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Factors shaping Vietnamese lower secondary teachers' perspectives on local-context STEM experiential activities in mathematics education

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ABSTRACT

This study investigates Vietnamese lower secondary mathematics teachers' perspectives on local-context STEM experiential activities and examines the factors shaping those perspectives. A cross-sectional survey was administered to 310 teachers across urban, rural, and mountainous regions from March to June 2025. The 45-item questionnaire, adapted from high-reliability scales, demonstrated strong internal consistency (Cronbach's $\alpha = 0.918$–0.956). Exploratory factor analysis indicated sampling adequacy (KMO = 0.962; Bartlett's test $p < 0.001$) and extracted four constructs: perceived knowledge (PK), perceived benefits (PB), difficulties barriers (DB), and motivation resources (MR), explaining 60.8% of the total variance. Independent-samples t-tests and ANOVA revealed significant differences based on teaching experience, work region, and knowledge of the local context; novice teachers and those working in mountainous areas reported lower PK and higher DB. PLS-SEM showed that PK positively predicted PB ($\beta = 0.496$; $R^2 = 0.446$) and MR ($\beta = 0.644$; $R^2 = 0.415$), and was positively associated with DB ($\beta = 0.324$). The most frequently cited barriers concerned limited instructional materials, insufficient training, and inadequate policy support. These findings provide an empirical account of teachers' perspectives on integrating local contexts into mathematics education through STEM experiential activities and suggest targeted professional development, resource provision, and enabling policies to address implementation challenges.

Contribution/Originality: This study contributes to the existing literature by validating a four-construct model (PK, PB, DB, MR) of teachers' perspectives on local-context STEM experiential activities in mathematics. It employs a new estimation methodology (PLS-SEM) to test predictive paths with 310 Vietnamese lower-secondary teachers and documents region- and experience-based differences.

1. INTRODUCTION

In the past decade, experiential orientations in STEM have become a strategic priority across education systems. International agendas emphasize that learning through real-world experience constitutes a core twenty-first-century competency and encourage tighter linkages between schools and their surrounding communities, including the integration of indigenous knowledge and local context to enhance cultural relevance and sustainability (OECD, 2023; UNESCO, 2023). These directions align with integrative STEM approaches, in which science, technology, engineering, and mathematics are connected through design, modeling, and problem-solving tasks that are meaningful to students' lives (Kelley & Knowles, 2016). In parallel, place-based education literature shows that anchoring learning in local issues, resources, and heritage can increase students' motivation, perceived meaning, and community engagement (Sobel, 2004). Accumulating evidence indicates that mathematics education benefits when students participate in STEM experiential activities tied to authentic contexts, with gains in achievement and interest (Becker & Park, 2011; Freeman et al., 2014; Mater, Daher, & Mahamid, 2023; Mercier, Sivitskis, Torbert, & Vallier, 2025; Thibaut et al., 2018; Uyen, Tong, & Lien, 2022). Yet such outcomes depend strongly on teachers' perspectives—how they construe value, feasibility, and their own capability to enact innovative practices (Jerrim, Prieto-Latorre, Marcenaro-Gutierrez, & Shure, 2025; Yang, Wu, & Li, 2023; Zhou, Shu, Xu, & Padrón, 2023).

Realizing the potential of local-context STEM experiential activities in mathematics is therefore not merely a matter of curriculum or materials. Teachers' perspectives encompassing beliefs, professional norms, and perceived control shape intentions and classroom enactment. The Theory of Planned Behavior posits that intention is directly influenced by attitudes, subjective norms, and perceived behavioral control (Ajzen, 1991), while self-efficacy theory explains how capability beliefs drive effort, persistence, and strategic choices in adopting innovations (Bandura, 1997). Prior research links instructional effectiveness to teachers' pedagogical knowledge. attitudes. perspectives. and professional beliefs (Pardimin & Huda, 2018) and highlights the constraints imposed by internal factors (beliefs, competence, motivation) and external conditions (infrastructure. organizational support. policy) when integrating technology and experience-based learning (Kaleli-Yilmaz, 2015). Recent work on professional identity further suggests that experience, gender, and work region shape how mathematics–science teachers understand and enact their roles, influencing pedagogical choices (Ambusaidi & Alhosni, 2023).

Despite these advances, the international literature still exhibits three gaps that limit the field's ability to forecast readiness and guide implementation at scale. First, empirical evidence on lower secondary teachers' perspectives within mathematics education, specifically for local-context STEM experiential activities, is sparse particularly in emerging education systems. Second, few studies model how specific components of teachers' perspectives interrelate in ways that can be targeted by policy and professional development. Third, cross-region contrasts (e.g., urban, rural, mountainous) and the role of teachers' knowledge of the local context remain underreported, constraining the design of context-sensitive capacity-building initiatives. Addressing these gaps is especially important in Vietnam's competency-based reform, where designing mathematics tasks that connect to regional realities such as agriculture, crafts, environment, and heritage presents both opportunities and challenges concerning resources, training, and assessment.

This study responds by theorizing and testing a four-construct perspective model tailored to local-context STEM experiential activities in mathematics education. We adopt terminology aligned with the article title and use the following constructs throughout: perceived knowledge (PK), perceived benefits (PB), difficulties, barriers (DB), and motivation/resources (MR). PK refers to teachers' self-appraised understanding of local-context STEM experiential activities (e.g., design principles, curricular alignment, assessment). PB captures their judgments about the value of such activities for students, teachers, and schools. DB indexes perceived obstacles (e.g., limited materials, training, time, or policy support). MR captures both personal motivation and perceived availability of organizational resources and support to enact these activities. Grounded in the theory of planned behavior and self-efficacy, we posit that higher PK should increase PB and MR, while reducing DB, because knowledge enhances perceived control, clarifies utility, and aligns available supports with intended practices.

We report on a cross-sectional survey of 310 lower secondary mathematics teachers from urban, rural, and mountainous regions of Vietnam (March–June 2025). A 45-item instrument, adapted from high-reliability scales, was validated using exploratory factor analysis and subsequently employed in a partial least squares structural equation modeling (PLS-SEM) framework to estimate predictive relationships among PK, PB, DB, and MR (Henseler, Ringle, & Sarstedt, 2015, 2016; Shmueli et al., 2019). We also test group differences based on teaching experience, work region, and knowledge of the local context using t-tests and ANOVA. Our approach adheres to best-practice reporting standards for reliability and validity, including internal consistency, convergent validity, and discriminant validity, as well as structural modeling, which considers explained variance and predictive interpretation.

The study makes three significant contributions. Theoretically, it integrates the Theory of Planned Behavior (TPB) and self-efficacy into a coherent framework that explains how Perceived Knowledge influences Perceived Benefits, Motivation, Resources, Difficulties, and Barriers within the specific context of local STEM experiential activities in mathematics education. Methodologically, it offers a validated measurement model comprising four constructs, demonstrating strong internal consistency and a clear factorial structure. Additionally, it estimates predictive relationships using Partial Least Squares Structural Equation Modeling (PLS-SEM) with a sizable, geographically diverse sample of lower secondary teachers. Practically, the study provides policy-relevant insights by identifying key constructs, such as Perceived Knowledge, that serve as levers to enhance Perceived Benefits and Motivation while reducing Difficulties and Barriers. It also documents differences across groups, which can inform targeted professional development and resource allocation strategies in urban, rural, and mountainous regions.

The research questions are as follows:

RQ1. What are the levels of PK, PB, DB, and MR among Vietnamese lower-secondary mathematics teachers?

RQ2. Do these constructs differ by teaching experience, work region (urban, rural, mountainous/highland), and knowledge of the local context?

RQ3. How do the structural relations among PK, PB, DB, and MR develop?

1.1. Hypotheses

H_1: PK positively predicts PB ($\beta > 0$).

H_2: PK positively predicts MR ($\beta > 0$).

H_3: PK is positively associated with DB ($\beta>0$), reflecting greater recognition of implementation constraints as knowledge increases.

2. LITERATURE REVIEW

2.1. Experiential STEM Activities

Experiential STEM activities are understood as "hands-on, minds-on" interdisciplinary learning designs that place students in authentic problem situations and connect science, technology, engineering, and mathematics with everyday life. Recent reviews indicate a relatively stable set of effective features: problem-centered tasks; an inquiry-design-test sequence; small-group collaboration; and direct work with materials and/or data (Kelley & Knowles, 2016; Smith & Rayfield, 2017). In Vietnam, Quang et al. (2015) illustrate sequences of “technical toy” tasks that require students to mobilize and verify subject knowledge in concrete contexts, while Thanh and Duong (2021) emphasize purposeful integration of science and mathematics knowledge to address real-world challenges. Experimental evidence shows marked gains in problem solving when experiential learning is combined with STEM strategies (Lestari, 2021); content retention and entrepreneurial dispositions are also strengthened through outdoor programs (Bowling, Tynes, & Reyna, 2017) and field-based courses on food systems (Goralnik, Millenbah, Nelson, & Thorp, 2012). On the technology front, virtual reality has been shown to be an effective experiential tool for STEM–DRR (disaster risk reduction) topics (Anggaryani et al., 2023), and peer-learning assistant models clarify support mechanisms in undergraduate STEM classes (Gong, Kwon, & Brock, 2022). At a system level, an analysis of 11,406 NSF-funded projects (2018–2022) indicates that experiential learning functions as a bridge between formal and informal education, enhancing learners' STEM competence and identity (Remington, Chou, & Topa, 2023) . These findings align with arguments positioning experiential learning as an approach that simultaneously advances knowledge and skills while cultivating motivation, critical thinking, and collaboration (Basu, 2020; Boakes, 2019).

That said, much of the evidence remains descriptive, skews toward non-mathematics domains or higher education, and rarely analyzes teacher-related factors in secondary mathematics classrooms. In particular, there is a lack of models linking teachers' perceived knowledge, perceived benefits, perceived difficulties or barriers, and motivation/resources—especially in implementations connected to the local context.

2.2. Factors Shaping Mathematics Teachers' Perspectives on Local-Context STEM Experiential Activities

In mathematics classrooms, teachers' perspectives on Local-Context STEM Experiential Activities are not merely reflections of content and pedagogical knowledge; they directly influence task selection, lesson implementation, and responses to students' initial ideas. Research links beliefs about the nature of mathematics, instructional goals, and the learner's role to the openness of tasks, the degree of scaffolding, and the handling of errors and emerging student thinking (Beswick, 2012; Philipp, 2007). Within behaviorally anchored frameworks, increases in perceived knowledge tend to elevate perceived benefits, mobilize motivation and resources, and temper perceived barriers by strengthening attitudes and perceived control (Ajzen, 1991; Bandura, 1997).

For integrated STEM approaches, teachers require actionable knowledge of task design, real-world alignment, and assessment precursors that enhance perceived control and expected utility (Kelley & Knowles, 2016). Reviews consistently report the benefits teachers value, including authentic connections, increased student motivation, and improved problem-solving skills. However, they also highlight recurring constraints such as limited time, insufficient materials, lack of organizational and policy support, and pressure from testing requirements (Roehrig, Dare, Ellis, & Ring-Whalen, 2021; Stohlmann, 2020). These patterns imply that PK, PB, DB, and MR are interdependent: perceived knowledge typically raises PB and MR while easing DB through the combined pathways of attitudes, perceived control, and self-efficacy (Ajzen, 1991; Bandura, 1997).

Local context adds complexity and opportunity. Place-based scholarship highlights the value of anchoring learning in heritage, production, and community issues; yet, teachers' "knowledge of the local context" is pivotal for translating local realities into authentic mathematical tasks (Gruenewald, 2003; Sobel, 2004). Cross-cultural studies show that beliefs and routines vary by region, shaping how teachers balance concrete exemplification with abstraction and teacher guidance with student construction (Cai & Wang, 2010; Chamberlin, 2013). In Vietnam, recent research suggests that collaborative professional development, such as lesson study, and locally grounded resources can influence teaching practices by encouraging the elicitation of student thinking and the use of contextualized tasks. However, the readiness to implement these approaches still depends on regional factors, including whether the area is urban, rural, or mountainous, as well as prior experience with integrated teaching methods (Nguyen & Tran, 2023; Tuong et al., 2023).

Together, this evidence motivates the present model in three ways. First, PK is a plausible lever for PB and MR because it clarifies expected value and enhances perceived control. Second, PK should relate negatively to DB, although system-level constraints likely bound the effect. Third, differences by tenure, region, and local-context knowledge warrant testing, as they reflect experiential capital and the capacity to mobilize on-site resources.

3. METHODOLOGY

3.1. Research Design

This study adopted a quantitative cross-sectional survey to (i) describe lower-secondary teachers' perspectives on local-context STEM experiential activities in mathematics teaching and (ii) model predictive relationships among four perspective components: PK, PB, DB, and MR. This design is appropriate for describing, comparing, and estimating associations among latent variables at a single time point (Cohen, Manion, & Morrison, 2002; Kline, 2023). Data were collected from March to June 2025 in northern Vietnam across three administrative regions: Northwest, Northeast, and the Red River Delta. The study encompassed three work-region categories: urban, rural, and mountainous/highland areas. Schools were sampled from multiple provinces and municipalities within each region.

Specifically, the Northwest included Hoa Binh, Dien Bien, Lai Chau, and Son La; the Northeast comprised Phu Tho, Ha Giang, Cao Bang, and Thai Nguyen; and the Red River Delta covered Hanoi, Hai Phong, and Vinh Phuc.

Sample. The sample size $n = 310$ meets: (i) EFA guidance ≈300 is "good"; (Tabachnick & Fidell, 2007) (ii) the PLS-SEM "10-times rule" (sample ≥ 10× the largest number of arrows pointing to any construct) (Hair et al., 2021) and (iii) contemporary SEM reporting practices (Hair et al., 2021; Kline, 2023). The suitability for factor analysis was confirmed based on our data: KMO = 0.962; Bartlett's test $p < 0.001$. An exploratory factor analysis (EFA) using Principal Components with Varimax rotation extracted four factors, accounting for a total variance explained of 60.83%. The sample was stratified by region to reflect the Vietnamese context: urban areas included 103 participants (33.2%), rural areas 119 participants (38.4%), and mountainous/highland regions 88 participants (28.4%). Regarding tenure, 217 out of 310 participants (70%) had at least five years of experience. Concerning prior practice, 195 participants (62.9%) had organized STEM experiential activities in mathematics, and 180 participants (58.1%) had taught mathematics with a STEM orientation. Self-reported knowledge of the local context was predominantly at normal, familiar, or very familiar levels.

Measures. The questionnaire consisted of two parts. Part A collected background information, including years of service, region, experience in organizing STEM experiential activities, STEM-oriented teaching, and knowledge of local issues. Part B included 45 items rated on a five-point Likert scale (1–5), structured into four constructs: (1) PK; (2) PB; (3) DB; and (4) MR. Definitions of STEM experiential activities and local context were provided beforehand to ensure a standardized understanding.

Conceptual bases and scale development. The four-factor structure was developed from the following frameworks: Theory of Planned Behavior (attitudes/subjective norms/perceived behavioral control → intention) (Ajzen, 1991); self-efficacy (Bandura, 1997); pedagogical content knowledge (Shulman, 1986); Integrated-STEM (Kelley & Knowles, 2016); and place-based education (Gruenewald, 2003; Sobel, 2004). Emphasis on teachers' beliefs/perspectives and self-efficacy follows influential syntheses in educational research (Pajares, 1992; Zee & Koomen, 2016) ensuring content validity for the four constructs.

Ethics and Administration. The study received institutional ethics approval. Participation was voluntary, anonymous, and based on informed consent. The survey was administered in two modes: face-to-face and online via Google Forms (https://forms.gle/tB6dvbsEuT3obvMe8). The estimated completion time was approximately 15–20 minutes.

Rationale for Method Choice. A cross-sectional survey allows for the description of the current state and enables between-group comparisons using t-tests or ANOVA on observed variables. The data also support predictive modeling among the four perspective components using PLS-SEM, which is useful when the aim is to explain or test the paths PK→ (PB; MR; DB) under reflective measurement and non-strict distributional assumptions (Hair et al., 2021). In addition, measurement decisions informed by research on teachers' beliefs, perspectives, and self-efficacy help ensure the scale's scholarly validity and applicability to the Vietnamese context.

3.2. Data Analysis

All analyses were conducted using SPSS 26.0 (including descriptives, screening, exploratory factor analysis, t-tests, and ANOVA) and SmartPLS 4 for PLS-SEM. Hypotheses were tested at an alpha level of 0.05 using two-tailed tests. We report exact p-values, 95% confidence intervals (CI95%), and effect sizes where appropriate.

Data screening and preparation before analysis. Questionnaires with more than 10% missing items were removed; remaining missing data (≤ 5%) were imputed using the Expectation–Maximization algorithm. Univariate outliers were flagged with $|z| > 3.29$, and multivariate outliers with Mahalanobis distance ($p < 0.001$). Distributional assumptions were checked via skewness and kurtosis ($|\text{skew}| < 2$; $|\text{kurtosis}| < 7$). Homogeneity of variance was examined with Levene's and Welch's tests prior to group comparisons. To mitigate and assess common-method bias, procedural remedies (anonymity; reverse-keyed items) and post-hoc checks Harman's single-factor test (< 50% variance) and full collinearity VIF (< 3.3) were employed.

Descriptive statistics and correlations. We computed means (M) and standard deviations (SD) for each construct and indicator to summarize central tendency and dispersion. Depending on distributional diagnostics, Pearson (approximately normal) or Spearman (non-normal/ordinal) correlations were used to estimate associations among constructs; each coefficient is reported with its p value and 95% CI. The correlation matrix provides quantitative context for factor exploration and later comparison with structural model results.

Reliability and measurement validity. Internal consistency was assessed using Cronbach's α (acceptable ≥ 0.70; good ≥ 0.80); in this study, the constructs ranged from $\alpha = 0.918$ to 0.956. Convergent validity was examined via Composite Reliability ($CR \geq 0.70$) and Average Variance Extracted ($AVE \geq 0.50$). Discriminant validity was assessed using HTMT (< 0.85/0.90), alongside Fornell–Larcker criteria and inspection of cross-loadings. Indicator-level VIFs were monitored to ensure the absence of problematic multicollinearity.

Exploratory factor analysis (EFA). Sampling adequacy was verified (KMO = 0.962; Bartlett's test $p < 0.001$), confirming sufficient intercorrelations for factor extraction. We used Principal Axis Factoring (or Maximum Likelihood when conditions held) with Oblimin rotation when factors were assumed correlated (Varimax was used if orthogonality was required). Item and factor retention followed standard rules: loading ≥ 0.50, cross-loading < 0.30, and content interpretability. EFA on the survey data extracted four factors with total variance explained = 60.83%, consistent with the intended conceptual structure. The rotated loading matrix is reported in Table 4 of the Results section.

Group comparisons. We tested differences by years of experience, prior STEM Experiential Activity teaching, region of work, and knowledge of the local context using independent-samples t-tests (two groups) and one-way ANOVA (three or more groups). Homogeneity was checked with Levene's test; where violated, we used Welch's ANOVA and Games–Howell post hoc tests. All comparisons include effect sizes (Cohen's d for t-tests; partial η^2 for ANOVA) with 95% CIs. Results indicate statistically significant differences on the background variables noted above; notably, early-career teachers and those in mountainous regions reported lower PK and higher DB ($p < 0.001$).

PLS-SEM. Structural modeling used PLS-SEM to test the hypotheses: H1 PK → PB (> 0), H2 PK → MR (> 0), and H3 PK → DB (< 0). Following a two-step approach, we first evaluated the measurement model using outer loadings (target ≥ 0.70; items between 0.40 and 0.70 were retained if CR/AVE and content were satisfactory), CR, AVE, HTMT, and VIF. We then estimated the structural model with 5,000 bootstrap resamples, reporting β, SE, t, p, and 95% CIs, together with R^2 (explained variance), f^2 (local effect sizes), Q^2 (in-sample predictive relevance), and SRMR (overall fit). Findings support the hypothesized paths: Perceived Knowledge predicts Perceived Benefits ($\beta = 0.496$; $R^2 = 0.446$) and Motivation, Resources ($\beta = 0.644$; $R^2 = 0.415$), and is negatively associated with Difficulties, Barriers ($\beta = -0.324$). Measurement and model-fit criteria met recommended thresholds throughout.

4. RESULTS

4.1. Descriptive Characteristics of the Sample

The survey included 310 lower secondary mathematics teachers, with a balanced distribution across tenure, work region, and professional experiences. Regarding years of experience, 38.7% had 5–10 years (n = 120), 31.3% had more than 10 years (n = 97), and 30.0% had fewer than 5 years (n = 93). In terms of work region, 38.4% worked in rural areas (n = 119), 33.2% in urban areas (n = 103), and 28.4% in mountainous or highland areas (n = 88). Concerning practice, 62.9% (n = 195) had previously organized STEM experiential activities in mathematics, and 58.1% (n = 180) had taught mathematics with a STEM orientation. Self-reported knowledge of the local context was concentrated at two levels: moderately familiar at 47.4% (n = 147) and familiar at 35.2% (n = 109). The unfamiliar group accounted for 4.5% (n = 14), the very familiar group 12.9% (n = 40), and there were no cases of very unfamiliar. Overall, the sample composition is reasonably balanced and provides sufficient granularity for subsequent group comparisons and structural modeling. Table 1 presents the demographic characteristics of the participating teachers (N = 310), including teaching experience, work region, and prior STEM-related practices.

Table 1. Demographic characteristics of the sample (N = 310).

No.	Characteristic	Frequency (n)	Percent (%)
A1	Teaching experience		
	< 5 years	93	30.0
	5–10 years	120	38.7
	> 10 years	97	31.3
A2	Work region		
	Urban	103	33.2
	Rural	119	38.4
	Mountainous/Highland	88	28.4
A3	Implemented STEM experiential activities in mathematics		
	No	115	37.1
	Yes	195	62.9
A4	Experience teaching mathematics using an integrated STEM approach		
	No	130	41.9
	Yes	180	58.1
A5	Knowledge of the Local-Context		
	Very unfamiliar	0.0	0.0
	Unfamiliar	14	4.5
	Moderately familiar	147	47.4
	Familiar	109	35.2
	Very familiar	40	12.9

Note: Percentages are column percentages; rounding to one decimal may yield totals of 100.0% due to rounding. Source: authors' analysis of the survey data.

Figure 1 illustrates the distribution of the sample across five background variables: teaching experience, work region, implementation of STEM experiential activities in mathematics, experience with integrated STEM teaching, and knowledge of the local context.

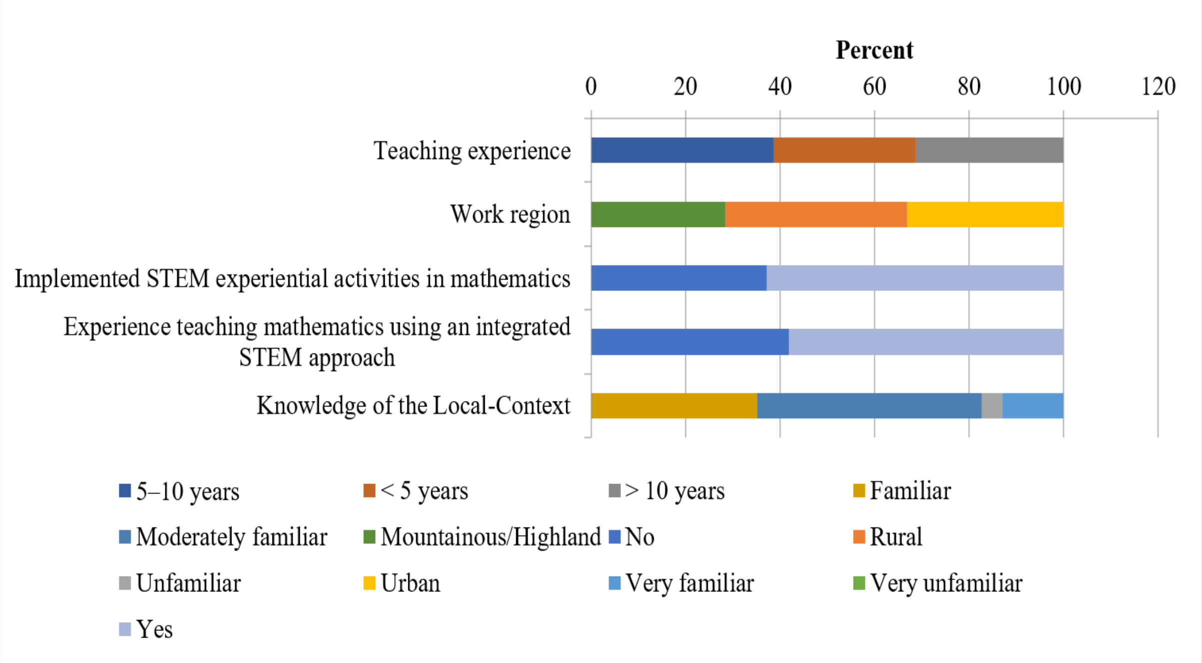

Figure 1. Distribution of sample characteristics across five variables.

4.2. Reliability (Cronbach's Alpha)

Reliability analyses demonstrated high internal consistency for all four scales: Perceived Knowledge ($\alpha = 0.956$; 15 items); Perceived Benefits ($\alpha = 0.929$; 10 items); Difficulties, Barriers ($\alpha = 0.924$; 10 items); and Motivation, Resources ($\alpha = 0.918$; 10 items). These coefficients indicate low measurement error and support the use of the scales in subsequent group comparisons and structural modeling within the context of Local-Context STEM Experiential Activities in mathematics.

In accordance with best-practice recommendations, the constructs were treated as reflective, and additional reliability and validity diagnostics (item statistics and latent-variable metrics) were evaluated against conventional thresholds; details are reported alongside the measurement-model results. Table 2 reports the internal consistency results (Cronbach's alpha) for the four scales (PK, PB, DB, MR), indicating excellent reliability across constructs.

Table 2. Internal consistency of the four scales (Teacher survey; N = 310).

Construct	Items (k)	Cronbach's alpha (α)	Interpretation
Perceived knowledge (PK)	15	0.956	Excellent
Perceived benefits (PB)	10	0.929	Excellent
Difficulties. barriers (DB)	10	0.924	Excellent
Motivation. resources (MR)	10	0.918	Excellent

Note: Alpha values ≥ 0.90 are commonly interpreted as excellent internal consistency for reflective scales in applied research. Consistent with reporting standards. the measurement section provides complementary evidence (Composite Reliability ≥ 0.70; AVE ≥ 0.50; HTMT $< 0.85/0.90$) and item-level diagnostics (corrected item–total correlations. alpha-if-deleted. mean inter-item correlations. and variance-inflation factors) to guard against redundancy and multicollinearity.

4.3. Sampling Adequacy and Factor Structure

The Kaiser–Meyer–Olkin statistic was 0.962, well above the conventional minimum of 0.50 (Howard, 2016; Kaiser & Rice, 1974) indicating that the data are fully suitable for factor analysis. A high KMO value suggests sufficiently strong inter-item correlations to justify grouping the items into factors. Bartlett's test of sphericity was significant, $\chi^2 = 9203.476$ with $p < 0.001$, rejecting the null hypothesis of an identity correlation matrix. This confirms that the items are correlated and that the assumptions for conducting factor analysis are satisfied. Table 3 summarizes the sampling adequacy diagnostics (KMO) and Bartlett's test of sphericity, supporting the suitability of the data for factor analysis.

Table 3. Sampling adequacy and sphericity: KMO and Bartlett's test.

Kaiser-Meyer-Olkin measure of sampling adequacy.		**0.962**
Bartlett's test of sphericity	Approx. chi-square	9203.476
	df	990
	Sig.	**0.000**

Exploratory factor analysis on the 45 indicators, using Principal Components extraction with Varimax rotation, yielded a clear four-factor structure that explained 60.830% of the total variance. The eigenvalues for the retained components were 16.199, 5.931, 3.121, and 2.123 (all remaining components had eigenvalues < 1), supporting the four-factor retention rule and the generalizability of the measurement model. The rotated solution showed that items loaded cleanly on the four intended content domains, with all primary loadings ≥ 0.50 and no salient cross-loadings, providing preliminary evidence of convergent and discriminant validity at the EFA stage. The Varimax rotation converged after seven iterations, indicating a stable solution. Overall, the PCA–Varimax results justify retaining four factors on both statistical and substantive grounds. Table 4 shows the eigenvalues and total variance explained, justifying the retention of a four-factor solution.

Table 4. Total variance explained (Eigenvalues).

Total	% of variance	Cumulative %	Total	% of variance	Cumulative %	Total	% of variance	Cumulative %
16.199	35.997	35.997	16.199	35.997	35.997	8.846	19.657	19.657
5.931	13.180	49.177	5.931	13.180	49.177	6.198	13.774	33.430
3.121	6.935	56.112	3.121	6.935	56.112	6.178	13.729	47.159
2.123	4.719	60.830	2.123	4.719	**60.830**	6.152	13.671	60.830
0.782	1.738	62.569						
0.751	1.670	64.239						
0.734	1.631	65.870						
0.703	1.562	67.432						
0.677	1.504	68.936						
0.636	1.413	70.349						
0.623	1.385	71.734						
0.608	1.352	73.086						
0.584	1.299	74.384						
0.566	1.257	75.641						
0.550	1.223	76.864						
0.546	1.213	78.077						
0.527	1.171	79.248						
0.502	1.115	80.363						
0.477	1.061	81.423						
0.464	1.031	82.454						
0.452	1.005	83.459						
0.443	0.984	84.443						
0.428	0.952	85.395						
0.409	0.909	86.304						
0.402	0.892	87.196						
0.383	0.851	88.047						
0.377	0.837	88.884						
0.361	0.803	89.687						
0.358	0.796	90.483						
0.342	0.759	91.242						
0.338	0.751	91.993						
0.322	0.717	92.709						
0.320	0.711	93.421						
0.313	0.696	94.117						
0.303	0.674	94.791						
0.295	0.655	95.446						
0.285	0.634	96.080						
0.269	0.597	96.677						
0.252	0.560	97.237						
0.245	0.545	97.782						
0.230	0.510	98.292						
0.216	0.479	98.771						
0.207	0.460	99.232						
0.183	0.406	99.638						
0.163	0.362	100.000						

Varimax-rotated loadings showed a clear four-factor pattern. Items B1–B15 loaded strongly on the factor interpreted as PK (range = 0.649–0.768). Items C1.1–C1.10 loaded on PB (0.684–0.744). Items C2.1–C2.10 loaded on DB (0.717–0.775). Items C3.1–C3.10 loaded on MR (0.634–0.837). All primary loadings exceeded 0.50, and no salient cross-loadings were observed, providing preliminary evidence of convergent and discriminant validity at the EFA stage. The Varimax solution with Kaiser normalization converged after seven iterations. Factor labels were assigned based on item content (B, C1, C2, C3) rather than extraction order to maintain alignment between the statistical solution and the conceptual structure of the instrument. Table 5 displays the Varimax-rotated factor loadings, indicating clean item–factor patterns aligned with the proposed constructs.

Table 5. Varimax-rotated factor matrix (Principal components).

	Component			
	1	2	3	4
B9	0.768			
B8	0.750			
B14	0.743			
B15	0.728			
B6	0.717			
B12	0.716			
B3	0.714			
B1	0.712			
B5	0.712			
B4	0.708			
B11	0.699			
B7	0.683			
B13	0.661			
B10	0.649			
B2	0.649			
C2.10		0.775		
C2.7		0.771		
C2.3		0.757		
C2.4		0.753		
C2.9		0.752		
C2.8		0.750		
C2.6		0.740		
C2.1		0.736		
C2.2		0.736		
C2.5		0.717		
C3.5			0.837	
C3.7			0.816	
C3.2			0.731	
C3.4			0.705	
C3.3			0.694	
C3.9			0.681	
C3.8			0.678	
C3.1			0.654	
C3.10			0.653	
C3.6			0.634	
C1.8				0.744
C1.1				0.728
C1.6				0.723
C1.2				0.721
C1.3				0.717
C1.7				0.714
C1.9				0.704
C1.4				0.698
C1.10				0.696
C1.5				0.684

Note: Extraction method: Principal Components. Rotation method: Varimax with Kaiser normalization. Rotation converged in 7 iterations. Loadings shown are primary loadings; all are ≥ 0.50 with no salient cross-loadings.

Table 6. Associations between teachers' perceived knowledge of local-context STEM Experiential Activities and background variables.

Independent variable	Groups	n	Mean ± SD	p-value	Test
Teaching experience	< 5 years	93	3.18 ± 0.45	< **0.001**	ANOVA
	5–10 years	120	3.44 ± 0.44		
	>10 years	97	3.72 ± 0.48		
Work region	Urban	103	3.73 ± 0.48	< **0.001**	ANOVA
	Rural	119	3.47 ± 0.39		
	Mountainous/Highland	88	3.11 ± 0.41		
Implemented STEM experiential activities in mathematics	No	115	3.01 ± 0.32	< **0.009**	t-Test
	Yes	195	3.71 ± 0.40		
Experience teaching mathematics using an integrated STEM approach	No	130	3.05 ± 0.34	< 0.077	t-Test
	Yes	180	3.75 ± 0.38		
Knowledge of the Local-Context	Very unfamiliar	0	-	< **0.001**	ANOVA
	Unfamiliar	14	3.12 ± 0.51		
	Moderately familiar	147	3.22 ± 0.45		
	Familiar	109	3.56 ± 0.45		
	Very familiar	40	3.86 ± 0.50		

Table 6 reports associations between Perceived Knowledge (PK) and background variables, highlighting significant differences across experience, region, and local-context familiarity.

4.4. Differences in Perceived Knowledge Across Background Variables

The analyses indicate meaningful variation in teachers' Perceived Knowledge (PK) of Local-Context STEM Experiential Activities by personal and workplace characteristics. By teaching experience, teachers with fewer than five years reported the lowest PK (M = 3.18, SD = 0.45), those with 5–10 years reported higher PK (M = 3.44, SD = 0.44), and those with more than 10 years reported the highest PK (M = 3.72, SD = 0.48). The overall difference was statistically significant (ANOVA, $p < 0.001$), suggesting experience is an important correlate of PK.

PK also differed by work region: urban teachers showed the highest levels (M = 3.73, SD = 0.48), followed by rural teachers (M = 3.46, SD = 0.43), while teachers in mountainous/highland areas reported the lowest (M = 3.11, SD = 0.41). This pattern was statistically significant (ANOVA, $p < 0.001$), consistent with the interpretation that regional context and associated access to resources and professional opportunities relate to teachers' knowledge.

With respect to practice, teachers who had implemented STEM experiential activities in mathematics reported higher PK (M = 3.71, SD = 0.40) than those who had not (M = 3.01, SD = 0.32), a difference that reached statistical significance (t test, $p = 0.009$). In the same direction, teachers who had taught mathematics using an integrated STEM approach reported higher PK (M = 3.75, SD = 0.38) than those without such experience (M = 3.05, SD = 0.34); this contrast did not meet the conventional $\alpha = 0.05$ threshold (t test, $p = 0.077$).

Finally, PK varied monotonically with knowledge of the local context: the unfamiliar group showed the lowest mean (M = 3.12, SD = 0.51), whereas the very familiar group showed the highest (M = 3.86, SD = 0.50). The omnibus test was significant (ANOVA, $p < 0.001$), underscoring the importance of teachers' familiarity with local issues for readiness to engage in local-context STEM experiential activities in mathematics.

4.5. Differences in Perceived Benefits Across Groups

T-tests and ANOVA revealed significant differences in teachers' perceived benefits (PB) of local-context STEM experiential activities by teaching experience and knowledge of the local context. Teachers with fewer than five years reported the lowest PB (M = 3.92, SD = 0.39); those with 5–10 years reported higher PB (M = 4.20, SD = 0.39); and those with more than 10 years reported the highest PB (M = 4.66, SD = 0.33). The omnibus difference was statistically significant (ANOVA, $p < 0.001$), indicating that experience is strongly associated with more favorable evaluations of the benefits.

Knowledge of the local context. PB also varied by familiarity with local issues. Teachers who were very familiar showed the highest PB (M = 4.65, SD = 0.39), whereas the unfamiliar group showed the lowest (M = 3.90, SD = 0.41). The group difference was significant (ANOVA, p < 0.001), suggesting that greater familiarity with the local context is linked not only to higher perceived knowledge but also to more positive appraisals of the benefits of local-context STEM experiential activities in mathematics. Table 7 presents group differences in Perceived Benefits (PB) across demographic and professional characteristics.

Table 7. Associations between perceived benefits of local-context STEM experiential activities in mathematics and demographic characteristics.

Independent variable	**Groups**	**n**	**Mean ± SD**	**p-value**	**Test**
Teaching experience	< 5 years	93	3.92 ± 0.39	**< 0.001**	ANOVA
	5–10 years	120	4.28 ± 0.36		
	>10 years	97	4.66 ± 0.33		
Work region	Urban	103	4,23 ± 0.28	< 0.270	ANOVA
	Rural	119	4,34 ± 0.43		
	Mountainous/Highland	88	4,29 ± 0.48		
Implemented STEM experiential activities in mathematics	No	115	3.90 ± 0.41	< 0.925	t-Test
	Yes	195	4.50 ± 0.37		
Experience teaching mathematics using an integrated STEM approach	No	130	3.95 ± 0.41	< 0.634	t-Test
	Yes	180	4.54 ± 0.34		
Knowledge of the Local-Context	Very unfamiliar	-	-	**< 0.001**	ANOVA
	Unfamiliar	14	3.90 ± 0.41		
	Moderately familiar	147	4.10 ± 0.47		
	Familiar	109	4.30 ± 0.41		
	Very familiar	40	4.65 ± 0.39		

4.6. Differences in Difficulties: Barriers Across Groups

One-way ANOVA revealed statistically significant differences in teachers' perceived difficulties and barriers (DB) when implementing local-context STEM experiential activities in mathematics across various background and professional characteristics.

Teachers with less than 5 years of teaching experience reported the lowest DB (M = 2.80, SD = 0.42), followed by those with 5–10 years of experience (M = 3.11, SD = 0.44). Teachers with more than 10 years of experience reported the highest DB (M = 3.25, SD = 0.46); the omnibus test was significant (p < 0.001). Regarding work region, DB was highest among teachers in mountainous/highland areas (M = 3.28, SD = 0.45), compared to rural (M = 3.10, SD = 0.39) and urban teachers (M = 2.80, SD = 0.47); these differences were statistically significant (p < 0.001). In contrast, DB did not differ significantly based on whether teachers had implemented STEM experiential activities in mathematics or had taught using an integrated STEM approach (both p > 0.05).

Notably, DB decreased monotonically with knowledge of the local context: the unfamiliar group reported the highest DB (M = 3.52, SD = 0.32), followed by the moderately familiar group (M = 3.17, SD = 0.45), and the familiar group (M = 2.94, SD = 0.44), with the lowest DB among the very familiar group (M = 2.79, SD = 0.47); this pattern was statistically significant (p < 0.001).

These findings suggest that limited familiarity with local conditions may heighten perceived barriers to implementing local-context STEM experiential activities in mathematics. Table 8 exhibits group differences in Difficulties/Barriers (DB) across demographic and professional characteristics.

Table 8. T-tests and ANOVA for group differences in difficulties. Barriers (DB) by demographic/professional factors.

Independent variable	Groups	n	Mean ± SD	p-value	Test
Teaching experience	< 5 years	93	2.80 ± 0.42	**< 0.001**	ANOVA
	5–10 years	120	3.11 ± 0.44		
	>10 years	97	3.25 ± 0.46		
Work region	Urban	103	2.80 ± 0.47	**< 0.001**	ANOVA
	Rural	119	3.12 ± 0.36		
	Mountainous/Highland	88	3.28 ± 0.47		
Implemented STEM experiential activities in mathematics	No	115	2.80 ± 0.44	< 0.829	t-Test
	Yes	195	3.22 ± 0.42		
Experience teaching mathematics using an integrated STEM approach	No	130	2.79 ± 0.42	< 0.700	t-Test
	Yes	180	3.26 ± 0.41		
Knowledge of the Local-Context	Very unfamiliar	-		**< 0.001**	ANOVA
	Unfamiliar	14	3.52 ± 0.32		
	Moderately familiar	147	3.17 ± 0.45		
	Familiar	109	2.94 ± 0.44		
	Very familiar	40	2.79 ± 0.47		

4.7. Differences in Motivation: Resources Across Groups

Statistical analyses revealed significant variation in teachers' evaluations of MR for implementing Local-Context STEM Experiential Activities in mathematics across various personal and professional characteristics. By work region, urban teachers reported the highest MR (M = 3.47, SD = 0.42), followed by rural teachers (M = 3.17, SD = 0.33), with the lowest levels observed in mountainous/highland areas (M = 2.80, SD = 0.35); the omnibus difference was statistically significant (ANOVA, p < 0.001). Regarding practice, teachers who had implemented STEM experiential activities reported higher MR (M = 3.41, SD = 0.35) than those without such experience (M = 2.80, SD = 0.28), a difference that was statistically significant (t-test, p < 0.001). A similar pattern was observed for teaching with an integrated STEM approach: experienced teachers reported higher MR (M = 3.42, SD = 0.36) than those without experience (M = 2.85, SD = 0.30; t-test, p < 0.001). In contrast, MR did not differ significantly by years of teaching experience (p = .636).

MR increased monotonically with knowledge of the local context: the unfamiliar group had the lowest mean (M = 3.00, SD = 0.45), followed by the moderately familiar group (M = 3.09, SD = 0.39), and the familiar group (M = 3.25, SD = 0.46), with the highest level among the very familiar group (M = 3.40, SD = 0.42). This gradient was statistically significant (ANOVA, p < 0.001). Taken together, these results indicate that teachers' motivation and perceived availability of resources are shaped most strongly by their work setting, hands-on STEM experience, and familiarity with the local context, rather than by tenure alone. Table 9 reports group differences in Motivation/Resources (MR) across demographic and professional characteristics.

Table 9. Associations between MR for local-context STEM experiential activities and background variables.

Independent variable	Groups	n	Mean ± SD	p-value	Test
Teaching experience	< 5 years	93	3.16 ± 0.43	.636	ANOVA
	5–10 years	120	3.17 ± 0.43		
	>10 years	97	3.22 ± 0.45		
Work region	Urban	103	3.47 ± 0.42	**< 0.001**	ANOVA
	Rural	119	3.17 ± 0.33		
	Mountainous/Highland	88	2.86 ± 0.37		
Implemented STEM experiential activities in mathematics	No	115	2.80 ± 0.28	**< 0.001**	t-test
	Yes	195	3.41 ± 0.35		
Experience teaching mathematics using an integrated STEM approach	No	130	2.85 ± 0.30	**< 0.001**	t-test
	Yes	180	3.42 ± 0.36		
Knowledge of the Local-Context	Very unfamiliar	-	-	**< 0.001**	ANOVA
	Unfamiliar	14	3.00 ± 0.45		
	Moderately familiar	147	3.09 ± 0.39		
	Familiar	109	3.25 ± 0.46		
	Very familiar	40	3.40 ± 0.42		

4.8. Structural Relations Among the Constructs (PLS-SEM)

Using PLS-SEM (see Figure 2), we estimated directional paths among Perceived Knowledge (PK), Perceived Benefits (PB), Difficulties, Barriers (DB), and Motivation, Resources (MR). Path coefficients, explained variance, and effect sizes are summarized below; p-values are reported in Table 10.

$$PK \rightarrow PB\ (\beta = 0.496;\ R^2 = 0.446;\ f^2 = 0.405).$$

PK shows a strong positive association with PB: teachers who report greater knowledge of Local-Context STEM Experiential Activities tend to appraise their benefits more favorably. The model explains about 45% of the variance in PB, indicating that knowledge is a major lever for shaping benefit appraisals, consistent with the Theory of Planned Behavior's emphasis on belief structures in forming evaluative judgments (Ajzen, 1991).

$$PK \rightarrow MR\ (\beta = 0.644;\ R^2 = 0.415;\ f^2 = 0.708).$$

PK strongly predicts MR. Approximately 41.5% of the variance in MR is accounted for by PK, and the effect size is very large. This pattern aligns with self-efficacy perspectives (Bandura, 1997), suggesting that better knowledge clarifies procedures, increases perceived control, and facilitates the mobilization of organizational supports and resources.

$$PK \rightarrow DB\ (\beta = 0.324;\ R^2 = 0.086;\ f^2 = 0.067).$$

PK shows a small positive association with DB. We interpret this calibrated pattern as heightened sensitivity: as teachers' knowledge deepens, they become more able to recognize concrete constraints in implementing Local-Context STEM activities (time, materials, assessment alignment, policy fit). Thus, higher PK may co-occur with a more realistic appraisal of barriers rather than a reduction in perceived constraints. The explained variance remains modest ($R^2 = 0.086$), suggesting that system-level conditions still dominate perceptions of barriers.

$$DB \rightarrow PB\ (\beta = 0.328;\ f^2 = 0.178).$$

DB shows a positive association with PB of moderate magnitude. One possible reading is that engagement with real constraints heightens teachers' appreciation of potential payoffs an effect reminiscent of "double-loop learning," where practitioners refine their understanding by reflecting on challenges as well as outcomes (Argyris, 1977). This should not be mistaken for a causal claim that barriers increase benefits; rather, teachers reporting higher barriers may simultaneously recognize clearer value propositions.

$$MR \rightarrow DB\ (\beta = -0.053;\ f^2 = 0.002;\ p = 0.193).$$

The path from MR to DB is small and non-significant. Motivation and perceived resources, on their own, do not reliably reduce perceived barriers; this underscores the importance of system-level supports (time, materials, infrastructure, policy) in addition to individual-level readiness.

Overall, the structural model indicates that PK is the central driver, substantively boosting PB and MR and showing a small relation with DB, while DB and MR exhibit weak direct interplay. These results support a policy emphasis on enhancing teachers' knowledge specific to local-context STEM experiential design, alongside parallel investments to address structural barriers. Table 10 summarizes the explained variance (R^2) and effect sizes (f^2) in the PLS-SEM model for the endogenous constructs.

Table 10. Summary of R^2 and f^2 indices in the PLS-SEM model.

Endogenous construct	**R^2**	**Exogenous predictor**	**f^2**	**Effect size (Cohen's guideline)**
Perceived benefits (PB)	0.446	Perceived knowledge (PK)	0.405	Large
		Difficulties. barriers (DB)	0.178	Medium
Difficulties barriers (DB)	0.086	Perceived knowledge (PK)	0.067	Small
		Motivation. resources (MR)	0.002	Negligible
Motivation resources (MR)	0.415	Perceived knowledge (PK)	0.708	Large

Note: Effect-size interpretation follows Cohen's conventional thresholds: $f^2 \approx .02$ small 0.15 medium 0.35 large.

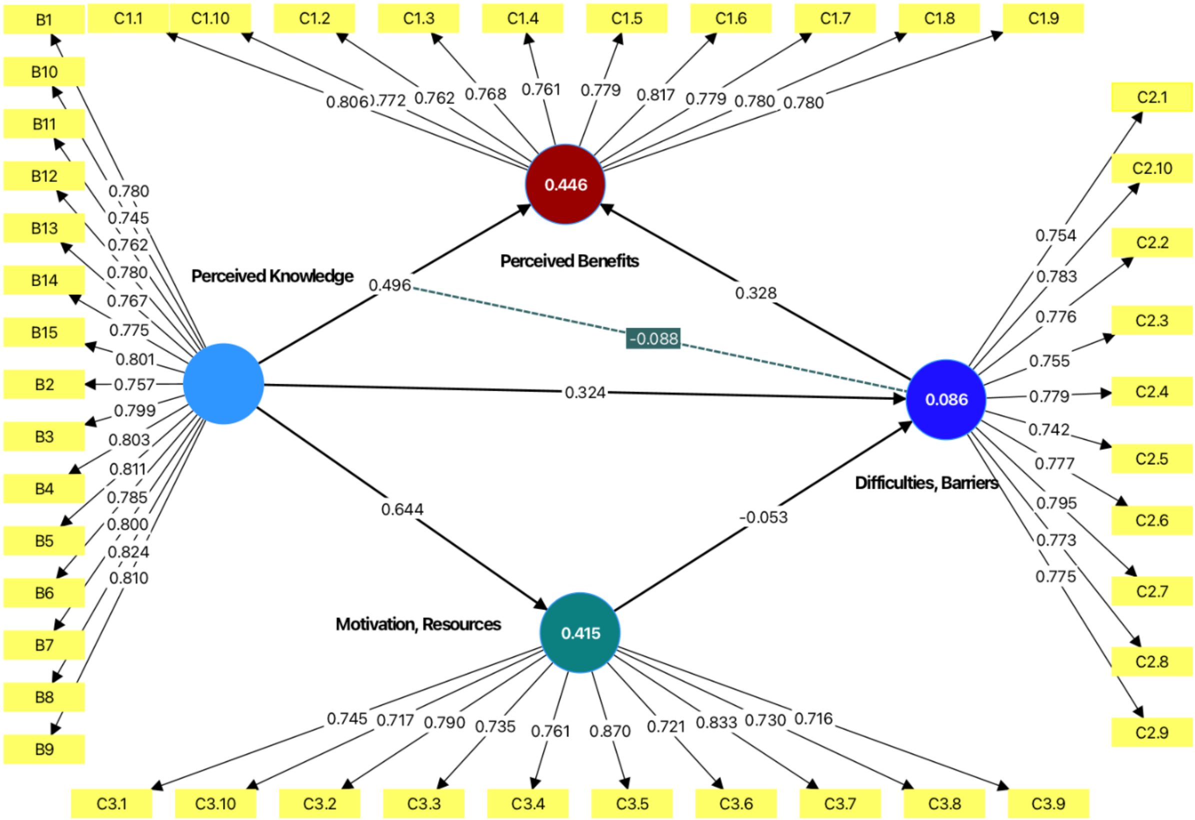

Figure 2. Structural model of factors influencing teachers' perspectives on local-Context STEM experiential activities in mathematics.

5. CONCLUSIONS

This study offers an empirical portrait of Vietnamese lower-secondary mathematics teachers' perspectives on Local-Context STEM Experiential Activities. Using data from 310 teachers, a 45-item instrument demonstrated high reliability and a stable four-factor structure Perceived Knowledge, Perceived Benefits, Difficulties, Barriers, and Motivation, Resources with excellent sampling adequacy and a total variance explained of 60.83%. These results support the measurement validity of the instrument in the Vietnamese context and provide a sound basis for subsequent inferences.

Analyses highlight the central role of Perceived Knowledge: higher knowledge is associated with more favorable appraisals of benefits and higher motivation/resources, and is inversely related to perceived barriers. Group comparisons reveal significant differences by tenure and work region: early-career teachers and those working in mountainous/highland areas report lower knowledge and higher perceived barriers. Practical experience (having implemented STEM experiential activities and having taught using an integrated STEM approach) and greater Knowledge of the Local Context are positively related to benefit appraisals and motivation/resources. Taken together, the evidence points to professional understanding and lesson-design capacity in local contexts as the most actionable levers.

Theoretically, the study validates a four-construct perspective model for teachers within the local context, integrated STEM approaches, and clarifies the predictive role of perceived knowledge for benefits, motivation/resources, and barriers. The findings reinforce belief-based, self-efficacy, and planned-behavior accounts of teachers' readiness to innovate, adding evidence from an education system undergoing curricular reform.

For practice and policy, several priorities emerge: modular professional development on designing mathematics tasks tied to local contexts and on facilitating experiential activities; regionally curated repositories of reusable instructional resources; protected time and school-level support for lesson preparation; communities of practice linking schools with local education providers, enterprises, and research institutes; and mentoring arrangements for early-career teachers. In mountainous/highland regions, targeted support packages are warranted, including low-cost resources, concrete implementation guides, in-situ training, and mechanisms to engage local communities.

Limitations include the cross-sectional, self-report design, which precludes causal claims; stratified convenience sampling, which reduces but does not eliminate selection bias; and validation that, in this study, relies on EFA and PLS-SEM. Future work should include longitudinal designs to track changes over time; intervention studies of professional development to test causal effects; measurement-invariance assessments across regions and tenure groups; mixed-methods designs and linkage to student outcomes; and multilevel modeling to incorporate school-level conditions.

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Institutional Review Board Statement: The study involved minimal risk and adhered to ethical guidelines for social science fieldwork. Formal approval from an Institutional Review Board was not required under the policies of Hung Vuong University, Vietnam. Informed verbal consent was obtained from all participants, and all data were anonymized to ensure participant confidentiality.

Transparency: The authors state that the manuscript is honest, truthful, and transparent, that no key aspects of the investigation have been omitted, and that any differences from the study as planned have been clarified. This study followed all writing ethics.

Competing Interests: The authors declare that they have no competing interests.

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