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Factors influencing the implementation of STEAM instruction in lower secondary local education: A hierarchical component PLS-SEM approach

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ABSTRACT

Implementing STEAM education in mountainous lower secondary schools is constrained by limited resources and uneven teacher capacity in northern Vietnam and beyond. This study aims to examine teachers' readiness and the feasibility of applying the STEAM model in teaching the Local Education subject in mountainous contexts, and to validate a hierarchical component PLS-SEM model of factors influencing STEAM implementation. Employing a deductive approach within a quantitative cross-sectional design, this study surveyed 285 lower secondary teachers. Data were analyzed using descriptive statistics to assess the current state of STEAM implementation, and a two-stage partial least squares structural equation modeling (PLS-SEM) approach after establishing measurement quality via Cronbach's alpha, composite reliability, and average variance extracted (AVE). Results show that both perception and implementation criteria are rated at a fairly good level (mean approximately 3.5/5), with satisfactory internal consistency for the main constructs (Cronbach's alpha > 0.88). The structural model indicates that Enabling Conditions (DB) and STEAM Element Specification (XD) have significant effects on the Implementation construct and jointly explain 82.3% of its variance ($R^2 = 0.823$). By contrast, teachers' knowledge, specific pedagogical measures, and existing procedures do not exhibit significant direct effects. These findings imply that improving STEAM instruction in mountainous lower secondary schools should prioritize strengthening foundational enabling conditions (infrastructure, school-level support, and teaching resources) and designing and standardizing clear, feasible STEAM procedures adapted to local teaching contexts, supported by coherent implementation strategies and adequate structural backing rather than relying solely on individual teacher competence.

Contribution/Originality: This study contributes an original hierarchical component PLS-SEM framework to explain STEAM instruction implementation in lower secondary local education in mountainous contexts. Findings from 285 teachers identified enabling conditions and STEAM element specification as decisive predictors, explaining 82.3% of implementation variance and guiding policy and school-level support.

1. INTRODUCTION

Over the past three decades, STEAM education has emerged as a prominent interdisciplinary approach for advancing innovations in school management and fostering creativity (Perignat & Katz-Buonincontro, 2019). Originated from educational initiatives in the United States, this model is closely associated with reform programs supported by the National Science Foundation (NSF) since the 1990s. Initially, the NSF used the term SMET to refer to Science, Mathematics, Engineering, and Technology; in the early 2000s, Ramaley, an NSF assistant director, rearranged the acronym into STEM (Kelley & Knowles, 2016). Since then, STEM has been institutionalized in U.S. policy documents and educational reforms and has been rapidly adopted by many education systems worldwide as a key trend in modern education (Li, Wang, Xiao, & Froyd, 2020). With the acceleration of technological change and the growing importance of creative industries and design thinking, the arts component was added, forming the term STEAM (Connor, Karmokar, & Whittington, 2015; Maeda et al., 2013). This approach is generally understood as an extension of the STEM foundation rather than an entirely new model, with the explicit aim of promoting creative thinking (Perignat & Katz-Buonincontro, 2019).

In the context of globalization and digital transformation, school systems in many countries face pressures to equip students with 21st-century competencies such as critical thinking, problem solving, creativity, and collaboration. Consequently, integrated STEM/STEAM education has gained international attention as a promising pedagogical approach for developing these skills (Harris & de Bruin, 2018). Compared with traditional STEM, STEAM more explicitly emphasizes the arts to nurture creativity and design thinking (Perignat & Katz-Buonincontro, 2019). It also encourages project-based learning and learning through exploration, discovery, and solving practical problems. These characteristics play an important role in explaining why STEAM features prominently in contemporary discussions of general education reform and how schools can prepare learners to adapt to rapid economic, social, and technological change (Quigley, Herro, & Jamil, 2017).

In recent years, STEAM has begun to be implemented in Vietnam's general education system, primarily in regions with relatively favorable conditions in terms of facilities and teacher resources (Bui et al., 2023; Quang & Thu, 2025). Nga and Trung (2021) argued that teaching processes in developing design thinking have strong potential for STEAM implementation in Vietnam, particularly through the design and organization of STEAM topics in the Natural Sciences (Anh, Em, & Bao, 2024). However, conspectus studies indicate that STEM/STEAM development remains constrained by multiple systemic barriers (Le, Tran, & Tran, 2021; Oliveira, Nguyen, Lê, Phạm, & Dang, 2026). In particular, schools in mountainous areas have been coping with substantial challenges related to limited facilities, insufficiently experienced teachers, a rigid curriculum, and heavy examination pressure (Hai, Linh, & Bich, 2023).

Local Education is a new subject introduced in Vietnam's 2018 General Education Program with an open-design orientation. This approach empowers provincial and municipal People's Committees to approve the curriculum and connect learning topics with each locality's cultural, social, and environmental identity. Through this subject, students are expected to develop the capacity to understand and solve practical problems relevant to their communities (Danh, 2023). However, implementation in lower secondary schools in the mountainous regions of Northern Vietnam remains challenging. In these areas, the population is predominantly ethnic minorities; socio-economic conditions are below the national average; school facilities are limited; teachers often teach multiple subjects; and time for subject designing and innovation is constrained. Consequently, both the delivery of the Local Education subject and teachers' access to and application of the STEAM model are hindered by teacher-, student-, and organizational-level factors (Dinh, 2021; Quang & Thu, 2025; Thao et al., 2024). A case study of STEAM teaching in six northern mountainous provinces identified 11 major barrier groups, including limited preparation time, inadequate facilities, low teacher confidence, contextual constraints, and examination pressure (Hai et al., 2023).

Given this context, the study addresses three key research questions: (1) What is the current status of local education teaching and teachers' capacity to access and apply the STEAM model in lower secondary schools in mountainous areas? (2) To what extent are teachers ready, and how feasible is the STEAM model under these specific conditions? (3) Which factors influence levels of readiness and feasibility? Addressing these questions provides a foundation for proposing pedagogical measures suited to mountainous contexts and for offering policy recommendations to support and scale STEAM-based instruction.

This study contributes by addressing three research gaps. First, it analyzes the current status of teachers' readiness and the feasibility of applying the STEAM model at scale across six provinces in the mountainous region of Northern Vietnam. Second, it examines influential factors, enabling conditions, awareness of STEAM, and the STEAM lesson-design process using the PLS-SEM model an approach still rarely applied in STEAM research in Vietnam. Third, based on the survey findings, it proposes context-specific pedagogical measures for mountainous regions and pilots the initial component (current status and feasibility) prior to broader intervention, thereby laying the groundwork for subsequent studies on the effectiveness of integrating STEAM into local education in other mountainous localities. By modeling factors that shape teachers' capacity to apply STEAM in local education, the study enriches the theoretical understanding of STEAM implementation under Vietnam's contextual conditions. It also offers education administrators and teachers clearer evidence on readiness levels, barriers, and potential support measures to support policy development, teacher professional learning, resource allocation, and infrastructure planning for more effective STEAM adoption in mountainous schools.

The remainder of this paper is organized as follows. The next section reviews the relevant literature and develops the conceptual framework and hypotheses for the hierarchical component model. The subsequent section describes the research design, participants, measures, and the PLS-SEM analytical procedure. The following section reports the empirical results, which are then discussed in terms of theoretical and practical implications. The final section concludes with key contributions, limitations, and directions for future research.

2. LITERATURE REVIEW

The STEAM integrated education model is widely regarded as a promising approach for developing students' competencies to meet 21st-century demands. Recent academic discourse has shifted from merely defining the evolution of STEM, STEAM, and STREAM (Tuyet, 2023) to analyzing their transformative pedagogical potential. In essence, STEAM emphasizes project-based learning, interdisciplinary connections, and problem-solving in practical contexts. Compared with traditional STEM, STEAM explicitly incorporates the Arts component to foster creativity, design thinking, and interdisciplinary application, thereby supporting a more holistic competency development (Amanova et al., 2025; Boice et al., 2021; Conradty & Bogner, 2018; Perignat & Katz-Buonincontro, 2019). Despite these advantages, the implementation of STEAM in secondary education encounters substantial challenges. While teachers generally acknowledge the value of STEAM, many of them have difficulties in matters relating to limited preparation time, highly subject-based curricula, insufficiently clear interdisciplinary structures, and a lack of supportive resources (Margot & Kettler, 2019). Notably, in-depth studies of classroom practice indicate that teachers may conceptualize STEAM as "a series of separate activities" rather than as a coherent, integrated pedagogical approach (Herro & Quigley, 2017; Oliveira et al., 2026). Such perceptions can lead to fragmented implementation and reduce the transformative potential of STEAM.

In the Vietnamese context, current scholarship reveals a significant disparity in STEAM adoption, which remains largely concentrated in affluent urban areas while remaining experimental and small-scale in broader educational settings (Truong & Tran, 2025). Critical synthesis of existing literature identifies three primary systemic barriers to STEAM integration in Vietnam. First, there is a distinct pedagogical gap between theoretical endorsement and classroom reality. Although STEAM has been utilized in humanities subjects like History (Huong, 2024) implementation is often hindered by an "innovation-lag" in mountainous regions. These areas, characterized by extreme socio-economic hardships and a high density of ethnic minority students, face geographic and infrastructural constraints that are far more severe than those in the lowlands. Despite government efforts to prioritize facilities, field-based evidence remains scarce and early-stage (Hai et al., 2023).

Second, the scarcity of physical and human capital continues to be the most cited limitation. Studies consistently highlight the inadequacy of specialized equipment and laboratories, compounded by a significant deficit in teacher capacity for organizing hands-on, contextualized activities (Hai et al., 2023; Le et al., 2021). Third, the lack of tailored guidance for disadvantaged schools suggests that moving from conceptual acceptance to effective practice requires a synergic alignment of teacher competence, material resources, and sustained organizational support.

In this regard, assessing teachers' readiness and the feasibility of STEAM implementation is a critical preliminary step before large-scale adoption (Hai et al., 2023; Le et al., 2021). Readiness typically refers to the extent to which individual teachers or school organizations possess the awareness, beliefs, competencies, and conditions necessary to receive and implement educational innovations such as STEAM (Thibaut, Knipprath, Dehaene, & Depaepe, 2019). When teachers are "ready", they demonstrate willingness, understanding, and the capacity to design and organize interdisciplinary learning. Feasibility, in contrast, concerns the extent to which a new model can be successfully enacted under actual school conditions, including the availability of human and material resources, time, supportive policies, and appropriate organizational structures (Boice et al., 2021). For example, Herro and Quigley (2017) reported that over 80% of teachers required additional support relating to preparation time, curriculum adjustment, interdisciplinary collaboration, and funding to implement STEAM effectively. The misalignment between innovation intentions and fragmented implementation often occurs when these two constructs—readiness and feasibility—are not adequately synchronized (Milara & Orduña, 2024). Accordingly, this study adopts readiness and feasibility as two key constructs for examining the current situation in lower secondary schools in the mountainous areas of Northern Vietnam. and for identifying the factors influencing the application of STEAM in teaching Local Education.

To implement STEAM teaching effectively, teachers and schools are two decisive factors.

Teacher-related factors. Teachers are at the center of instructional innovation. Numerous studies indicate that teachers' professional competence, awareness and attitudes toward innovation, interdisciplinary experience, and skills in using equipment are key determinants of successful STEAM implementation (Heredia-Sacio & Herrera-San Martín, 2025; Thibaut et al., 2019). Syntheses of the literature suggest that teachers and pre-service teachers often hold positive attitudes toward STEAM, yet many still lack confidence in practice because teacher education programs do not provide sufficient interdisciplinary integration content or the pedagogical skills required for STEAM instruction (Margot & Kettler, 2019). In Vietnam, research in Ho Chi Minh City as an urban context similarly highlights gaps in practical guidance and resource access, showing that teachers face difficulties due to a shortage of reference materials and clear guidance for organizing STEAM activities. Many teachers trained in single disciplines remain unfamiliar with interdisciplinary teaching. The absence of STEAM lesson-design guidelines and interdisciplinary coordinators further increases teachers' hesitation. Therefore, given that lower secondary teachers in mountainous areas typically have limited experience with STEAM and fewer professional learning opportunities, teachers' capacity and readiness are critical variables for investigation (Le et al., 2021).

School-related factors. Schools and their organizational environments strongly shape STEAM teaching conditions. Key influences include leadership support, collaboration among teachers from different subjects, adequate preparation and planning time, facilities (laboratories and equipment), flexible learning spaces, and a culture that encourages innovation (Geng, Jong, & Chai, 2019). Internationally, the lack of shared planning time and specialized budgets is identified as a major feasibility barrier (Boice et al., 2021). In Vietnam, although the government has committed to building 200 schools in mountainous and border areas, there is still a critical "support gap" regarding specialized STEAM equipment and professional mentoring. To bridge this, selecting STEAM topics that align with local realities is viewed as a strategy to enhance students' interest and improve feasibility (Miller & Roehrig, 2018; The Politburo, 2025).

The conjunction of teacher capacity and institutional support is non-negotiable for high-quality implementation. If one remains underdeveloped, the other cannot sustain innovation. Herro and Quigley (2017) and Spyropoulou, Mathiopoulos, and Kameas (2025).

Local Education is a compulsory subject at the lower secondary level, implemented from the 2021-2022 school year. The subject aims to facilitate students to develop a deep understanding of local culture, history, and socio-economic-environmental contexts, thereby strengthening practical problem-solving skills and community engagement. However, empirical evidence reveals that Local Education in Northern mountainous regions suffers from three major shortcomings: (i) Teachers have not been sufficiently trained in subject-specific pedagogy and interdisciplinary integration; (ii) Textbooks and learning materials remain limited; and (iii) Topic content is not consistently connected to authentic local issues (Hai et al., 2023). Teaching and learning continue to rely heavily on traditional, theory-oriented approaches, while experiential activities and problem solving linked to local contexts have not been effectively leveraged (Hai et al., 2023; Le et al., 2021).

Integrating STEAM into local education topics holds considerable promise. It supports the development of 21st-century student competencies while linking learning to the lived environment, community, and local practices (culture, nature, and regional economies). Yet this integration imposes specific requirements, including the design of locally relevant themes and activities and the provision of adequate school resources such as materials, experiential learning spaces, and community partnerships. These demands underscore the need for schools and teachers in mountainous regions to be proactive and to establish feasible conditions for implementation (Kidman & Tan, 2025; Oliveira et al., 2026). Evidence on STEAM feasibility also indicates that strong local relevance and engaging hands-on practices can significantly enhance teachers' interest and implementation capacity (Özsoy, 2025).

3. METHODOLOGY

3.1. Sample and Survey Process

The study was conducted from January to March 2025 to examine teachers' readiness and the feasibility of applying the STEAM model in teaching Local Education in lower secondary schools in Northern Vietnam's mountainous region.

Data were collected through online questionnaires and in-person surveys with teachers from 35 lower secondary schools across six mountainous provinces before the merger on July 1, 2025 (Lao Cai, Yen Bai, Ha Giang, Tuyen Quang, Son La, and Dien Bien). A total of 302 questionnaires were returned. After data screening, 17 invalid responses were excluded (e.g., selecting only level 5 for all items or omitting personal/background information), resulting in a final analytical sample of 285 questionnaires. The sampling approach ensured representation of areas with diverse geographical, economic, social, and ethnic characteristics, including cities, towns, and remote communities. The valid response rate was 94.4%, which is considered adequate for PLS-SEM analysis (Hair, Risher, Sarstedt, & Ringle, 2019).

Participating teachers varied in qualifications and teaching experience, with seniority ranging from 5 to more than 15 years. Figure 1 illustrates the distribution of participating teachers by teaching seniority, showing that the largest group has 10–15 years of experience (48.8%), followed by 5–10 years (22.1%), more than 15 years (17.9%), and less than 5 years (11.2%). Approximately half of the participants reported 10–15 years of teaching experience.

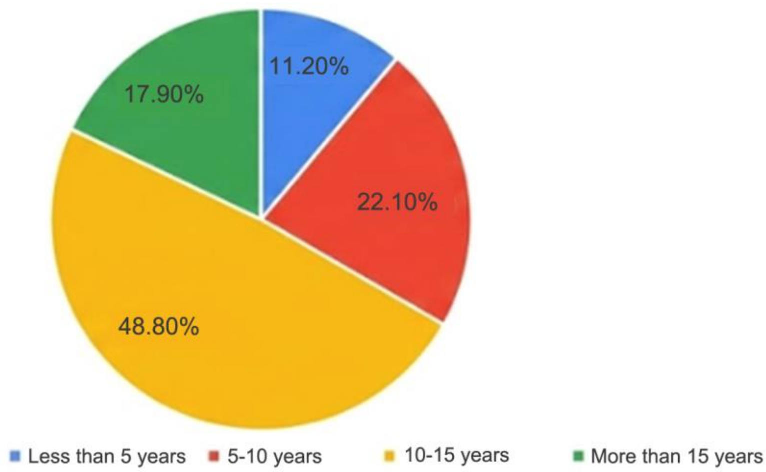


Figure 1. Classification of participating teachers by seniority.

Demographic data indicate that 73.3% of the teachers are female, 58.2% have more than 10 years of teaching experience, 46% hold a bachelor's degree, and 38.9% hold a postgraduate degree. Additionally, 52.3% of the participants reported having participated in at least one STEM/STEAM training activity within the past two years. Detailed characteristics of the sample are presented in Table 1.

Table 1. Characteristics of participating teachers (n = 285).

Variables	Grouping	Frequency (n)	Proportion (%)
Sex	Male	76	26.7
	Female	209	73.3
Teaching experience	< 5 years	38	13.3
	5 – 10 years	81	28.4
	> 10 years	166	58.2
Level	College	43	15.1
	University	131	46.0
	Postgraduate	111	38.9
Participated in STEAM training	Yes	149	52.3
	Not yet	136	47.7

3.2. Data Analysis Method

This study utilizes Partial Least Squares Structural Equation Modeling (PLS-SEM) for data analysis. Unlike traditional Covariance-Based SEM (CB-SEM), often used in previous educational research requiring large samples and strict normal distribution, PLS-SEM is particularly advantageous for this study due to its high predictive power with complex models involving hierarchical component constructs (HOCs). Furthermore, while previous studies on STEAM implementation have frequently relied on first-order regression or basic path analysis, our approach employs a hierarchical component PLS-SEM.

This allows for a more nuanced examination of "Readiness" and "Feasibility" as multidimensional constructs, capturing the complex relationship between individual teacher capacities and broader school-level environmental factors that simpler models often overlook (Hair et al., 2019). The analysis was conducted in two phases: (1) evaluation of the measurement model (reliability and validity) and (2) evaluation of the structural model (path coefficients and explanatory power).

3.3. Survey Instrument

The questionnaire was developed based on the theoretical framework of readiness and feasibility for implementing educational innovations and was adapted from the scales proposed by Herro and Quigley (2017) and Geng et al. (2019). It comprises seven main factors with a total of 35 items, measured using a five-point Likert scale (1 = completely disagree to 5 = completely agree).

The teacher questionnaire includes 30 closed-ended items assessing teachers' overall perceptions of STEAM-based instruction, covering awareness, current implementation status, and proposed measures for effective adoption, along with three open-ended questions to elicit additional perspectives on local STEAM implementation. An overview of the teacher survey results is presented in Table 2.

Overall, preliminary findings indicate fair ratings across most criteria, suggesting that teachers recognize the role and significance of STEAM and have a basic understanding of the steps required to apply this model in teaching.

Table 2. Teacher evaluation score classification statistics (n=285).

Construct / Item code	Mean	Std. Deviation	Skewness		Kurtosis	
	Statistic	Statistic	Statistic	Std. error	Statistic	Std. error
NT. Awareness of the STEAM model						
NT.1	3.64	1.103	-1.379	0.144	1.139	0.288
NT.2	3.17	1.181	-0.499	0.144	-0.944	0.288
NT.3	3.60	1.022	-1.211	0.144	1.074	0.288
VT. Awareness of the role and significance of STEAM						
VT.1	3.68	1.081	-1.335	0.144	1.186	0.288
VT.2	3.75	1.097	-1.306	0.144	1.170	0.288
VT.3	3.61	1.057	-1.265	0.144	1.025	0.288
VT.4	3.64	1.068	-1.220	0.144	0.918	0.288
DB. Conditions to ensure the application of STEAM in teaching						
DB.1	3.55	1.029	-1.115	0.144	0.761	0.288
DB.2	3.63	1.055	-1.156	0.144	0.851	0.288
DB.3	3.65	1.049	-1.275	0.144	1.122	0.288
DB.4	3.66	1.071	-1.173	0.144	0.818	0.288
DB.5	3.63	1.036	-1.065	0.144	0.675	0.288
DB.6	3.62	1.060	-1.268	0.144	1.030	0.288
TT. STEAM Model Implementation Status						
TT.1	3.50	1.050	-0.923	0.144	0.222	0.288
TT.2	3.55	1.049	-1.058	0.144	0.523	0.288
TT.3	3.51	1.037	-0.959	0.144	0.385	0.288
XD. Identify STEAM elements						
XD.1	3.58	1.031	-1.137	0.144	0.786	0.288
XD.2	3.65	1.086	-1.144	0.144	0.709	0.288
XD.3	3.63	1.069	-1.245	0.144	0.979	0.288
XD.4	3.68	1.055	-1.225	0.144	1.052	0.288
XD.5	3.65	1.056	-1.137	0.144	0.823	0.288
QT. Building processes						
QT.1	3.66	1.074	-1.219	0.144	0.900	0.288
QT.2	3.64	1.051	-1.151	0.144	0.857	0.288
QT.3	3.65	1.022	-1.296	0.144	1.248	0.288
VD. Proposing measures to apply the STEAM education model						
VD.1	3.48	1.077	-1.025	0.144	0.415	0.288
VD.2	3.58	1.106	-1.033	0.144	0.376	0.288
VD.3	3.58	1.103	-1.052	0.144	0.434	0.288
VD.4	3.59	1.111	-1.003	0.144	0.327	0.288
VD.5	3.56	1.085	-1.050	0.144	0.432	0.288
VD.6	3.64	1.085	-1.135	0.144	0.732	0.288

The teacher scale was tested for reliability using Cronbach's alpha. To ensure unidimensionality and acceptable internal consistency, a threshold of 0.70 or higher is commonly applied in educational research (Taber, 2018). As shown in Table 3, the teacher scale meets the reliability requirements.

Table 3. Cronbach's Alpha reliability test.

Survey criteria	Cronbach's Alpha
NT. Awareness of the STEAM model	0.884
VT. Awareness of the role and significance of STEAM	0.960
DB. Conditions to ensure the application of STEAM in teaching	0.969
TT. STEAM Model Implementation Status	0.930
XD. Identify STEAM elements	0.968
QT. Building processes	0.956
VD. Proposing measures to apply the STEAM education model	0.976

3.4. Data Analysis Process

Data were analyzed using SmartPLS 4.0 following the two standard stages of PLS-SEM (Hair et al., 2019).

Phase 1 – Measurement model evaluation. The model was assessed against commonly accepted criteria: *(i)* indicator reliability (outer loadings > 0.70), *(ii)* internal consistency reliability (Cronbach's alpha and composite reliability), *(iii)* convergent validity (AVE > 0.50), and *(iv)* discriminant validity (Fornell–Larcker criterion and HTMT < 0.85). All indicators met these thresholds, indicating that the measurement scales demonstrated satisfactory reliability and validity.

Phase 2 – Structural model evaluation. Path coefficients were examined using bootstrapping with 5,000 resamples to estimate the reliability and statistical significance of the relationships ($p < 0.05$). The results indicate that the key hypothesized paths are statistically significant.

- Ensuring conditions (DB) → STEAM implementation status (TT): $\beta = 0.361$, $p = 0.001$.
- Determining STEAM factors (XD) → STEAM implementation status (TT): $\beta = 0.554$, $p < 0.001$.

The remaining constructs (VT, QT, VD) did not show statistically significant direct effects ($p > 0.05$). The model's explanatory power is substantial, with $R^2 = 0.823$, indicating that 82.3% of the variance in teachers' STEAM implementation status is explained by the predictor variables. Effect sizes were in the small-to-moderate range ($f^2 = 0.19$–0.28), and predictive relevance was supported by $Q^2 > 0$, suggesting good predictive capability.

3.5. Ethics and Reliability Assurance

All participants were informed of the study's purpose and participated voluntarily. Data were anonymized and used solely for research purposes. Reliability was strengthened through a two-step coding process and random duplicate checks. Data processing and PLS-SEM analyses were conducted by the research team and subsequently reviewed by an independent expert in statistical methods.

4. FINDINGS

To examine the factors influencing teachers' perceptions of the current status of STEAM implementation in teaching, the study proposes an influence model as shown below. In this model, the Understanding construct is specified as a hierarchical component model, also referred to as a higher-order construct (HOC). Specifically, Understanding is treated as a higher-order variable, while its two dimensions are modeled as lower-order constructs (LOCs), each measured by their respective observed indicators (survey items). The hierarchical component structure is illustrated in Figures 2 & 3.

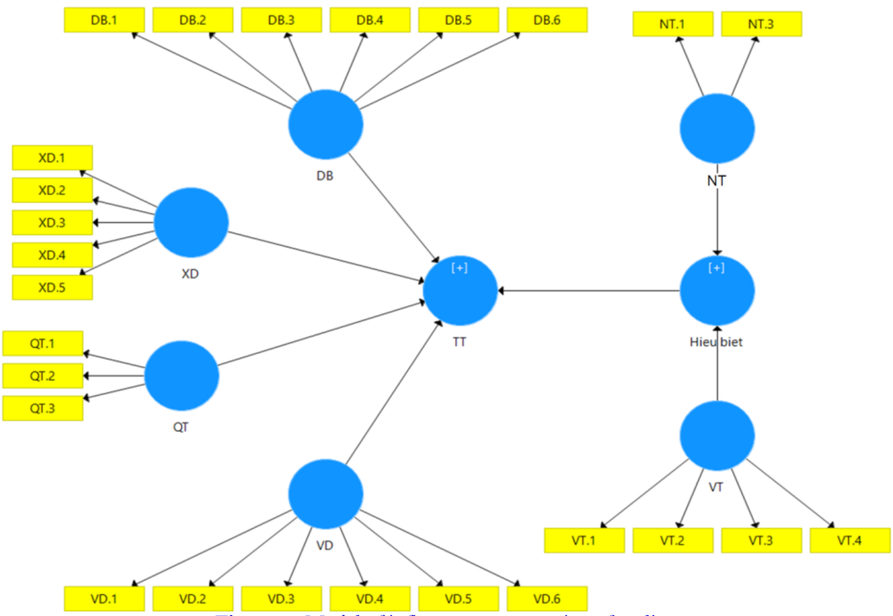


Figure 2. Model of influence on perception of reality.

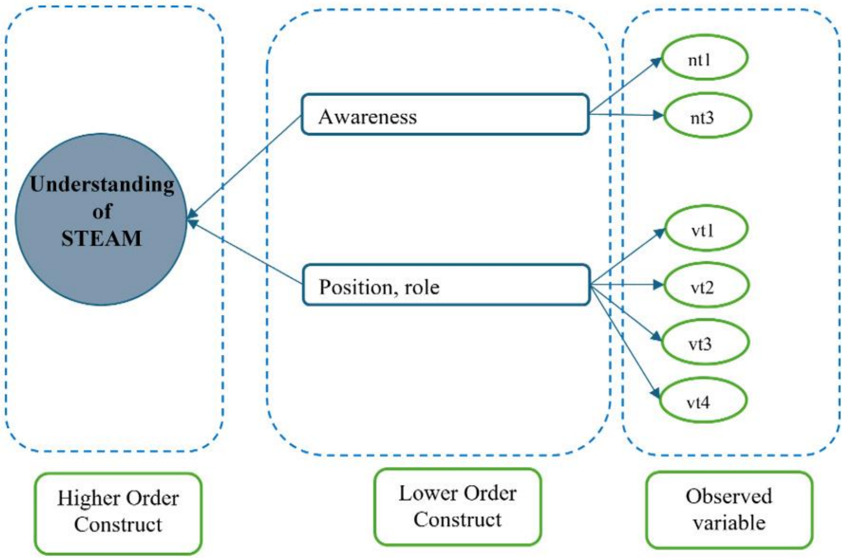


Figure 3. Hierarchical component model.

4.1. Phase 1: Measurement Model Evaluation

In Phase 1, the theoretical measurement model for the Understanding construct was specified in the SmartPLS diagram using the repeated-indicator approach. At this stage, only the lower-order constructs (LOCs) were analyzed. The evaluation criteria included indicator quality, reliability, convergent validity, and discriminant validity of the scales.

Indicator quality: Hair et al. (2019) suggest that outer loadings should be at least 0.70 to ensure adequate indicator reliability. Table 4 presents the outer loadings of the observed indicators for the lower-order constructs (NT and VT). The results show that all observed variables exceeded the 0.70 threshold (ranging from 0.929 to 0.955), indicating that the indicators are statistically meaningful and contribute adequately to the measurement model.

Table 4. Outer loading of low-order variables

Indicator (Item code)	NT	VT
NT.1	0.939	
NT.3	0.955	
VT.1		0.952
VT.2		0.953
VT.3		0.947
VT.4		0.929

Table 5 presents the reliability and convergent validity results for the lower-order constructs (LOCs). The results indicate that the scale demonstrates satisfactory reliability and convergent validity, with Composite Reliability (CR) values exceeding 0.70 (Henseler & Sarstedt, 2013) and Average Variance Extracted (AVE) values surpassing 0.50 (Hock & Ringle, 2010).

Table 5. Reliability and convergent validity of the scale.

Construct (LOC)	Cronbach's alpha	Composite reliability	Average variance extracted (AVE)
NT	0.885	0.946	0.897
VT	0.960	0.971	0.893

Discriminant validity: Discriminant validity was assessed using the Fornell–Larcker criterion (Fornell & Larcker, 1981). This approach compares the square root of the AVE (√AVE) for each construct with the correlations between that construct and the other constructs in the model. Here, AVE (average variance extracted) reflects the average amount of variance a latent construct explains in its observed indicators. Table 6 presents the Fornell–Larcker matrix for assessing discriminant validity, including the square root of AVE values on the diagonal and inter-construct correlations in the off-diagonal cells. Discriminant validity is supported when the √AVE value of a construct is greater than its correlations with all other constructs. As shown in Table 6, the √AVE values exceed the corresponding inter-construct correlations, indicating that the scale demonstrates adequate discriminant validity.

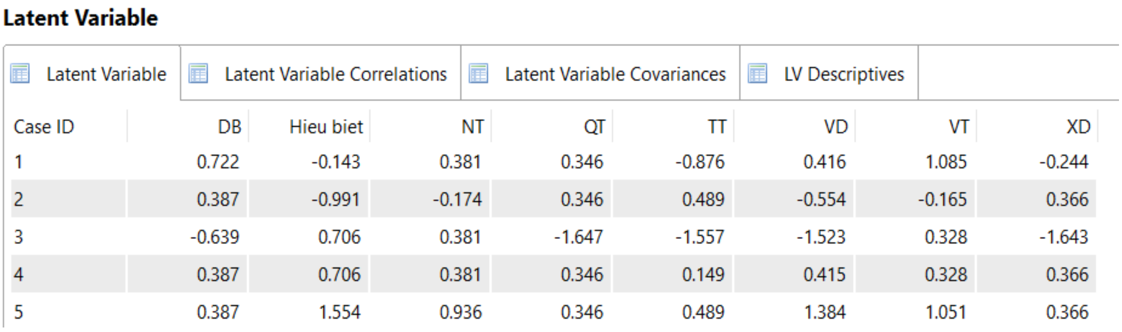
Table 6. Scale discrimination.

Constructs	Hieu biet (Understanding)	NT	VT
Hieu biet (Understanding)	1		
NT	0.567	0.947	
VT	0.53	0.92	0.945

Note: Diagonal values represent the square root of AVE (√AVE), and off-diagonal values represent inter-construct correlations.

4.2. Phase 2: Structural Model Evaluation

The Phase 1 results indicated that the measurement scales demonstrated adequate indicator quality, reliability, convergent validity, and discriminant validity. Therefore, these scales were retained for Phase 2. Figure 4 illustrates the SmartPLS output of latent variable scores for the lower-order constructs (LOCs). The scores were then exported and used as input data for the Phase 2 analysis.


Latent Variable

Latent Variable | Latent Variable Correlations | Latent Variable Covariances | LV Descriptives

Case ID	DB	Hieu biet	NT	QT	TT	VD	VT	XD
1	0.722	-0.143	0.381	0.346	-0.876	0.416	1.085	-0.244
2	0.387	-0.991	-0.174	0.346	0.489	-0.554	-0.165	0.366
3	-0.639	0.706	0.381	-1.647	-1.557	-1.523	0.328	-1.643
4	0.387	0.706	0.381	0.346	0.149	0.415	0.328	0.366
5	0.387	1.554	0.936	0.346	0.489	1.384	1.051	0.366

Figure 4. Latent variable scores of lower-order constructs (LOCs) exported from SmartPLS.

The SDL impact model and its influencing factors in Phase 2 are presented in Figure 5.

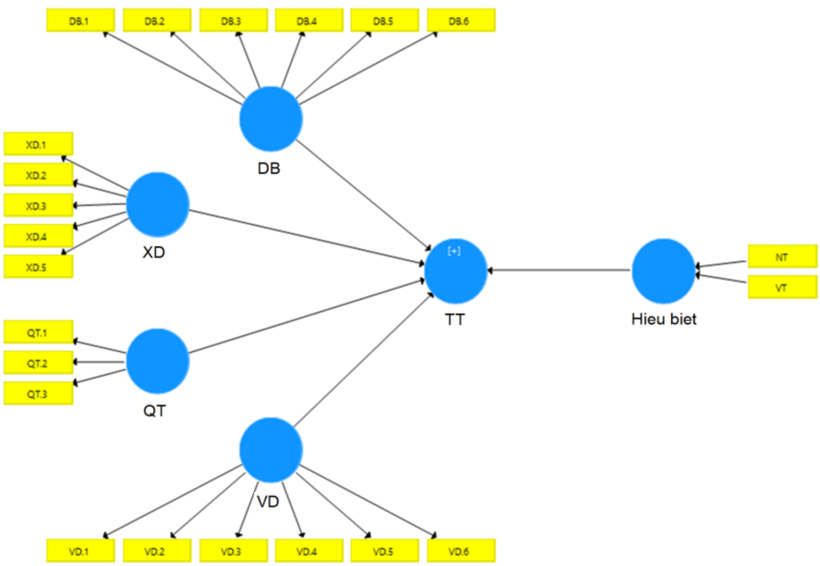


Figure 5. Relationship between SDL impact and influencing factors.

Assessment of the quality of the lower-order constructs (NT and VT): In the causal model, the quality of the two lower-order constructs was assessed using two indicators: outer weights and outer loadings. Table 7 presents the outer weights of the lower-order constructs (LOCs) on the higher-order construct (Hieu biet/Understanding). With p-values < 0.05, both constructs are statistically significant in the model, even without considering their outer loadings.

Table 7. Outer weights of LOC table

Path (LOC → HOC)	Original sample (O)	Sample mean (M)	Standard deviation (STDEV)	T statistics (|O/STDEV|)	P Values
NT -> Hieu biet	0.3	0.299	0.116	2.597	0.009
VT -> Hieu biet	0.717	0.718	0.112	6.409	0

4.3. Evaluation of the Measurement Model (Outer Model)

For the outer model, the study assessed the independent constructs influencing the current status of implementation, including Ensuring conditions (DB), Determining STEAM factors (XD), Building processes (QT), and Application measures (VD). These constructs were evaluated in terms of indicator quality, reliability, convergent validity, and discriminant validity.

Indicator quality was examined using outer loadings. Hair et al. (2019) recommend that outer loadings should be at least 0.70 to ensure adequate indicator reliability. As shown in Figure 6, all indicators of the independent constructs meet the > 0.70 threshold and were therefore retained for subsequent analyses.

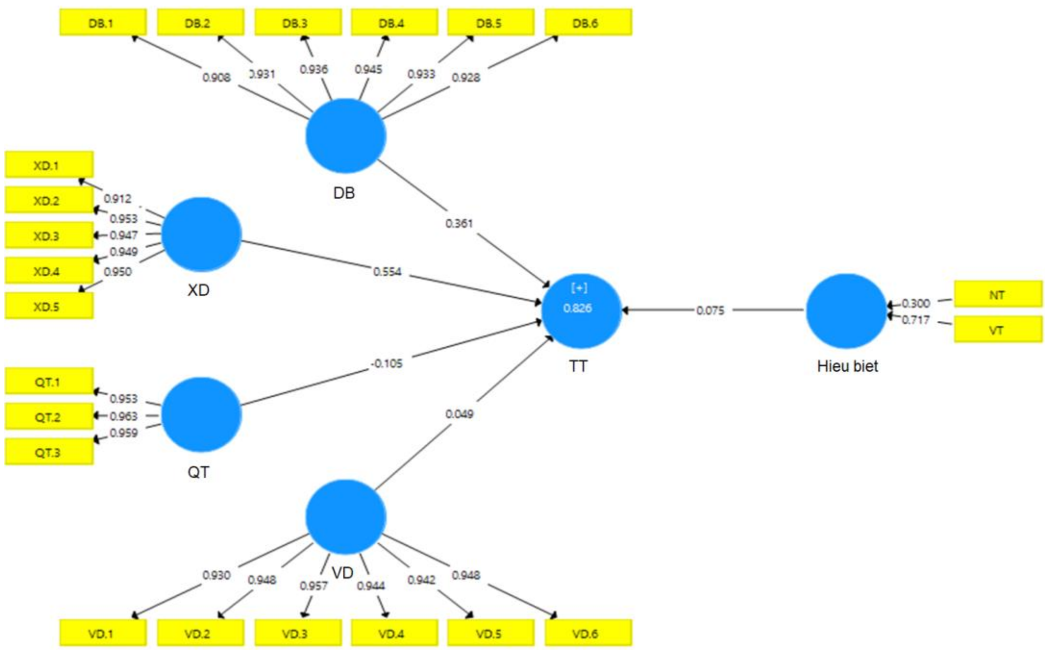


Figure 6. Quality of observed variables of independent variables.

Reliability and convergent validity of the scales were assessed using the Composite Reliability (CR) and Average Variance Extracted (AVE) indices. According to Henseler and Sarstedt (2013), CR values greater than 0.70 indicate satisfactory reliability, while Hock and Ringle (2010) suggest that AVE values above 0.50 provide evidence of convergent validity. Table 8 presents the reliability and convergent validity statistics for the lower-order constructs (DB, QT, TT, VD, and XD). All constructs show Cronbach's alpha and Composite Reliability values above 0.70, and AVE values above 0.50, indicating satisfactory reliability and convergent validity.

Table 8. Scale reliability and convergence.

Construct	Cronbach's alpha	Composite reliability	Average variance extracted (AVE)
DB	0.969	0.975	0.865
QT	0.956	0.971	0.919
TT	0.930	0.956	0.877
VD	0.976	0.98	0.893
XD	0.968	0.975	0.888

Discriminant validity was assessed using the Fornell–Larcker criterion (Fornell & Larcker, 1981). This method compares the square root of the AVE (√AVE) for each construct with the correlations between that construct and the other constructs in the model. AVE (average variance extracted) reflects the average amount of variance a latent construct explains in its observed indicators. Discriminant validity is established when a construct's √AVE is greater than its correlations with all other constructs. The results in Table 9 indicate that this condition is met, confirming adequate discriminant validity of the scales.

Table 9. Fornell and Larcker table.

Construct	DB	QT	TT	VD	XD
DB	0.93				
QT	0.893	0.959			
TT	0.879	0.828	0.937		
VD	0.817	0.861	0.776	0.945	
XD	0.909	0.912	0.893	0.831	0.942

Evaluation of the structural model (Inner model): For the structural model, the analysis focused on the significance of the relationships among constructs (path coefficients), the explained variance (R^2), and effect sizes (f^2).

As shown in Table 10, the path coefficients with p-values < 0.05 indicate that ensuring conditions for STEAM implementation and process development significantly influence the current status of STEAM application in lower secondary teaching. This finding suggests a practical direction for improving the quality of STEAM integration in Local Education: priority should be given to strengthening foundational support, ranging from school-level support and facilities to teachers' knowledge and skills and to developing a clear, detailed implementation process to guide teachers' practice. In this view, specific application measures or STEAM-infused lesson content appear to be outcomes that are more likely to emerge once a solid foundation and structured process are in place, rather than serving as the decisive input factors for increasing STEAM implementation in teaching.

Table 10. Impact relationship between factors.

Relationship	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values	Significance
DB -> TT	0.361	0.341	0.111	3.244	0.001	**
Hieu biet -> TT	0.075	0.069	0.088	0.852	0.394	ns
QT -> TT	-0.105	-0.085	0.122	0.864	0.387	ns
VD -> TT	0.049	0.055	0.064	0.772	0.440	ns
XD -> TT	0.554	0.553	0.114	4.847	0.000	***

Note: ns = Not significant; ** $p < 0.01$; *** $p < 0.001$.

The R^2 and f^2 values reported in Table 11 indicate that the study variables explain 82.3% of the variance in TT, with XD exerting the strongest influence. This suggests that, in terms of implementation priorities, emphasis should be placed on developing the application process and organizing instruction in alignment with the STEAM model.

Table 11. R2 and f2 indexes.

Path	Loading Factor			f-Square	R-square
	Direct effect	Indirect effect	Total effect		
DB -> TT	-	-	0.361	0.082	0.823
XD -> TT	-	-	0.554	0.206	

Note. Blank cells in the exported output reflect the software's default display format and do not indicate missing data.

5. DISCUSSION

The present study aimed to examine teachers' readiness and the feasibility of implementing the STEAM model in teaching the Local Education subject in mountainous lower secondary schools, as well as to identify the key factors shaping current implementation. *First*, with regard to readiness and feasibility, the PLS-SEM results show that Enabling Conditions (DB) and STEAM Element Specification (XD) significantly predict the Current State of STEAM implementation (TT) (β_DB→TT = 0.361; β_XD→TT = 0.554; $p < 0.001$), whereas Implementation Procedure (QT), Perceived STEAM Role (VT) and Practical Application (VD) do not exhibit statistically significant effects. This finding suggests that in mountainous contexts, material conditions and organizational environments remain foundational determinants of whether STEAM can be enacted, beyond teachers' awareness or motivation alone (Thibaut et al., 2019). In other words, in the absence of facilities, equipment, instructional materials, time and professional support from schools, even knowledgeable and committed teachers face difficulties in implementing STEAM effectively. This aligns with Herro and Quigley (2017) who reported that more than 80% of teachers in their sample struggled with STEAM due to limited preparation time, lack of interdisciplinary collaboration and insufficient resources, and with Le et al. (2021) who observed that Vietnamese teachers tend to hold positive views of STEAM but lack the "foundational conditions" to practice it, particularly in disadvantaged settings. *Second*, the strong effect of STEAM Element Specification (XD) ($\beta = 0.554$) indicates that teachers' ability to identify, analyze and integrate STEAM-related components into specific Local Education topics is a critical link in the implementation chain. When teachers can determine "where STEAM is" within local issues such as environment, culture, or livelihoods, they are better positioned to design project-based and experiential activities that are both meaningful and feasible. This type of integrated professional competence is still underdeveloped among many teachers in mountainous areas, largely due to limited training and a lack of exemplar materials. The finding reinforces the need for teacher education to move beyond general awareness-raising and toward explicit training in designing STEAM lessons and recognizing STEAM elements in context-specific local education topics. *Third*, comparison with studies conducted in more advantaged contexts reveals a clear regional gap. Mean scores for mountainous teachers (Mean ≈ 3.4–3.5) are approximately 0.5 points lower than corresponding scores reported in urban or better-resourced settings (e.g., Ho (2023) Mean ≈ 4.0). This suggests that inequalities in resources extend not only to infrastructure but also to opportunities for professional development, access to materials and participation in professional networks. A distinctive contribution of this study is its focus on the Local Education subject a relatively new component of the 2018 Vietnamese General Education Program, rather than on science subjects alone. Integrating STEAM into Local Education appears to make learning more situated and meaningful for students, but simultaneously raises demands on teachers' lesson design capacity, particularly in connecting local knowledge with STEAM elements.

These findings lead to several practical implications. *First*, there is a need to develop a procedural framework for STEAM implementation in the Local Education subject, outlining steps from topic selection and STEAM element identification to the design of project-based tasks, organization of experiential activities and assessment of students' problem-solving competence in local contexts. *Second*, provincial Departments of Education and Training should foster a supportive ecosystem through open educational resources, online repositories and provincial "STEAM Hubs" that enable teachers to share lesson ideas, videos, materials and classroom practices. *Third*, school-based professional development through professional learning communities (PLCs), supported by universities and STEAM experts, can help teachers build design skills and experiment with the use of locally available materials. These implications are consistent with international literature emphasizing the roles of organizational conditions, policy support and continuous professional development in STEAM implementation (Geng et al., 2019; Heredia-Sacio & Herrera-San Martín, 2025). Several limitations should also be acknowledged. *First*, the data are based on teachers' self-reports and may be subject to social desirability bias; future research should incorporate classroom observations and in-depth interviews to enhance validity. *Second*, the PLS-SEM model captures correlational relationships and does not establish causality; intervention studies using pre–post designs are needed to evaluate the actual impact of the proposed pedagogical measures. *Third*, the sample is limited to six northern mountainous provinces and cannot represent all mountainous regions in Viet Nam, such as the Central region or Central Highlands; broader comparative studies across regions could clarify the roles of cultural, socio-economic and policy-related factors. *Fourth*, the present work draws only on teacher data; incorporating student perspectives and outcome measures (e.g., STEAM competence, engagement, problem-solving performance) would provide a more comprehensive picture of readiness and feasibility for STEAM in the Local Education subject.

6. CONCLUSION

This study aimed to evaluate teachers' readiness and the feasibility of implementing the STEAM model in teaching the Local Education subject in mountainous lower secondary schools, and to identify the key factors shaping current implementation. Drawing on survey data from teachers in six northern mountainous provinces and PLS-SEM analysis, the findings indicate that Enabling Conditions (DB) and STEAM Element Specification (XD) are the most influential predictors of the Current State of STEAM implementation (TT), jointly explaining a substantial proportion of its variance ($R^2 = 0.823$), while other factors show no significant direct effects. Theoretically, the study extends existing frameworks of readiness and feasibility for STEAM by examining a distinctive context, disadvantaged mountainous regions and by demonstrating how STEAM can be meaningfully embedded in the Local Education subject. The results suggest that STEAM should not be confined to science subjects; it can also operate as a pedagogical approach that connects students with local culture, environment, and community issues. Practically, the study underscores two priority pillars for advancing STEAM in mountainous areas: strengthening organizational and resource foundations (infrastructure, materials, interdisciplinary collaboration and professional support) and developing teachers' integrated professional competence, particularly their ability to identify and embed STEAM elements in specific Local Education topics. On this basis, the study proposes directions for procedural frameworks, professional networks and policy support that can help move STEAM from isolated initiatives toward a more sustainable, system-level strategy. Despite limitations related to the use of self-reported data, the absence of experimental evidence, and the restricted geographical scope, the study provides empirical support for the readiness and feasibility of STEAM in the local education subject in mountainous lower secondary schools. Future intervention studies that incorporate student outcomes will be crucial for testing and refining the proposed pedagogical measures and for consolidating STEAM as a long-term strategy rather than a short-lived reform trend in education for mountainous regions.

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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.
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REFERENCES

Amanova, A. K., Butabayeva, L. A., Abayeva, G. A., Umirbekova, A. N., Abildina, S. K., & Makhmetova, A. A. (2025). A systematic review of the implementation of STEAM education in schools. *Eurasia Journal of Mathematics, Science and Technology Education, 21*(1), em2568. https://doi.org/10.29333/ejmste/15894

Anh, N. T. K., Em, V. V. D., & Bao, N. Q. (2024). Designing and organizing teaching on the topic "Danger warning lights on winding roads and steep passes" to develop the ability to apply knowledge and skills in natural science. *VNU Journal of Science: Education Research, 40*(2), 227–237.

Boice, K. L., Jackson, J. R., Alemdar, M., Rao, A. E., Grossman, S., & Usselman, M. (2021). Supporting teachers on their STEAM journey: A collaborative STEAM teacher training program. *Education Sciences, 11*(3), 105. https://doi.org/10.3390/educsci11030105

Bui, T.-L., Tran, T.-T., Nguyen, T.-H., Nguyen-Thi, L., Tran, V.-N., Dang, U. P., . . . Hoang, A.-D. (2023). Dataset of Vietnamese preschool teachers' readiness towards implementing STEAM activities and projects. *Data in Brief, 46*, 108821. https://doi.org/10.1016/j.dib.2022.108821

Connor, A. M., Karmokar, S., & Whittington, C. (2015). From STEM to STEAM: Strategies for enhancing engineering & technology education. *International Journal of Engineering Pedagogy, 5*(2), 37–47. https://doi.org/10.3991/ijep.v5i2.4458

Conradty, C., & Bogner, F. X. (2018). From STEM to STEAM: How to monitor creativity. *Creativity Research Journal, 30*(3), 233-240. https://doi.org/10.1080/10400419.2018.1488195

Danh, T. (2023). Literature review on local education for high school students. *Dong Thap University Journal of Science, 12*(3), 89-99. https://doi.org/10.52714/dthu.12.3.2023.1050

Dinh, L. T. (2021). Difficulties in implementing STEAM education model at the Northern mountainous preschool in Vietnam. *Journal of Physics: Conference Series, 1835*(1), 012020. https://doi.org/10.1088/1742-6596/1835/1/012020

Fornell, C., & Larcker, D. F. (1981). Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research, 18*(1), 39-50. https://doi.org/10.1177/002224378101800104

Geng, J., Jong, M. S.-Y., & Chai, C. S. (2019). Hong Kong teachers' self-efficacy and concerns about STEM education. *The Asia-Pacific Education Researcher, 28*(1), 35-45. https://doi.org/10.1007/s40299-018-0414-1

Hai, T. D., Linh, N. Q., & Bich, N. T. (2023). Obstacles and challenges in implementing STEM education in high schools: A case study in the Northern mountains of Vietnam. *European Journal of Educational Research, 12*(3), 1363-1375. https://doi.org/10.12973/eu-jer.12.3.1363

Hair, J. F., Risher, J. J., Sarstedt, M., & Ringle, C. M. (2019). When to use and how to report the results of PLS-SEM. *European Business Review, 31*(1), 2-24. https://doi.org/10.1108/EBR-11-2018-0203

Harris, A., & de Bruin, L. R. (2018). Secondary school creativity, teacher practice and STEAM education: An international study. *Journal of Educational Change, 19*(2), 153-179. https://doi.org/10.1007/s10833-017-9311-2

Henseler, J., & Sarstedt, M. (2013). Goodness-of-fit indices for partial least squares path modeling. *Computational Statistics, 28*(2), 565-580. https://doi.org/10.1007/s00180-012-0317-1

Heredia-Sacio, M. D., & Herrera-San Martín, E. D. C. (2025). Teachers in training: Perceptions and attitudes towards STEAM education, a systematic literature review. *Revista Electrónica Educare, 29*(2), 1–19.

Herro, D., & Quigley, C. (2017). Exploring teachers' perceptions of STEAM teaching through professional development: Implications for teacher educators. *Professional Development in Education, 43*(3), 416-438. https://doi.org/10.1080/19415257.2016.1205507

Ho, T. C. (2023). The application of STEAM teaching: A case study of STEAM teachers' beliefs and practice at secondary schools in Ho Chi Minh city. *Science & Technology Development Journal—Social Sciences & Humanities, 6*(S1), 42–51.

Hock, M., & Ringle, C. M. (2010). Local strategic networks in the software industry: An empirical analysis of the value continuum. *International Journal of Knowledge Management Studies, 4*(2), 132-151. https://doi.org/10.1504/IJKMS.2010.030789

Huong, C. T. M. (2024). Research on some methods to organize teaching activities according to STEAM education orientation in History subject in high school. Master's Thesis. Vietnam National University, Hanoi, Vietnam.

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. *International Journal of STEM Education, 3*(1), 11. https://doi.org/10.1186/s40594-016-0046-z

Kidman, G., & Tan, H. (2025). Interdisciplinary integration for future-Making education in STEAM. In Knowledge Generation in STEM and STEAM Education: Integrative Thinking and Agency. In (pp. 341-355). Cham: Springer Nature Switzerland.

Le, L. T. B., Tran, T. T., & Tran, N. H. (2021). Challenges to STEM education in Vietnamese high school contexts. *Heliyon, 7*(12), e08649. https://doi.org/10.1016/j.heliyon.2021.e08649

Li, Y., Wang, K., Xiao, Y., & Froyd, J. E. (2020). Research and trends in STEM education: A systematic review of journal publications. *International Journal of STEM Education, 7*(1), 11. https://doi.org/10.1186/s40594-020-00207-6

Maeda, H., Ota, Y., Wang, Y., Ramachandran, K., Montgomery, R. A., Williams, G. M., & Sun, Z. (2013). Contribution of extrahepatic small cells resembling small hepatocyte-like progenitor cells to liver mass maintenance in transplantation model of retrorsine-pretreated liver. *SpringerPlus, 2*(1), 446. https://doi.org/10.1186/2193-1801-2-446

Margot, K. C., & Kettler, T. (2019). Teachers' perception of STEM integration and education: A systematic literature review. *International Journal of STEM Education, 6*(1), 2. https://doi.org/10.1186/s40594-018-0151-2

Milara, I. S., & Orduña, M. C. (2024). Possibilities and challenges of STEAM pedagogies. *arXiv preprint arXiv:2408.15282*. https://doi.org/10.48550/arXiv.2408.15282

Miller, B. G., & Roehrig, G. (2018). Indigenous cultural contexts for STEM experiences: Snow snakes' impact on students and the community. *Cultural Studies of Science Education, 13*(1), 31-58. https://doi.org/10.1007/s11422-016-9738-4

Nga, N. T., & Trung, T. T. (2021). STEAM education and the potential of applying the design thinking process to implement STEAM education. *Journal of Science, Ho Chi Minh City University of Education, 18*(2), 310–321.

Oliveira, A. W., Nguyen, C. Y., Lê, H. H., Phạm, H. T. T., & Dang, V. T. (2026). STEM education in Vietnam: Examining the impact of an internationally transferred educational approach. *Discover Education, 5*, 74. https://doi.org/10.1007/s44217-025-01086-1

Özsoy, V. (2025). Effect of STEAM education on schools and universities in Türkiye. In Y. Cooper & A. Lai (Eds.), STEAM education: Intersections and thresholds. In (pp. 57–73). Leiden, The Netherlands: Brill.

Perignat, E., & Katz-Buonincontro, J. (2019). STEAM in practice and research: An integrative literature review. *Thinking Skills and Creativity, 31*, 31-43. https://doi.org/10.1016/j.tsc.2018.10.002

Quang, L. N., & Thu, H. L. T. (2025). The role of STEM education in reducing educational inequalities: A case study in the Northern mountainous provinces of Vietnam. *International Journal of Innovative Research and Scientific Studies, 8*(2), 2268–2277. http://doi.org/10.53894/ijirss.v8i2.5679

Quigley, C. F., Herro, D., & Jamil, F. M. (2017). Developing a conceptual model of STEAM teaching practices. *School Science and Mathematics, 117*(1-2), 1-12. https://doi.org/10.1111/ssm.12201

Spyropoulou, N., Mathiopoulos, K., & Kameas, A. (2025). "We believe in STEAM education, but we need support": In-service teachers' voices on the realities of STEAM implementation. *Education Sciences, 15*(10), 1300. https://doi.org/10.3390/educsci15101300

Taber, K. S. (2018). The use of Cronbach's alpha when developing and reporting research instruments in science education. *Research in Science Education, 48*(6), 1273-1296. https://doi.org/10.1007/s11165-016-9602-2

Thao, N. P., Huong, L. T. T., Dinh, N. V., Hang, N. T. T., Quyen, C. V., Cuong, L. M., & Thao, T. T. P. (2024). Current situation of primary school teachers' integrated STEM teaching competence: An exploratory study in the Northern mountainous provinces of Vietnam. *Jurnal Pendidikan IPA Indonesia, 13*(1), 64-75. https://doi.org/10.15294/jpii.v13i1.49636

The Politburo. (2025). *Notice No. 81-TB/TW dated July 18, 2025 on the policy of investing in building schools for border communes*. Hanoi, Vietnam: Communist Party of Vietnam.

Thibaut, L., Knipprath, H., Dehaene, W., & Depaepe, F. (2019). Teachers' attitudes toward teaching integrated STEM: The impact of personal background characteristics and school context. *International Journal of Science and Mathematics Education, 17*(5), 987-1007. https://doi.org/10.1007/s10763-018-9898-7

Truong, T. D., & Tran, Q. G. (2025). Factors influencing STEAM teaching at private schools in Vietnam: A case study of Ho Chi Minh City. *Educational Process: International Journal, 17*, e2025340. https://doi.org/10.22521/edupij.2025.17.340

Tuyet, H. T. (2023). STEM, STEAM, and STREAM education from world and Vietnam perspectives. *Vietnam Journal of Educational Sciences, 19*(3), 68–73.