By contrast, MM1 recorded the lowest mean score ($M = 3.45$, $SD = 0.51$), although it also remained within the high category. The overall indicator mean of 3.59 ($SD = 0.51$) indicates that teachers consistently expressed the need for support in incorporating mathematical modelling into mathematics learning.

Table 6. Teachers' needs for mathematical modelling

Item	Statement	Mean	SD	Category
MM1	I need learning activities involving the use of data	3.45	0.51	High
MM2	I need guidance on teaching mathematical modeling	3.62	0.49	High
MM3	I need examples of mathematical modeling activities for elementary school students	3.69	0.47	High
MM4	I need learning activities that use real-world data to construct mathematical models	3.59	0.57	High
Indicator Mean		3.59	0.51	High

The final indicator examined teachers' readiness to implement STEM-Eco-Mathematics learning. The questionnaire emphasized on the readiness to utilize technology, the development of environment-based learning, the integration of technology into classroom instruction, and the participation in professional development related to educational technology. Table 7 comprises the descriptive statistics.

Table 7. Teacher readiness for implementing STEM-Eco-Mathematics learning

Item	Statement	Mean	SD	Category
TR1	I am ready to use technology in mathematics learning	3.48	0.57	High
TR2	I am ready to develop learning based on environmental data	3.45	0.57	High
TR3	I have the ability to use technology in teaching and learning	3.31	0.54	Moderate
TR4	I need training on the use of technology in teaching and learning	3.66	0.48	High
Indicator Mean		3.47	0.54	High

The responses summarized in Table 7 suggest that three items were classified as high, while one item was classified as moderate. The mean score for TR4 was the highest ($M = 3.66$, $SD = 0.48$), which suggests that teachers have a strong desire for professional training in the use of technology for teaching and learning. Conversely, TR3 was awarded the lowest mean score ($M = 3.31$, $SD = 0.54$), indicating that it was the sole moderate-rated item. Teachers generally reported a high level of readiness, but further professional support is still required, particularly to enhance their confidence and competence in technology-supported instruction, as indicated by the overall indicator mean of 3.47 ($SD = 0.54$).

Gap identification between perceived needs and readiness

The results reveal a strong pattern of difference between instructors perceived instructional needs and their readiness to use STEM-Eco-Mathematics. Contextual learning and STEM integration consistently scored highly while teacher readiness and mathematical modelling scored comparatively low. This contrast emphasizes the fact that a liking for a teaching approach does not necessarily translate into confidence or professional competence to teach it well. It seems that STEM-Eco-Mathematics has received more traction from educators than the practical competencies required to put it into practice in the classroom.

This pattern is explained by the association of teacher readiness and mathematical modeling. Both dimensions are competencies that go beyond content knowledge. Teachers are challenged with designing interdisciplinary learning experiences, facilitating inquiry, and integrating technology in authentic classroom contexts. Therefore, their low ratings are not only indicative of individual professional needs but also of structural barriers such as limited access to interdisciplinary teaching practices, instructional resources, and ongoing professional development in border schools.

The results underscore the importance of professional support that addresses both classroom implementation and conceptual understanding. The results reveal a consistent pattern across all five dimensions of instruction when viewed collectively. Instead of isolating specific aspects of classroom practice, the teachers viewed STEM-Eco-Mathematics as a holistic approach with the capacity to improve mathematics learning in multiple interconnected ways. The needs that emerged were the need for contextual learning and the need for STEM integration, which indicates the growing expectation that mathematics should be learned through real experiences, not through abstract procedures. This transition aligns with the changes in mathematics education, where students are increasingly linked to real-world situations and can build knowledge through experiences connected to a deep understanding (Esina et al., 2021; Yuldashovich, 2022).

This is particularly true of the emphasis on contextual learning in the context of border schools. The environmental conditions, local occupations, and community experiences in Bengkayang can naturally support the learning of mathematics in authentic contexts. Teachers seem to be aware of the need to make links between mathematical concepts and situations that students meet in their everyday lives. As shown by Menezes et al. (2022) and Wijnia et al. (2024), contextual learning can enhance students' engagement and conceptual understanding by enabling them to comprehend abstract mathematical concepts through familiar experiences. However, the continued high level of perceived necessity also suggests that educators are still looking for practical guidance on how to

develop contextual learning activities that they can confidently implement in their own classrooms

Teachers' enthusiasm for the integration of STEM also reflects the growing expectation that mathematics education should transcend disciplinary boundaries. Rather, respondents seemed to view STEM as a pragmatic way to make mathematics more relevant by connecting it to science, technology and engineering. In the contemporary view of interdisciplinary learning (Saputro et al., 2025; Wang et al., 2011), mathematical reasoning is developed together with scientific inquiry, technological application, and problem solving in authentic contexts. This orientation is thus consistent. However, knowing the value of STEM integration does not automatically translate into successful implementation in the classroom. Teachers need to integrate content knowledge with suitable pedagogical practices and technology skills so that they can develop interdisciplinary learning. From the TPACK perspective these forms of knowledge must operate together, rather than separately. The findings of the present study suggest that this is difficult to accomplish especially in border institutions where access to technological resources and sustained opportunities for professional development are relatively limited (Nugraha et al., 2024; Zinth et al., 2020).

The same is true for the mathematical modeling dimension. Although the instructors consistently indicated a high level of need, this indicator was rated lower than STEM integration and contextual learning. Mathematical modeling requires students to model real-world situations, develop mathematical representations, and evaluate solutions based on evidence from real-world contexts. This necessitates pedagogical skills that extend beyond the instruction of procedural mathematics, including the creation of interdisciplinary learning opportunities, steering thinking, and promoting inquiry (Buriro et al., 2023; Fauzi & Hayya, 2022; Ruef et al., 2019).

This is also corroborated by the much lower teacher readiness ratings; they do not show hesitance towards adopting educational innovations but instead counsel educators to recognize the importance of STEM-Eco-Mathematics while being cautious about their readiness for implementation. The discovery aligns with the TPACK paradigm, which underscores the significance of integrating pedagogical, technical, and disciplinary knowledge instead of only excelling in one area for successful technology-enhanced teaching (Li & Manzari, 2025). Sustained professional learning is a critical factor in successful STEM-Eco-Mathematics implementation as opportunities to develop these interrelated competencies may still be scarce for teachers in border schools.

Perhaps the most important contribution of this study is its demonstration of a gap between the perceived instructional needs of instructors and their actual readiness. This should not be interpreted as resistance to educational innovation, but rather as an indication that educators understand the significance of STEM-Eco-Mathematics and require more support to be confident in its integration into their classroom instruction. Similar observations have been made in previous studies of educational reform where awareness often exceeds capacity (Su & Yang, 2023; Tordai et al., 2026). The present results therefore provide support to the argument that successful educational innovation is not only about introduction of new models, but also about providing sufficient opportunities for teachers to acquire the professional knowledge and practical skills needed to implement new instructional models.

These findings also highlight the importance of considering the educational context in which teachers work. Schools in border areas often operate under limited conditions that differ significantly from urban educational environments. These differences are particularly evident in the quality of infrastructure, access to professional learning communities, and opportunities for sustainable pedagogical mentoring (English, 2023; Falloon et al., 2022; Pakpahan & Saragih, 2022). These real-world conditions are closely related to teachers' capacity to adopt interdisciplinary approaches, such as STEM-Eco-Mathematics. Therefore, it is crucial to design professional, up-to-date teaching practices that are responsive to the realities of border schools. Professional development is most effective when it encompasses more than just short theoretical seminars. Developing learning materials based on local environmental issues, collaborative lesson planning, regular mentoring, and classroom experimentation have proven effective in helping teachers integrate new teaching ideas into their classroom practices (Chen et al., 2024; Fatimah et al., 2023). These approaches have also been successful in fostering sustainable educational progress and increasing teaching confidence.

Furthermore, the findings of this study have broader implications for educational policy and curriculum design. The primary goal should not be simply to create teaching resources to enhance STEM-Eco-Mathematics. Establishing a sustainable professional learning system is equally important to enable educators to improve their teaching approaches over time. STEM education needs to uphold interdisciplinary concepts, and teaching frameworks in border schools must be adaptable to align with local contexts. This study provides empirical evidence for the ongoing discussion on equitable and context-sensitive mathematics education by investigating the needs of teachers in geographically marginalized educational settings. The findings not only articulate educators' perspectives but also provide actionable recommendations for the formulation of professional development initiatives, teaching frameworks, and educational policies aimed at facilitating STEM-Eco-Mathematics integration in border elementary schools.

CONCLUSION

This study concludes that STEM-Eco-Mathematics is of significant importance to elementary school educators in border areas, particularly for its novel pedagogical methods, STEM integration, and contextual learning. Concurrently, relatively low proficiency in mathematical modeling and teacher preparedness suggests that practical barriers to implementing integrative mathematics education remain. The findings suggest that educators' understanding of educational innovations has progressed more rapidly than their ability to develop the instructional skills, confidence, and knowledge needed for effective classroom implementation. Rather than viewing this gap as a limitation, it should be viewed as an opportunity to enhance teachers' professional development as educators. Professional development designed for border schools should include direct instructional support with future opportunities for collaborative lesson planning, classroom experimentation, mentoring, and professional introspection. Such a methodology is expected to enhance educators' pedagogical confidence while facilitating a more meaningful integration of mathematics, STEM, and environmental contexts. This study advances the existing understanding of STEM-Eco-Mathematics implementation in border elementary schools by presenting data from an educational context often overlooked in the literature.

The findings of this study also provide pragmatic guidance for formulating professional learning initiatives, instructional frameworks, and educational policies tailored to the educational context in border areas. This study can be expanded with further research examining the long-term impact of STEM-Eco-Mathematics on students' mathematical reasoning, environmental literacy, and problem-solving skills, as well as the influence of professional development on educators' teaching methods.

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