Teachers' Perceptions of Integrated STEM Learning Management in Compulsory Education

Punyapat Chanpet, Muban Chombueng Rajabhat University, Thailand
Kanphitcha Kodkanon, Muban Chombueng Rajabhat University, Thailand

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Abstract

This study aims to examine the integrated STEM learning management model in basic education schools and to compare teachers' perceptions of STEM-based learning management across different groups categorized by teaching experience and school type. Additionally, it explores strategies to enhance teachers' implementation of integrated STEM education. The sample consisted of 224 teachers from the subject groups of Science, Mathematics, Career and Technology, selected through stratified random sampling. The research instrument was a questionnaire on teachers' perceptions of STEM-based learning management, with a reliability coefficient of 0.96. Data were analyzed using frequency, percentage, mean, standard deviation, t-test, one-way ANOVA, and content analysis. The findings revealed that teachers' overall and specific aspects of perception regarding STEM-based learning management were at a high level. There were no significant differences in perceptions when categorized by teaching experience and school type. The study identified key strategies for improving STEM-based learning management, including encouraging teachers' participation in curriculum planning, providing necessary support and resources for learning management, ensuring the availability of ICT tools and internet access, fostering understanding of authentic student assessment, and developing both internal and external learning environments conducive to integrated STEM education. Additionally, continuous monitoring and assessment of learning outcomes should be implemented to refine and improve diverse models of STEM-based learning management.

Keywords: STEM education, integrated learning management, teacher perception, basic education, instructional development

Introduction

In today's rapidly changing world, digital technology and scientific innovation play a crucial role in driving both the economy and society. Consequently, education must evolve to align with the demands of the 21st century, focusing on the development of key skills such as analytical thinking, creativity, problem-solving, and collaboration (Firat, 2020; Thibaut et al., 2018). One educational approach that addresses these changes is STEM Education, which integrates knowledge from the fields of science, technology, engineering, and mathematics to cultivate interdisciplinary skills essential for future living and careers (Kelley et al., 2020).

The basic education level is a critical period for developing foundational concepts and skills. Therefore, effectively promoting STEM learning in primary and secondary schools is imperative. Numerous international studies have found that the success of implementing STEM Education depends on several factors, particularly teachers' knowledge, understanding, and attitudes (Shernoff et al., 2017; Yabaş & Abanoz, 2024). Teachers who are well-prepared to design integrated learning activities can more effectively foster student learning. In the context of Thailand, the National Science and Technology Development Agency has developed a framework for organizing STEM Education activities that emphasizes design thinking and problem-solving based on real-world situations. This framework also advocates for the pivotal role of teachers in designing learning experiences, supported by training, resource development, and the establishment of professional networks to enhance the quality of integrated learning. Domestic research, such as those by (Gardner, 2017), confirms that for sustainable implementation of STEM learning, it is essential to empower teachers in terms of content knowledge, activity design skills, and systemic support. However, the implementation of STEM learning in basic education is varied due to different contextual factors such as school type, physical environment, and teachers' instructional experiences, which may affect their perceptions and capabilities in delivering such instruction. This research, therefore, aims to examine the implementation of integrated STEM learning in the basic education system by comparing teachers' perceptions based on their teaching experience and school type, and to propose recommendations for enhancing the effective and sustainable implementation of STEM Education. The concept of STEM Education has become a key approach in developing modern international education, with the goal of enhancing students' analytical thinking, creativity, and problem-solving abilities (Firat, 2020). STEM encompasses four core disciplines—science, technology, engineering, and mathematics—each playing a significant role in preparing learners for a rapidly changing world (Cao et al., 2024). In Thailand, the promotion of STEM learning is driven by national policies and initiatives within educational institutions, particularly at the basic education level—a critical period for laying the foundation for lifelong skills and thinking. Nonetheless, the success of STEM implementation in schools relies on teachers' preparedness in terms of understanding, attitudes, and the ability to design integrated learning activities (Shernoff et al., 2017; Thibaut et al., 2018). This study, therefore, aims to investigate the implementation of STEM learning in basic education schools, compare teachers' perceptions based on teaching experience and school type, and examine teachers' recommendations for further development of this approach.

Literature Review

The integration of science, technology, engineering, and mathematics (STEM) into basic education has garnered widespread international attention, with the aim of fostering analytical thinking, creativity, and problem-solving skills among learners. However, the success of implementing integrated STEM learning largely depends on teachers' perspectives, their teaching experiences, and the contextual factors of their schools. This article seeks to explore teachers' viewpoints on integrated STEM learning across different groups based on teaching experience and school type. It also examines strategies to enhance teachers' capacities in implementing such learning approaches. The discussion draws on relevant literature, including works of (Azman & Maat, 2019), Shernoff et al. (2017), and Kelley et al. (2020), all of which emphasize the critical role of teachers in driving successful STEM education.

Experienced teachers tend to have a more positive outlook on STEM integration, as they are more adept at adapting new approaches to teaching and recognize the value of interdisciplinary learning that promotes 21st-century skills. In contrast, novice teachers may face challenges due to limited experience and fewer opportunities for professional development. Comparisons of teachers' perspectives across different school contexts reveal disparities between urban and rural schools, as well as between public and private institutions. These differences manifest in varying levels of support, resource availability, and policy flexibility for implementing integrated learning. Common obstacles faced by teachers across all groups include resource scarcity, insufficient professional training, and the complexities involved in designing integrated curricula. Recommended strategies to support STEM implementation include designing professional development (PD) programs tailored to specific contexts, establishing professional learning communities (PLCs), allocating appropriate resources and infrastructure, and securing policy-level support from school administrators. Furthermore, assessments should focus on interdisciplinary skills—such as design thinking, problem-solving, and collaboration—rather than on evaluations segmented by individual subjects (Delahunty et al., 2021).

The literature review thus indicates that effective promotion of STEM requires addressing factors at the individual, school, and policy levels. In particular, continuous enhancement of teachers' knowledge, skills, and support systems is essential to creating meaningful and sustainable learning experiences for students.

A review of the STEM Education framework, teacher perceptions, and the development of integrated learning approaches—as evidenced by both domestic and international studies—reveals that teachers with a strong grasp of the STEM approach are better equipped to design effective learning activities (Guerzon & Busbus, 2023). Additionally, the availability of resources and contextual support within schools significantly influences the success of STEM implementation (Grancharova, 2024; Wang, 2023).

Methodology

This research employs a mixed-methods design, incorporating both quantitative and qualitative data collection to provide comprehensive and in-depth insights into the implementation of integrated STEM education by teachers in the compulsory education system.

Population and Sample

The study population consists of teachers in the subject areas of science, mathematics, vocational education, and technology at basic education schools under the Ratchaburi Primary Educational Service Area Office 1, totaling 509 teachers from 169 schools. The sample comprises 224 teachers, selected through stratified random sampling based on teaching experience and school type, in order to ensure a diverse and representative range of learning contexts.

Research Instruments

The instrument used for data collection is a 5-point Likert scale questionnaire that covers four dimensions: (1) learning design, (2) organization of learning activities, (3) assessment, and (4) the development of learning resources and the use of technology, comprising a total of 12 items. The questionnaire's reliability was confirmed through Cronbach's Alpha, yielding a high reliability coefficient of 0.96.

Instrument Development Process

1. A review of theories, concepts, and related research on STEM learning and teacher perceptions was conducted to establish the structure of the questionnaire.
2. A draft questionnaire was developed and reviewed by three experts to assess content validity (IOC).
3. The questionnaire was revised based on expert feedback and pilot tested with a sample of 30 participants.
4. The reliability analysis using Cronbach's Alpha produced a coefficient of 0.96, indicating high confidence in the instrument.

Data Collection

The researcher personally coordinated with the schools to distribute the questionnaire to the designated subject-area teachers. The participants took approximately 15–20 minutes to complete the questionnaire, with continuous follow-up to maximize and ensure the completeness of the responses.

Data Analysis

Quantitative data were analyzed using descriptive statistics, including frequency, percentage, mean, and standard deviation, as well as inferential statistics such as the t-test and One-Way ANOVA to compare teacher perceptions based on teaching experience and school type. Qualitative data were analyzed using content analysis on the open-ended responses related to strategies for enhancing the implementation of STEM learning.

Results

Section 1: General Profile of Respondents

The sample data indicate that the majority of respondents were primary school teachers, particularly from Educational Opportunity Expansion schools, and most had between 6 and 20 years of teaching experience. This period reflects a stage in which teachers have acquired substantial professional expertise, thereby establishing a solid baseline of awareness regarding the implementation of STEM education.

Table 1
Number and Percentage of Respondents Classified by Teaching Experience and School Type

Respondent Status	*n* = 224	Percentage (%)
Teaching Experience		
Less than 5 years	58	25.89
5–10 years	76	33.93
More than 10 years	90	40.18
Total	224	100.00
School Type		
Primary School	134	59.82
Secondary School	58	25.89
Educational Opportunity Expansion	32	14.29
Total	224	100.00

As shown in Table 1, 40.18% of the respondents had more than 10 years of teaching experience, followed by those with 5–10 years, and less than 5 years, respectively. Regarding school type, the majority of respondents were from primary schools (59.82%), with secondary schools and Educational Opportunity Expansion schools accounting for 25.89% and 14.29% respectively. These findings suggest that the respondents generally possess sufficient teaching experience and exposure to diverse educational settings, which are crucial factors in effectively implementing integrated STEM learning practices.

Section 2: Analysis of Teachers' Perceptions on STEM-Based Learning Implementation

This section aims to assess the level of teachers' perceptions regarding the implementation of STEM-based learning, divided into four primary dimensions: (1) learning design, (2) organization of learning activities, (3) learning assessment, and (4) the development of learning resources and technology utilization. Descriptive statistics, including the mean and standard deviation, were employed to systematically interpret the teachers' perceptions in each dimension.

Table 2
Overall Analysis of Perceptions on STEM-Based Learning Implementation by Dimension (n = 224)

Dimension of STEM-Based Learning Perception	Mean	SD	Perception Level
1. Learning Design	4.26	0.45	Very Good
2. Organization of Learning Activities	4.18	0.49	Very Good
3. Learning Assessment	4.10	0.52	Very Good
4. Development of Learning Resources and Technology Use	4.05	0.50	Very Good
Overall	4.15	0.49	Very Good

The analysis in Table 2 reveals that the teachers in the sample exhibit a "Very Good" level of perception regarding the implementation of STEM-based learning across all dimensions. Notably, the learning design dimension achieved the highest mean score (4.26), followed by the organization of learning activities (4.18), learning assessment (4.10), and the development of learning resources and technology use (4.05). The overall mean of 4.15 suggests that teachers generally understand, accept, and are prepared to apply the STEM approach comprehensively in their instructional practices.

Table 3
Mean and Standard Deviation of Perceptions on Learning Design

Item	Mean	SD	Perception Level
1. I can design integrated STEM learning activities effectively across multiple disciplines.	4.28	0.43	Very Good
2. I set learning objectives that are consistent with the curriculum and learners' contexts.	4.32	0.44	Very Good
3. I can select appropriate media and technology for my learning plan.	4.19	0.47	Very Good
Overall	4.26	0.45	Very Good

The analysis of Table 3 indicates that teachers' overall perception of learning design is rated as "Very Good" with an overall mean of 4.26. Among the items, the highest mean score is observed for the statement "I set learning objectives that are consistent with the curriculum and learners' contexts" (mean = 4.32), suggesting that teachers possess a clear understanding of how to establish learning goals that are well-suited to their teaching contexts. This is followed by "I can design integrated STEM learning activities effectively across multiple disciplines" (mean = 4.28), which reflects teachers' ability to develop coherent and interdisciplinary lesson plans. The item with the lowest mean, although still at a "Very Good" level, is "I can select appropriate media and technology for my learning plan" (mean = 4.19). This lower score indicates a potential need for additional support to enhance teachers' access to and integration of technology in their instructional planning. Overall, the findings demonstrate that the sample of teachers is well-equipped with the knowledge and skills necessary for planning, designing, and organizing high-quality STEM-based learning activities.

Table 4
Mean and Standard Deviation of Perceptions on the Organization of Learning Activities

Item	Mean	SD	Perception Level
1. I can organize activities that promote analytical thinking and problem solving.	4.22	0.46	Very Good
2. I encourage learners to work collaboratively in STEM activities.	4.17	0.50	Very Good
3. I can implement STEM activities in a systematic manner.	4.15	0.52	Very Good
Overall	4.18	0.49	Very Good

The analysis of teachers' perceptions regarding the organization of learning activities indicates an overall "Very Good" level with a mean score of 4.18. The highest-rated item is "I can organize activities that promote analytical thinking and problem solving" (mean = 4.22), suggesting that teachers are highly capable of designing activities that effectively stimulate higher-order thinking skills among learners. The next item, "I encourage learners to work collaboratively in STEM activities" (mean = 4.17), reflects a strong emphasis on teamwork and collaborative learning within an integrated STEM context. The item "I can implement STEM activities in a systematic manner" received the lowest mean (4.15), which, although still within the "Very Good" range, indicates an area where there is potential for further development to enhance teachers' confidence in executing systematic STEM activity procedures. Overall, these findings suggest that teachers are proficient in organizing hands-on, collaborative, and analytically challenging STEM activities—an essential component for effective STEM-based learning.

Table 5
Mean and Standard Deviation of Perceptions on Learning Assessment

Item	Mean	SD	Perception Level
1. I use various assessment tools such as tests, rubrics, and portfolios.	4.08	0.54	Very Good
2. I can assess learners' abilities in problem-solving and analytical thinking.	4.12	0.51	Very Good
3. I allow learners to engage in self-assessment and reflect on their learning outcomes.	4.10	0.52	Very Good
Overall	4.10	0.52	Very Good

Analysis of Learning Assessment

Teachers' perceptions regarding learning assessment are rated at a "Very Good" level, with an overall mean of 4.10. The highest mean score is found for the statement "I can assess learners' abilities in problem-solving and analytical thinking" (mean = 4.12), indicating that teachers are effectively using assessments to capture authentic learning outcomes. The item "I allow learners to engage in self-assessment and reflect on their learning outcomes" follows closely (mean = 4.10), demonstrating a commitment to participatory assessment and fostering metacognitive skills. Although the statement "I use various assessment tools such as tests, rubrics, and portfolios" received the lowest mean (4.08), it still reflects a strong effort by teachers to employ diverse assessment methods to comprehensively evaluate learners' competencies across multiple dimensions. Overall, these results suggest that teachers are inclined to adopt an integrated approach to assessment, effectively capturing content knowledge, skills, and cognitive processes.

Table 6
Mean and Standard Deviation of Perceptions on the Development of Learning Resources and Technology Use

Item	Mean	SD	Perception Level
1. I can use digital technology to enhance classroom learning.	4.06	0.49	Very Good
2. I actively participate in the development of learning resources within the school and community.	4.03	0.51	Very Good
3. I can select out-of-school learning resources for implementing STEM activities.	4.05	0.50	Very Good
Overall	4.05	0.50	Very Good

Analysis of Learning Resources Development and Technology Use

The findings indicate that the teachers' perceptions in this area are also rated at a "Very Good" level, with an overall mean of 4.05. The highest-rated item is "I can use digital technology to enhance classroom learning" (mean = 4.06), which demonstrates that teachers possess the fundamental skills required to integrate digital tools effectively into their instructional practices. The item "I can select out-of-school learning resources for implementing STEM activities" (mean = 4.05) underscores teachers' ability to leverage external resources to enrich integrated learning experiences. The lowest mean score is for "I actively participate in the development of learning resources within the school and community" (mean = 4.03). Although this rating remains within the "Very Good" range, it suggests that there is an opportunity to further encourage teachers' involvement in developing and optimizing local learning resources. Overall, the results reflect that teachers are proficient in incorporating both technology and diverse learning resources—internal and external—to support effective STEM-based instruction.

Section 3: Comparison of Teachers' Perceptions on STEM-Based Learning Implementation by Teaching Experience and School Type

This section aims to compare teachers' perceptions regarding the implementation of STEM-based learning in basic education schools, based on two factors: (1) teaching experience and (2) school type. Inferential statistics, specifically One-Way ANOVA, were utilized to examine differences in mean perception scores across different groups within the sample.

Comparison by Teaching Experience

The One-Way ANOVA results indicate that there is no statistically significant difference in teachers' perceptions of STEM-based learning across the three groups categorized by teaching experience (less than 5 years, 5–10 years, and more than 10 years). This finding is illustrated in Table 7.

Table 7
One-Way ANOVA Results on STEM Perceptions by Teaching Experience

Source of Variation	df	SS	MS	F	Sig.
Between groups (different teaching experience groups)	2	0.472	0.236	1.018	0.363
Within groups (variation within each experience group)	221	51.267	0.232		
Total	223	51.739			

Since the significance value (Sig. = 0.363) is greater than the predetermined alpha level of 0.05, it can be concluded that there is no statistically significant difference in the perception levels of STEM-based learning among teachers with varying teaching experiences. All groups consistently exhibit a "Very Good" level of perception, reflecting equal opportunities and understanding of the STEM approach across different levels of teaching experience.

Comparison by School Type

Similarly, the One-Way ANOVA conducted to compare teachers' perceptions among those working in primary schools, secondary schools, and Educational Opportunity Expansion schools revealed no statistically significant differences ($p > 0.05$). This indicates that regardless of the type of school, teachers' perceptions of STEM-based learning implementation remain consistently high.

Overall, these findings suggest that both teaching experience and school type do not significantly influence teachers' perceptions of STEM-based learning. The consistent "Very Good" perception across all groups implies that teachers, irrespective of their background or institutional context, have received equitable exposure to and understanding of STEM-based educational strategies.

Table 8
One-Way ANOVA Results on STEM Perceptions by School Type

Source of Variation	df	SS	MS	F	Sig.
Between school types (different types of schools)	2	0.385	0.193	0.814	0.444
Within school types (variation within each school type)	221	52.198	0.236		
Total	223	52.583			

As shown in Table 8, the significance level (Sig. = 0.444) exceeds the predetermined alpha level of 0.05. This result indicates that there is no statistically significant difference in the level of STEM-based learning perceptions among teachers across different types of schools. In other words, teachers from all school types demonstrate uniformly high levels of understanding and positive attitudes toward STEM-based instruction.

Summary of Comparative Results

The comparison of teachers’ perceptions regarding the implementation of STEM-based learning—categorized by teaching experience and school type—revealed no statistically significant differences in either factor. This finding suggests that regardless of their teaching experience (whether limited or extensive) or the type of school to which they belong, teachers consistently exhibit a “Very Good” level of perception. This uniformity is a positive indicator for the effective development and implementation of STEM-based learning in the basic education system.

Section 4: Analysis of Strategies to Promote STEM-Based Learning Implementation

The analysis of strategies to enhance the implementation of STEM-based learning was conducted using qualitative methods. Open-ended questionnaire responses from 224 teachers were analyzed through content analysis to systematically synthesize key themes regarding proposed strategies for advancing and supporting STEM-based instruction within schools, as well as the contextual support from relevant agencies.

Based on the analysis of teachers’ responses, five major strategic areas for promoting STEM-based learning were identified:

1. **Teacher Participation in Curriculum and Learning Plan Design:**
   Most teachers emphasized the importance of involving educators in the planning and design of STEM learning from the curriculum level. Such participation ensures that learning activities are well aligned with the specific contexts of schools and learners, fostering a sense of ownership and sustainability in implementation.
2. **Provision and Support of Educational Resources:**
   Teachers called for enhanced support in terms of educational resources—such as ICT equipment, science laboratory kits, dedicated workspaces, and digital media—as well as reliable high-speed internet access. These resources are deemed essential for delivering high-quality STEM activities, which are critical for 21st-century learning.
3. **Continuous Professional Development:**
   There was a strong recommendation for regular, context-specific training programs, including hands-on workshops, model teaching observations, and the establishment of professional learning communities (PLCs). Such initiatives are seen as pivotal to

enhancing teachers' capabilities in delivering STEM-based learning across content, process, and technology integration.

4. **Development of Assessment Systems Aligned with STEM:**
   Many teachers suggested that student assessment systems should be reformed to encompass interdisciplinary skills such as analytical thinking, problem solving, communication, and teamwork. They recommended the use of diverse assessment tools (e.g., rubrics, portfolios, and self-assessments) that better reflect authentic learning outcomes compared to traditional end-of-term exams.
5. **Support and Monitoring by School Administrators and Affiliated Agencies:**
   Teachers indicated that school leaders should actively support STEM initiatives by providing adequate budgets, time, personnel, and encouragement. Moreover, there should be ongoing monitoring and evaluation of STEM-related activities to inform continuous improvement and expansion of effective practices.

Overall, the strategies for promoting STEM-based learning should be comprehensive, addressing policy, institutional, and individual levels. Establishing robust infrastructure, ensuring continuous professional development, fostering teacher involvement, and implementing appropriate assessment systems are key mechanisms to enhance the quality and sustainability of STEM learning in basic education.

Discussion

The study, which examined the implementation of integrated STEM-based learning in basic education schools, found that teachers generally hold "Very Good" perceptions regarding STEM-based learning across all dimensions. Notably, the highest perception was observed in the area of learning design, indicating that teachers are effective at designing interdisciplinary lesson plans. This was followed by the organization of learning activities, learning assessment, and the development of learning resources and technology use, respectively.

When comparing teachers' perceptions by teaching experience, no significant statistical differences were observed; teachers, regardless of their years of experience, consistently reported a "Very Good" level of perception. Similarly, the type of school did not significantly affect teachers' perceptions, suggesting that national STEM initiatives have successfully promoted equitable professional development across diverse educational contexts.

Conclusion

The results confirm that teachers in basic education possess a very high level of understanding and positive attitudes toward STEM-based learning. Teachers are proficient in designing lessons, organizing learning activities, conducting assessments, and integrating resources and technology effectively. These findings align with the views of Loh et al.(2020), who argue that successful STEM education relies on the integration of academic content and learner-centered processes that foster essential 21st-century skills such as analytical thinking, communication, and collaboration. The absence of significant differences in perceptions when categorized by teaching experience and school type is noteworthy. It likely reflects the widespread and systematic implementation of STEM policies and support measures at the national level. As proposed by Wang (2023), the success of STEM learning is dependent on systemic drivers, including curriculum development, teacher training, and inter-agency collaboration. The similar levels of teacher perception across urban, rural, public, and private schools indicate a positive trend toward educational equity and professional development nationwide(Khuyen et al., 2020). Furthermore, the qualitative findings reveal that teachers provide concrete and varied suggestions for enhancing STEM-based instruction. Their recommendations—ranging from increased participation in curriculum design to better resource support and ongoing professional development—demonstrate a deep understanding of the practical challenges and opportunities in implementing STEM learning (Holincheck et al., 2024). In particular, the area concerning the development of learning resources and technology, while rated "Very Good," emerged as a relatively lower-scoring aspect compared to other dimensions, highlighting a clear need for further support in this area. This aligns with the findings of Muchtar and Ding (2024), who noted that resource and infrastructure limitations are significant challenges, especially in schools outside major urban centers.

Overall, this discussion underscores the initial success of STEM initiatives in Thailand, as evidenced by high levels of teacher awareness and readiness. However, continuous, systemic development—particularly in terms of flexible curriculum design, budgetary support, and context-appropriate assessment methods—remains crucial for ensuring the long-term sustainability and effectiveness of STEM education in the basic education system.

Recommendations

Policy Recommendations

- Establish systematic and continuous STEM support policies at all levels of basic education.
- Allocate dedicated budgets for developing learning resources and providing effective teacher training.

Practical Recommendations

- Promote active teacher participation in curriculum design, the formation of professional learning communities (PLCs), and inter-school knowledge exchange.
- Organize hands-on workshops that address real-world contexts and support the sustainable integration of technology into STEM activities.

Recommendations for Future Research

- Investigate the long-term impact of STEM training programs or curricula on teachers' instructional practices.
- Examine the relationship between teachers' perceptions and student outcomes in STEM activities to develop a more in-depth and systematic understanding.

This comprehensive study aimed to (1) explore the implementation of integrated STEM-based learning in basic education schools, (2) compare teachers' perceptions based on teaching experience and school type, and (3) examine strategies to promote STEM-based instruction. The sample consisted of 224 teachers from the subject areas of science, mathematics, vocational education, and technology, selected through stratified random sampling. The findings offer valuable insights into the current state of STEM education in Thailand and suggest actionable strategies for further enhancement and sustainability.

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