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Perspectives of Administrators and Teachers on Factors Affecting STEM Professional Development Management in Primary Schools in the Mekong Delta

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Abstract

This study examined administrators' and teachers' perceptions of the factors affecting the management of professional development for primary school teachers' STEM teaching competencies in the Mekong Delta, Vietnam. The paper reports the quantitative phase of a mixed-methods study and employed a cross-sectional survey of 1,100 participants, including 350 school administrators and 750 primary school teachers. The 64-item instrument covered eight factor groups: teachers' competencies, awareness, and attitudes; administrators' management capacity and commitment; facilities and technological infrastructure; organizational culture and coordination mechanisms; education policies; support from teacher education institutions and experts; parents, communities, and local authorities; and international integration, digital transformation, Industry 4.0, and artificial intelligence. The scales demonstrated acceptable reliability, with Cronbach's alpha coefficients ranging from 0.751 to 0.772. Data were analyzed using descriptive statistics and independent-samples t-tests. The findings indicated that all eight factor groups were perceived to exert a high level of influence, with overall mean scores ranging narrowly from 3.77 to 3.78. Nevertheless, administrators consistently reported substantially higher ratings than teachers: factor-level means ranged from 4.35 to 4.38 among administrators, compared with 3.49 to 3.50 among teachers. Areas of shared concern included a weak culture of professional knowledge sharing, limited inspirational leadership, insufficient safety conditions for STEM practice, restricted decentralization, inadequate post-professional-development expert support, and unstable school-community collaboration. The study recommends need-based management, stronger instructional leadership, professional learning communities, sustained follow-up support, and regional partnership networks to enhance the effectiveness of STEM teacher professional development in primary schools.

1. INTRODUCTION

STEM education is widely regarded as an important orientation that enables students to integrate knowledge from science, technology, engineering, and mathematics to solve real-world problems. At the primary level, STEM education has foundational significance because it creates early opportunities to develop scientific thinking, collaboration, creativity, and problem-solving through inquiry, experiential learning, and engineering design activities (Bybee, 2013; Honey et al., 2014; National Research Council, 2012). Under Vietnam's 2018 General Education Curriculum, the emphasis on developing learners' qualities and competencies, together with guidance on organizing STEM education in primary schools, has provided a basis for schools to strengthen integrated and context-based teaching (Ministry of Education and Training, 2018b, 2023).

The quality of STEM education implementation depends directly on teachers' competencies. Primary school teachers need not only an understanding of interdisciplinary knowledge but also the ability to design themes, organize experiential activities, use technology and instructional resources, and assess students' learning processes and products. The pedagogical content knowledge (PCK) and technological pedagogical content knowledge (TPACK) frameworks indicate that contemporary teaching competence is an integration of content, pedagogical, and technological knowledge rather than a mechanical aggregation of separate skills (Mishra & Koehler, 2006; Shulman, 1986). Professional development for STEM teaching competencies should therefore be organized as a continuous process connected to classroom practice, reflection, and collaborative learning. Nevertheless, numerous domestic studies have shown that primary school teachers continue to face considerable challenges in developing STEM teaching competence, particularly in designing STEM topics, integrating interdisciplinary content, organizing experiential learning activities, and applying technology. However, numerous studies indicate that developing primary school teachers' STEM teaching competencies still faces significant challenges-such as limitations in designing STEM topics, interdisciplinary integration, organizing experiential activities, and applying technology-while professional development activities lack a systematic approach and are not closely aligned with teachers' professional development needs. (Avalos, 2011; Darling-Hammond et al., 2017; Desimone, 2009).

However, the effectiveness of professional development (PD) depends not only on program content or delivery methods but also on how professional development activities are managed. Such management includes needs assessment, planning, program and resource development, implementation, resource mobilization, monitoring and evaluation, follow-up support, and continuous improvement. In this study, the PDCA cycle is employed as an analytical framework to examine the relationship between management functions and the continuous improvement of professional development activities. From a Plan-Do-Check-Act (PDCA) perspective, these functions must operate as an interconnected feedback cycle; when the stages are fragmented, professional development can become a short-term exercise focused on administrative compliance rather than changes in professional practice. In addition to the PDCA cycle, this study draws on teacher PD theory, as well as the PCK and TPACK frameworks, to develop an analytical framework for examining the factors influencing the management of PD activities aimed at developing STEM teaching competence. This analytical framework also provides the basis for identifying the study variables and developing the survey instrument. (Deming, 1986; Guskey, 2002; Truong & Vo, 2026).

The Mekong Delta presents both favorable conditions and challenges for STEM education development. Its ecosystems of agriculture, aquaculture, water resources, marine economy, and climate-change adaptation provide rich real-world learning resources for STEM instruction. At the same time, variations in educational development conditions across localities within the region provide an appropriate basis for examining the effects of management factors across different contexts of STEM education implementation. Conversely, geographical dispersion, disparities in facilities and digital infrastructure, and unequal access to experts across localities may widen differences in teachers' professional learning opportunities. Consequently, the management of STEM professional development in the region should be viewed as an open system simultaneously influenced by internal school conditions and the external environment.

Previous studies have clarified the roles of teacher competence, school leadership, professional learning communities, technological conditions, and stakeholder support in PD. However, most studies have examined individual factors in isolation or focused on teacher PD in general, without systematically analyzing the factors influencing the management of PD activities aimed at developing STEM teaching competence in primary schools. (DuFour, 2004; Leithwood et al., 2008; Margot & Kettler, 2019; Vescio et al., 2008). Nevertheless, evidence remains limited regarding simultaneous comparisons of administrators' and teachers' perceptions across a relatively comprehensive system of influencing factors in the context of primary education in the Mekong Delta. This gap is particularly important because perceptual differences between management actors and program beneficiaries may reflect a divide between policy and planning on the one hand and implementation experience on the other.

This study addresses three research questions: (1) To what extent are internal and external factor groups perceived to influence the management of PD for STEM teaching competencies? (2) How do administrators' and teachers' perceptions differ? and (3) Which bottlenecks are recognized relatively consistently by both groups and should therefore be prioritized? The findings contribute empirical evidence to the theoretical framework for managing STEM professional development and provide a basis for designing management solutions suited to regional conditions, the study also identifies differences in perceptions between school administrators and teachers, thereby providing a scientific basis for prioritizing management factors in policy formulation and the organization of PD activities that are aligned with the practical conditions of the Mekong Delta region.

2. THEORETICAL FOUNDATIONS AND ANALYTICAL FRAMEWORK

2.1. Management of PD for STEM Teaching Competencies

In this study, PD management for primary school teachers' STEM teaching competencies is understood as a purposeful, systematic, and continuous process through which management actors perform planning, organizing, directing, monitoring and evaluation, and improvement functions to mobilize and coordinate resources and create conditions for teachers to develop their ability to design, organize, and assess STEM teaching. The choice of a functional approach to management stems from the need to conceptualize PD as a comprehensive management process in which management functions are organically interconnected and mutually influence one another, thereby ensuring continuity, coherence, and effectiveness. This approach integrates functional management theory with the perspective of teacher PD, according to which PD outcomes should be demonstrated through changes in teaching practice and, at a higher level, improvements in student learning. This conceptualization also provides the basis for identifying the management areas to be examined and analyzing the extent to which management factors influence PD activities aimed at developing primary school teachers' STEM teaching competence. (Guskey, 2002; Koontz & Weihrich, 2010).

Primary school teachers' STEM teaching competencies are conceptualized as an integrated construct comprising interdisciplinary STEM knowledge; the ability to design STEM lessons or projects; the ability to organize inquiry, experiential learning, and engineering design activities; the ability to use technology and instructional resources; and the ability to assess learning processes and products. The components of STEM teaching competence were synthesized based on STEM teaching competence models reported in international studies and cross-referenced with the requirements of Vietnam's 2018 General Education Curriculum and the practical context of STEM teaching in Vietnamese primary schools. This structure is consistent with the nature of STEM education and competency-based teaching requirements. In this study, the structure of STEM teaching competence is used not only to clarify the focus of PD activities but also to provide a basis for developing assessment criteria and identifying factors influencing the management of these activities within the study's analytical framework. (Honey et al., 2014; Mishra & Koehler, 2006; National Research Council, 2012).

2.2. Internal School Factors

First, teachers' competencies, awareness, and attitudes constitute direct input conditions for professional development. Teachers are both beneficiaries of PD and agents who transform its outcomes into classroom practice. Interdisciplinary competence, technological competence, self-directed learning capacity, readiness for change, and willingness to share professional knowledge influence both participation and the effective application of learning after PD. In this study, teacher-related factors are regarded as a central component of the management system for PD activities because they directly reflect teachers' capacity to receive, internalize, and translate PD outcomes into STEM teaching practice. (Avalos, 2011; Shernoff et al., 2017).

Second, administrators' management capacity, attention, and commitment determine the extent to which policy directions can be translated into plans, resources can be allocated, and motivation for innovation can be generated. Leadership has a substantial influence on educational outcomes through goal setting, engagement in instructional leadership, staff development, and the construction of professional learning environments (Leithwood et al., 2008; Robinson et al., 2008). In STEM education, administrators need strategic, digital, and data-use competencies, together with the capacity to inspire staff. Therefore, in this study, school administrator-related factors are considered to play a coordinating role in creating a supportive environment for the effective implementation of PD activities aimed at developing STEM teaching competence.

Third, physical facilities, teaching equipment, and information technology infrastructure establish objective limits on the scope and depth of PD activities. STEM education requires practice spaces, materials, equipment, software, Internet connectivity, and appropriate safety conditions. Infrastructure creates genuine value only when teachers have regular access to it, can use it effectively, and receive appropriate technical support. Accordingly, in the analytical framework of this study, infrastructure and technological conditions are considered a group of factors that ensure the effective implementation of PD activities and STEM teaching in schools. (Mishra & Koehler, 2006; Redecker, 2017).

Fourth, organizational culture, coordination mechanisms, and motivation for professional growth function as the school's 'soft infrastructure.' An open culture, trust, two-way communication, appropriate delegation of authority, and equitable recognition policies enable teachers to share practices, experiment with new methods, and sustain continuous learning. Professional learning communities become effective only when they are supported by adequate time, coordination mechanisms, and consistent leadership. This group of factors reflects the organizational environment of schools and is included in the study to examine the extent to which organizational culture and coordination mechanisms affect the effectiveness of managing PD activities aimed at developing STEM teaching competence. (DuFour, 2004; Schein, 2010; Vescio et al., 2008).

Based on a synthesis of previous studies, the four aforementioned school-level internal factors were selected for inclusion in the analytical framework because they represent management components that may directly affect the effectiveness of organizing PD activities aimed at developing STEM teaching competence among primary school teachers. These factor groups also provided the basis for developing the observed variables and designing the survey instrument for the study.

2.3. External School Factors

The system of policies, regulations, and reform orientations issued by the State and the education sector establishes the legal framework, standards, and resources for professional development. In addition to providing a legal framework, the policy system also guides the objectives, content, organizational approaches, and quality assurance mechanisms of PD activities for STEM teachers. Therefore, the adequacy, coherence, and feasibility of policies are considered foundational factors influencing the effectiveness of managing PD activities in educational institutions. The clarity, coherence, and feasibility of policy documents affect schools' capacity to prepare plans, allocate funding, recognize outcomes, and align PD with teacher professional standards (Ministry of Education and Training, 2018a, 2019, 2023). However, policy produces substantive effects only when it is translated into procedures, responsibilities, and support mechanisms at the school level.

Support from teacher education institutions, experts, and science and technology organizations enables schools to expand professional capacity and gain access to standardized resources, equipment, and modern practice environments. In particular, follow-up support through mentoring, coaching, and online consultation helps sustain program effects and address difficulties that arise when teachers apply new learning in their classrooms. Research on teacher PD has shown that the effectiveness of this task depends not only on the quality of training courses but also on sustained support following PD. Therefore, establishing regular collaborative networks among schools, universities, research institutes, and experts is considered an important condition for sustaining and further developing teachers' STEM teaching competence. (Darling-Hammond et al., 2017; Desimone, 2009).

Parents, communities, and local authorities influence social consensus, resource mobilization, and the contextual relevance of STEM education. In the context of primary STEM education, community involvement also contributes to providing authentic contexts, locally relevant learning resources, and supporting resources for experiential learning activities, thereby enhancing the feasibility and sustainability of teacher PD. School-family-community partnerships facilitate experiential activities, the use of local knowledge, and the expansion of learning spaces, provided that participation remains voluntary, transparent, and equitable (Epstein, 2011).

Finally, international integration, digital transformation, Industry 4.0, and artificial intelligence are changing both the content and modes of professional development. Online learning platforms, open educational resources, simulations, AI, and digital professional communities create opportunities for personalization and broader access, while simultaneously requiring digital competence, ethical technology use, and data governance (OECD, 2023; UNESCO, 2018, 2021).

Thus, external factors do not directly affect teachers' STEM teaching competence but exert their influence by shaping the policy environment, resources, collaboration opportunities, and conditions for implementing PD activities. The extent to which external factors are coordinated with internal school conditions determines the effectiveness of managing PD activities aimed at developing STEM teaching competence among primary school teachers.

2.4. Analytical Framework

Based on the preceding arguments, the study developed an analytical framework comprising eight factor groups, divided into four internal and four external factors. The analytical framework was developed based on established theories of educational management, teacher PD, and STEM teaching competence, as well as findings from a review of domestic and international studies. The selection of eight groups of factors was intended to provide a relatively comprehensive representation of the components that may influence the management of PD activities aimed at developing STEM teaching competence in the context of primary schools. These factors are not treated as isolated causes but as interacting components within a PD management ecosystem. Based on this analytical framework, the factor groups were operationalized as observed variables to develop the survey questionnaire and assess their perceived influence on the management of PD activities among school administrators and teachers. The study focuses on measuring perceived levels of influence and comparing administrators' and teachers' perceptions; consequently, the results should not be interpreted as evidence of causal relationships.

Because the aim of the study was to identify and compare the perceived influence of the factor groups among the surveyed participants, the findings were used to determine the factors that should be prioritized in the management of PD activities, rather than to test causal relationships among the study variables.

3. RESEARCH METHODOLOGY

3.1. Research Design

The paper uses data from the quantitative phase of a mixed-methods study conducted through a cross-sectional survey design. This design is appropriate for describing perceived levels of influence and comparing differences between participant groups at a specific point in time (Creswell & Creswell, 2018).

A cross-sectional survey design was adopted because it was appropriate for identifying the current situation and comparing differences in perceptions among different groups of participants at a single point in time, rather than assessing changes over time or determining causal relationships among the study variables. This research design ensures consistency among the research questions, analytical framework, survey instrument, and data analysis procedures presented in the following sections. The use of a cross-sectional survey design was also consistent with the objective of determining the relative perceived influence of the factor groups among the survey participants within the specific research context.

3.2. Participants and Sampling

Table 1. Demographic Characteristics of the Participants (N = 1,100)

Characteristic	Category	n	%
Gender	Male	394	35.8
	Female	706	64.2
Teaching experience	<5 years	161	14.6
	5-10 years	264	24.0

Characteristic	Category	n	%
	11-20 years	382	34.7
	>20 years	293	26.6
School location	Urban	329	29.9
	Rural	501	45.5
	Peri-urban	270	24.5
Position	School administrators	350	31.8
	Teachers	750	68.2
Total		**1,100**	**100**

The sample comprised 1,100 participants: 350 primary school administrators (principals and vice principals) and 750 primary school teachers who had directly participated in, or had experience implementing, STEM education. The sample size was determined to ensure an adequate number of participants for descriptive statistical analyses and comparisons across participant groups. With a total of 1,100 participants, the sample size exceeded the minimum recommended threshold for survey research in educational science, thereby contributing to the reliability and generalizability of the research findings (Hair et al., 2019). Stratified sampling combined with purposive selection was used in public primary schools across the Mekong Delta to ensure diversity among urban, rural, and coastal settings. Stratifying the sample by geographic area was intended to capture differences in educational development conditions, infrastructure, digital infrastructure, and access to PD activities across localities in the Mekong Delta, thereby enhancing the representativeness of the sample within the research context. Including both groups enabled comparison between the perspectives of management actors and the experiences of those directly participating in PD and classroom instruction.

Surveying both groups of participants enabled the study not only to assess the perceived influence of the factors from the perspective of each group but also to compare differences in perceptions between school administrators and teachers. These comparisons provide an important basis for proposing management solutions that are appropriate to the practical implementation of PD activities aimed at developing STEM teaching competence in primary schools.

3.3. Survey Instrument

The questionnaire was developed from the study's theoretical framework and comprised 64 observed variables across eight scales, with eight items in each scale. The observed variables were not developed independently; rather, they were adapted and further developed based on theoretical foundations related to the management of teacher PD development, teacher PD, STEM education, and relevant empirical studies. The questionnaire development process involved a review of the literature, alignment with the study's analytical framework, and semantic refinement to ensure suitability for the context of managing professional development activities aimed at developing STEM teaching competence among primary school teachers in the Mekong Delta. Items were measured using a five-point Likert scale ranging from 1 (very low influence) to 5 (very high influence) (Likert, 1932). Experts reviewed the instrument before the formal survey. Reliability testing showed that Cronbach's alpha coefficients ranged from 0.751 to 0.772, meeting internal consistency requirements for exploratory and descriptive research (Hair et al., 2019).

Table 2. Structure and Reliability of the Measurement Scales

Code	Factor group	Classification	No. of items	Cronbach's α
TCA	Teachers' competencies, awareness, and attitudes	Internal	8	0.755
AMC	Administrators' management capacity, attention, and commitment	Internal	8	0.751
FITI	Facilities, teaching equipment, and information technology infrastructure	Internal	8	0.766
OCC	Organizational culture, coordination mechanisms, and professional motivation	Internal	8	0.772
EP	Education policies, regulations, and reform orientations	External	8	0.767
TES	Support from teacher education institutions, experts, and science and technology organizations	External	8	0.759
PCL	Parents, communities, and local authorities	External	8	0.763
DTAI	International integration, digital transformation, Industry 4.0, and artificial intelligence	External	8	0.757

3.4. Data Analysis

Data were analyzed using descriptive statistics and independent-samples t-tests. Mean scores were interpreted across five intervals: 1.00-1.80 (very low), 1.81-2.60 (low), 2.61-3.40 (moderate), 3.41-4.20 (high), and 4.21-5.00 (very high). The mean score for each factor group was calculated as the arithmetic mean of its eight observed variables. Independent-samples t-tests were conducted at the item level to examine differences between administrators and teachers, using a significance threshold of $p < 0.05$.

3.5. Research Ethics

Participants were informed of the study's purpose, the voluntary nature of participation, and their right to decline to answer. Before participating in the survey, participants were provided with information about the research objectives, procedures, and intended use of the data. Completion of the questionnaire was considered an indication of voluntary informed consent to participate in the study. The questionnaire did not collect personally identifying information; data were used solely for research purposes and reported in aggregate form.

The study was conducted in accordance with ethical principles governing social science and educational research, including respect for participants' voluntary participation, protection of the confidentiality of participants' information, avoidance of harm to participants, and the use of data solely for research purposes.

4. RESULTS

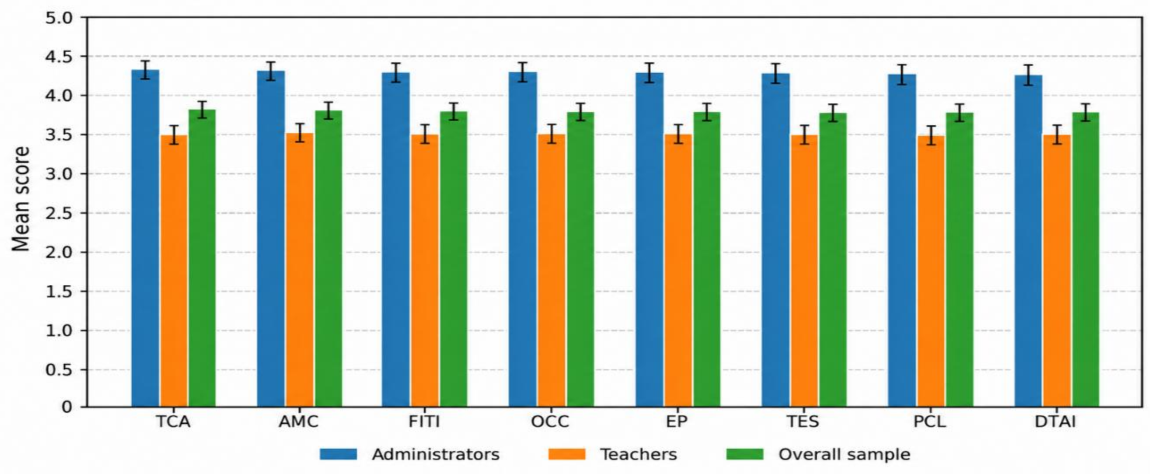
4.1. Overall Assessment Across the Eight Factor Groups

Table 2 shows that all eight factor groups were perceived to have a high level of influence, with overall mean (M) scores ranging within the very narrow interval of 3.767 to 3.781. The similarity of these scores indicates that the management of STEM professional development is simultaneously shaped by multiple components within and beyond the school; no single factor group clearly dominates. Support from teacher education institutions, experts, and science and technology organizations received the highest mean score (M = 3.781), followed by education policies and reform orientations (M = 3.777), parents and communities (M = 3.776), and the digital transformation and AI context (M = 3.774).

Table 3. Mean Scores by Participant Group and Factor Group

Code	Factor group	Administrators (n = 350) M (SD)	Teachers (n = 750) M (SD)	Overall (N = 1,100) M (SD)	Mean Difference	95% CI [LL, UL]
TCA	Teachers' competencies, awareness, and attitudes	4.358 (0.557)	3.491 (0.574)	3.767 (0.625)	0.867	[0.796, 0.938]
AMC	Administrators' management capacity, attention, and commitment	4.348 (0.514)	3.498 (0.533)	3.768 (0.588)	0.850	[0.784, 0.916]
FITI	Facilities, equipment, and IT infrastructure	4.368 (0.611)	3.494 (0.630)	3.772 (0.680)	0.874	[0.796, 0.952]
OCC	Organizational culture, coordination, and professional motivation	4.384 (0.455)	3.485 (0.474)	3.771 (0.544)	0.899	[0.840, 0.958]
EP	Education policies, regulations, and reform orientations	4.376 (0.581)	3.498 (0.602)	3.777 (0.656)	0.878	[0.803, 0.953]
TES	Support from teacher education institutions, experts, and science and technology organizations	4.374 (0.526)	3.504 (0.547)	3.781 (0.603)	0.870	[0.802, 0.938]
PCL	Parents, communities, and local authorities	4.371 (0.525)	3.498 (0.543)	3.776 (0.600)	0.873	[0.806, 0.940]
DTAI	International integration, digital transformation, Industry 4.0, and AI	4.370 (0.530)	3.496 (0.568)	3.774 (0.617)	0.874	[0.805, 0.943]

Figure 1. Comparison of Administrators', Teachers', and Overall Mean Scores Across the Eight Factor Groups



The most salient finding is not the ranking of the factor groups but the perceptual gap between the two participant groups. Administrators rated the factors at a very high level, with means ranging from 4.348 to 4.384, whereas teachers rated them only at a high level, with means ranging from 3.485 to 3.504. Differences ranged from 0.850 to 0.899 points. Within each scale, seven of the eight observed variables differed significantly between the groups, primarily at $p < 0.001$. These results indicate a systematic divide between management actors' assessments and teachers' experiences.

4.2. Internal School Factors

For teachers' competencies, awareness, and attitudes, the three highest-rated indicators all reached an overall mean of 3.83: awareness of the need for STEM professional development, confidence in connecting interdisciplinary knowledge, and readiness to change teaching methods. These findings reflect the roles of professional motivation, integrative competence, and readiness for innovation. However, active contribution of ideas and sharing of experience in professional meetings achieved only M = 3.43; this was the lowest-rated indicator and did not differ significantly between the groups ($p = 0.296$). The limitation therefore concerns not only individual capacity but also the culture of collaborative learning.

For management capacity, understanding policies, translating PD objectives into concrete terms, and mobilizing resources all reached M = 3.83. In contrast, effectiveness in inspiring, building trust, and motivating staff reached only M = 3.43, with relatively consistent assessments from both groups ($p = 0.247$). Administrative and technical management competencies were thus perceived more positively than transformational leadership and the capacity to lead people.

Regarding facilities and infrastructure, space for storing and displaying STEM products received the highest score (M = 3.84), suggesting that schools have paid attention to visual learning environments and the dissemination of student products. However, electrical infrastructure, fire prevention, and electrical safety conditions reached only M = 3.45; this was the only indicator without a significant difference between the groups ($p = 0.511$). The result implies that investment in equipment must be accompanied by risk management and safety standards.

For organizational culture and coordination mechanisms, incorporating STEM education into schools' long-term strategic objectives reached M = 3.83. By contrast, autonomy and decentralization mechanisms that allow professional teams to proactively propose professional-development content reached only M = 3.45 and did not differ significantly between the groups (p = 0.255). This finding indicates that strategic orientation has been established, but initiative and decision-making authority at the professional-team level remain limited.

4.3. External School Factors

Within the policy factor group, the clarity of guidance on PD content, methods, and delivery formats reached M = 3.84. Conversely, the effectiveness of inspection, supervision, and direct professional guidance from higher management levels reached only M = 3.48, with virtually no difference between administrators and teachers (t = 0.073; p = 0.942). The function of issuing directions was therefore rated more highly than the function of accompanying and supporting schools in implementation.

Support from teacher education institutions and experts was the factor group with the highest overall mean. The availability of university-provided STEM PD programs reached M = 3.86, while standardized resources reached M = 3.85. However, mechanisms for feedback and online expert support after professional development reached only M = 3.45 and were assessed similarly by both groups (p = 0.671). Program and resource provision was therefore viewed positively, but continuity of support remained a weak link.

Regarding parents, communities, and local authorities, parents' capacity to contribute resources reached M = 3.84, while the availability of craft villages or local enterprises that could support STEM experiences reached M = 3.83. In contrast, effective school-community coordination in organizing STEM festivals or field experiences reached only M = 3.45 and did not differ significantly between the groups (p = 0.626). These findings suggest that social resource potential is considerable, but mechanisms for converting that potential into stable educational activities remain limited.

Within international integration, digital transformation, and AI, the development of e-learning platforms and massive open online courses reached M = 3.84, while the roles of AI and online professional communities both reached M = 3.82. The lowest-rated indicator concerned the effect of future labor-market changes on the need to develop STEM human resources from an early stage (M = 3.50; p = 0.981). Both groups acknowledged this trend, but the rating was not particularly high, indicating that the relationship between future occupational transformation and teacher PD content has not yet been clearly translated into management practice.

4.4. Bottlenecks Jointly Identified by Both Groups

A managerially significant finding is that each factor group contained one lowest-rated indicator for which no statistically significant difference existed between administrators and teachers. These indicators may be regarded as bottlenecks identified with relative consensus because they were not strongly affected by participants' positions or by the more optimistic rating tendency of the administrator group.

Table 4. Low-Rated Indicators Without Significant Differences between the Two Groups

Factor group	Lowest-rated indicator	Administrators M (SD)	Teachers M (SD)	Overall M	*t*	*p*
TCA	Active contribution of ideas and sharing of professional experience	3.457 (0.638)	3.413 (0.665)	3.43	1.046	0.296

Factor group	Lowest-rated indicator	Administrators M (SD)	Teachers M (SD)	Overall M	*t*	*p*
AMC	Inspiring teachers, building trust, and creating motivation	3.377 (1.021)	3.455 (1.059)	3.43	1.159	0.247
FITI	Electrical infrastructure, fire prevention, and practice safety	3.489 (1.198)	3.437 (1.218)	3.45	0.657	0.511
OCC	Autonomy and decentralization for professional teams to propose professional-development content	3.474 (0.544)	3.433 (0.581)	3.45	1.138	0.255
EP	Inspection, supervision, and direct professional guidance from higher levels	3.483 (1.162)	3.477 (1.187)	3.48	0.073	0.942
TES	Online feedback and professional support from experts after professional development	3.440 (0.620)	3.457 (0.653)	3.45	0.425	0.671
PCL	School-community coordination in organizing STEM festivals and experiential activities	3.471 (0.814)	3.445 (0.853)	3.45	0.488	0.626
DTAI	Awareness of the impact of future labor-market change on STEM education	3.497 (0.740)	3.496 (0.777)	3.50	0.023	0.981

5. DISCUSSION

5.1. STEM Professional-Development Management as a Multifactor Ecosystem

The fact that all eight factor groups received high and nearly equivalent mean scores indicates that the effectiveness of STEM PD management cannot be improved through a single measure. Teacher competence, leadership capacity, organizational culture, facilities, policy, experts, communities, and technology constitute an interdependent ecosystem. This finding is consistent with the view of teacher PD as a process simultaneously shaped by individual characteristics, PD activities, and organizational contexts (Avalos, 2011; Desimone, 2009). The findings are consistent with previous studies on teacher PD, which emphasize that PD effectiveness depends not only on program quality but also on the organizational environment, school leadership support, and opportunities to apply acquired knowledge and skills in practice (Darling-Hammond et al., 2017; Guskey, 2002). This convergence suggests that the findings of the present study are broadly aligned with international research on teacher PD.

The findings further indicate that no single factor plays a decisive role in determining the effectiveness of managing PD activities. Rather, management effectiveness emerges from the interaction among internal and external factors. This suggests that prioritizing investment in or improving any single factor is unlikely to produce sustainable improvements without coordinated efforts across the other factors.

The results also reinforce the systems approach articulated in Theme 1, according to which PD management must connect planning, organizing, directing, monitoring and evaluation, and improvement functions. For example, the existence of university programs or digital resources does not automatically produce change when teachers lack time, receive no follow-up support, or are not empowered to experiment. Similarly, equipment investment creates little value in the absence of safety standards, maintenance, and user competence. Solutions should therefore be designed as a cycle with monitoring indicators for each stage.

5.2. The Gap Between Management Perspectives and Teachers' Experiences

The gap of 0.85 to nearly 0.90 points between administrators and teachers is the study's most prominent finding. Administrators tend to assess conditions on the basis of the presence of plans, regulations, investments, or organized activities, whereas teachers assess them according to accessibility, usefulness, and direct effects on professional practice. An activity that has been 'implemented' from a management perspective may therefore not be experienced by teachers as high-quality support.

This finding is consistent with studies on teacher PD, which indicate that school administrators' perceptions often reflect the extent to which plans are implemented and organizational conditions are ensured, whereas teachers tend to place greater emphasis on the applicability of acquired knowledge, the level of support provided during implementation, and the impact on their actual teaching practice (Desimone, 2009; Darling-Hammond et al., 2017). This suggests that evaluating the effectiveness of managing PD activities should not rely solely on input indicators or the extent to which plans are implemented, but should also consider teachers' experiences and the extent to which their professional practice changes.

This phenomenon may be explained by an implementation gap within organizations. Schein (2010) argues that formal declarations and espoused values may differ from underlying assumptions and actual practices. In PD management, the gap emerges when two-way feedback mechanisms are weak, teachers do not participate substantively in needs identification or planning, and data on teachers' experiences are not sufficiently incorporated into management decisions. Narrowing the perceptual gap should therefore be regarded as a governance objective rather than merely a communication issue.

This finding provides further empirical evidence supporting the study's assumption that the effectiveness of managing PD activities depends not only on the effective implementation of management functions but also on the degree of alignment in perceptions between school administrators and teachers. Therefore, narrowing the perception gap should be regarded as an important indicator of the quality of management of PD activities aimed at developing STEM teaching competence in primary schools.

5.3. Bottlenecks in the Transformation and Maintenance Stages

The indicators jointly rated lowest by the two groups largely concern neither initiation nor plan issuance; instead, they occur in the stages where professional-development outcomes must be transformed into practice and sustained over time. These indicators include professional sharing, inspirational leadership, decentralization, post-course expert support, community coordination, and direct guidance from higher levels. This finding is consistent with research on effective PD, which emphasizes the decisive roles of duration, sustained support, feedback, and learning communities in producing durable change (Darling-Hammond et al., 2017; Garet et al., 2001; Guskey, 2002).

This finding also indicates that the limitations in managing PD activities do not primarily stem from the planning stage but are more evident in ensuring the continuity of teachers' PD following such activities. This is consistent with the view that the effectiveness of professional development can only be fully realized when teachers have opportunities to apply acquired knowledge in practice, receive ongoing support, and participate in professional learning communities that help sustain changes in teaching practice (Desimone, 2009; Timperley et al., 2007).

In particular, the low ratings for knowledge-sharing culture and inspirational capacity suggest that PD management remains at risk of being more technical and administrative than learning-centered. School leaders need to move from merely 'organizing teacher participation' to creating conditions in which teachers learn together, experiment together, and share responsibility for improvement. This is consistent with evidence that leadership focused on teaching and learning has a stronger influence on educational outcomes than purely administrative management (Robinson et al., 2008).

From a management perspective, this finding suggests that efforts to improve the effectiveness of PD in the coming period should not focus solely on expanding the scale or increasing the number of PD courses. Instead, greater attention should be given to establishing post- PD support mechanisms, fostering a culture of learning within schools, and strengthening instructional leadership. This finding also provides an important practical basis for identifying management priorities to improve the quality of PD aimed at developing STEM teaching competence among primary school teachers.

5.4. Implications of the Regional Context and Digital Transformation

The Mekong Delta offers favorable conditions for localizing STEM content through issues related to agriculture, aquaculture, water resources, climate change, and the circular economy. However, contextual advantages can be transformed into learning resources and experiences only when cooperation networks connect schools, universities, enterprises, parents, and communities. The low rating for community coordination indicates that available resource potential has not yet been organized into stable mechanisms.

This finding is also consistent with international research on context-based STEM education, which suggests that the effectiveness of STEM teaching and teacher PD can be enhanced by addressing local real-world issues and strengthening stakeholder engagement within the educational ecosystem (Honey et al., 2014; National Research Council, 2012).

Digital transformation substantially expands PD opportunities across geographically dispersed areas. E-learning platforms, digital resources, and online communities were rated highly, yet post- PD support remained weak. This finding confirms that technology does not automatically generate quality; effectiveness depends on pedagogical design, interaction, mentoring, and feedback. UNESCO (2018, 2021) and OECD (2023) likewise emphasize that digital competence development must be accompanied by ethical governance, user support, and organizational adaptability.

Thus, the findings indicate that the effectiveness of managing PD activities aimed at developing STEM teaching competence in the context of the Mekong Delta depends simultaneously on the capacity to leverage local resources and the capacity to organize digital transformation in PD management. These two factors do not operate independently but need to be integrated into a coherent management strategy to enhance the relevance, accessibility, and sustainability of PD activities for STEM teachers.

5.5. Contributions of the Study

Theoretically, the study provides empirical support for the appropriateness of an eight-factor framework developed from systems thinking, management functions, competency development, and contextual perspectives. Methodologically, the simultaneous comparison of administrators and teachers reveals an implementation gap that would be difficult to identify through a single-group survey. The use of data from both participant groups also contributes to the reliability of the findings by enabling a comparison of perceptions between school administrators and those directly involved in PD activities. This approach provides greater insight into the gaps between policy, implementation processes, and teachers' practical experiences, thereby providing a scientific basis for improving the management of PD activities. Practically, the study not only identifies important factor groups but also highlights bottlenecks characterized by a high level of agreement, thereby supporting resource prioritization and the design of focused management solutions.

In addition to these contributions, the study provides a foundation for future research on the management of PD activities for STEM teachers by validating, refining, or extending the analytical framework across different educational contexts. Such research may enhance the generalizability of the findings and contribute to advancing research on the management of PD activities aimed at developing STEM teaching competence in general education.

6. MANAGEMENT IMPLICATIONS

The following management implications are proposed based on the survey findings regarding the perceived influence of factors on the management of PD activities aimed at developing STEM teaching competence among primary school teachers, while also drawing on the approaches to educational management, teacher PD, and STEM education presented in the theoretical framework. Therefore, these implications are grounded not only in the empirical evidence of the study but also in relevant theoretical perspectives and are applicable to the context of primary schools in the Mekong Delta.

First, PD needs should be managed through a data-informed and teacher co-design approach. Schools should combine self-assessment, classroom observation, analysis of lesson products, student outcomes, and feedback from professional teams to identify competency gaps. Teachers should participate in selecting priorities, designing pathways, and evaluating programs to reduce the distance between management plans and actual professional needs.

Second, administrators' instructional and transformational leadership competencies should be developed. Professional development for administrators should extend beyond planning and resource management to classroom observation, professional feedback, data use, motivation, change management, and the creation of psychologically safe environments for pedagogical experimentation.

Third, professional learning communities and follow-up support mechanisms should be established as mandatory components of PD programs. Each program should be followed by lesson study, mentoring or coaching, online forums, and needs-based consultation. Core teachers should be assigned clear time allocations, responsibilities, and evaluation criteria to support colleagues within their schools.

Fourth, management should shift from equipment investment to lifecycle management of STEM infrastructure. In addition to procurement, schools need procedures for maintenance, inventory control, equipment sharing, replenishment of consumable materials, electrical safety, and fire prevention. Digital infrastructure should be integrated with technical support and pedagogical guidance to prevent underuse of available equipment.

Fifth, regional partnership networks should be formed among primary schools, teacher education institutions, experts, enterprises, and local authorities. These networks should move from event-based cooperation to long-term collaboration supported by agreements on responsibilities, shared resource repositories, schedules for professional support, and mechanisms for organizing experiences connected to local issues. Universities in the region can serve as professional hubs and resource coordinators.

Sixth, monitoring and evaluation should be reformed toward supportive, evidence-based approaches. PD outcomes should be assessed through lesson plans, STEM products, videos of practice, classroom observations, and student progress; these data should then be used to adjust programs, recognize competencies, and support career development. Inspections by higher management levels should strengthen consultation, problem solving, and the dissemination of effective models rather than focus solely on compliance control.

The above management implications are complementary and mutually reinforcing and should be implemented coherently as part of an integrated management system rather than as isolated measures. Depending on the specific conditions of each locality and school, educational institutions may determine appropriate priorities and implementation pathways to enhance the effectiveness of managing PD activities aimed at developing STEM teaching competence among primary school teachers.

7. CONCLUSION

The study shows that the management of PD for primary school teachers' STEM teaching competencies in the Mekong Delta is simultaneously influenced by eight factor groups located both within and beyond the school. This finding also provides empirical support for the appropriateness of the analytical framework comprising eight groups of factors, which was developed by integrating the PDCA management cycle, teacher PD theory, and STEM teaching competence models. All groups were rated at a high level and received nearly equivalent mean scores, confirming the multidimensional and interconnected nature of the PD management system.

The large and consistent perceptual gap between administrators and teachers reflects a difference between organizational-management perspectives and implementation experience. Although many plans, policies, resources, and programs were viewed positively at the management level, teachers did not perceive a corresponding level of support. Bottlenecks characterized by strong agreement centered on professional knowledge-sharing culture, leaders' motivational capacity, decentralization, practice safety, follow-up support, community coordination, and direct guidance from higher levels. This also provides empirical evidence that the effectiveness of managing PD activities should be assessed from the perspectives of both school administrators and teachers to fully capture the quality of implementation in practice.

Enhancing the effectiveness of STEM professional-development management therefore requires a shift from the logic of organizing discrete training events to the logic of continuous PD grounded in needs, practice, data, and support networks. Connecting instructional leadership, professional communities, safe infrastructure, expert support, and local resources is essential for transforming PD outcomes into sustainable STEM teaching competencies among teachers.

8. LIMITATIONS AND DIRECTIONS FOR FUTURE RESEARCH

The study has several limitations, these limitations should be considered when interpreting the findings and assessing their generalizability. *First,* data were collected through a self-report questionnaire at a single point in time; they therefore reflect perceptions rather than objective effects and do not permit causal inference. Therefore, the findings may be subject to some degree of perceptual and self-report bias, although measures were taken to ensure participants' anonymity and voluntary participation and to minimize these potential effects. *Second,* the paper focuses on public primary schools in the Mekong Delta, and its generalizability to private schools or other regions requires further testing. Therefore, the application of these findings to other educational contexts should be considered in light of similarities in organizational conditions and management characteristics. *Third,* the current analysis relies primarily on descriptive statistics and two-group comparisons and does not test the factor structure or direct, mediating, and moderating relationships among variables. Therefore, the study is limited to describing and comparing the perceived levels of influence across participant groups and does not test the theoretical model or the relationships among the study variables.

Future studies should use exploratory factor analysis, confirmatory factor analysis, and structural equation modeling to test the eight-factor model; conduct multigroup analyses by locality, seniority, digital readiness, and school conditions; and incorporate classroom-observation data, teacher competency profiles, and student outcomes. Longitudinal research is also needed to evaluate changes after the implementation of management measures and sustained professional support.

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