Platform Development Using T-STEP to Elevate the Production Quality of Pre-service Teachers in the 21st Century

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Duangjai Puttasem
Nakhon Sawan Rajabhat University, Thailand
https://orcid.org/0000-0002-8548-5670

Kraiwit Dee-aim
Nakhon Sawan Rajabhat University, Thailand

Abstract
This research aims to study the current state of driving STEM education-based learning management in schools, develop an integrated platform alongside the schools' STEM education-based learning management processes, and examine the outcomes of utilizing this integrated platform. This study employed a Research and Development (R&D) methodology, dividing the operational procedure into four phases. The sample group consisted of 40 third-year students majoring in Digital Technology for Education during the second semester of the 2025 academic year, selected via purposive sampling. Additionally, key informants included teachers and educational personnel from 27 schools under the primary and secondary educational service area offices in Nakhon Sawan, Uthai Thani, and Chai Nat. The research instruments included a survey on the current state of STEM education implementation administered via interviews, and an assessment form evaluating the outcomes of platform usage. Detailed outcome measurements were conducted by evaluating the quality of the STEM lesson plans and the integration of STEM education covering knowledge, activity management, and measurement and evaluation using mean ( ) and standard deviation (S.D.) statistics.
The findings revealed that regarding STEM integration in educational institutions, the majority of schools primarily supported STEM activities in the Science and Technology learning area (96.30%), followed by Mathematics (77.80%). The most prevalent format was within-subject integration (81.50%). Regarding the outcomes of piloting the platform across 14 collaborative network schools, the overall evaluation of the STEM lesson plans was at a high level (= 3.93, S.D. = 0.74), and the evaluation of STEM integration was at the highest level (= 2.97, S.D. = 0.76). In terms of practical implications, the study found that utilizing a virtual world platform to develop lesson plans helped create a highly interactive online space, effectively resolving constraints related to physical resource shortages in schools. Furthermore, it serves as a crucial mechanism for elevating learners' 21st-century skills through Project-based and Problem-based learning. This aligns with the observation that most schools integrated STEM activities with Active Learning policies (48.10%) and 21st-century skill development (18.50%).
The distinguishing feature of the T-STEP platform lies in its transition from being a mere data repository to a digital "Virtual Community of Practice". It serves as a centralized shortcut space that compels concrete cross-disciplinary learning design, breaking down the barriers of single-subject adherence prevalent in the physical world. Furthermore, the platform is highly significant in acting as a virtual laboratory and exhibition space, effectively compensating for disparities and resolving the network schools' budgetary constraints in purchasing STEM equipment. In conclusion, the T-STEP virtual reality platform innovation is a vital mechanism that bridges the gap between university theory and actual classroom practice. It elevates the quality of modern pre-service teachers by equipping them with competencies in project-based and problem-based learning management, directly leading to the concrete development of learners' 21st-century skills. For future research directions, studies should explore expanding the platform's trial to pre-service teachers in other disciplines or schools with different contexts, conduct longitudinal follow-ups on learners' 21st-century skill achievements, and investigate the integration of Artificial Intelligence (AI) and automated evaluation systems into the platform for personalized learning design.

Keywords: STEM Education, Pre-service Teacher Education, Digital Learning Platform, T-STEP, Pre-service Teachers in the 21st Century, Professional Learning Community

Introduction

Government policies aligned with the 20-Year National Strategy (2017-2036), the 3rd ICT Master Plan, and the Higher Education Act B.E. 2562 (2019) advocate for the increased utilization of computers, the internet, and Education Digital Platforms. This drive is rooted in the necessity to connect and share educational data and knowledge globally, enabling people worldwide to develop new learning paradigms that lead to intellectual wealth (Azorin, 2020). Beyond national policy drivers, in the international context, developing STEM education learning management competencies for pre-service teachers via digital platforms is a widely recognized priority within the academic community. Contemporary international literature indicates that digital learning platforms do not merely serve as data repositories but function as "Virtual Communities of Practice" (VCoP), enabling pre-service teachers to collaboratively design, exchange, and reflect upon integrated lesson plans effectively (Falloon, 2020; Kennedy & Odell, 2022). International studies demonstrate that the use of highly interactive digital platforms elevates Technological Pedagogical Content Knowledge (TPACK), a crucial conceptual framework and competency for 21st-century educators (Chai et al., 2019; Dong et al., 2020). Furthermore, recent research supports that using online platforms in conjunction with the Professional Learning Community (PLC) process can significantly bridge the gap between theoretical knowledge acquired in universities and practical implementation in school contexts (Chen & Wang, 2021). This process results in pre-service teachers becoming more confident and skilled in facilitating Project-based and Problem-based Learning. Consequently, the development of the T-STEP platform innovation in this research aligns with both national demands and international trends, focusing on creating a digital learning ecosystem to prepare and elevate the production quality of new-era teachers equipped with comprehensive skills for 21st-century educational management. Therefore, the Ministry has established policies and standards to encourage educational institutions and agencies to execute ICT development policies for educational innovation. This ensures that instructors, educational personnel, and learners enhance their proficiencies in utilizing educational platforms. All educational institutions are required to manage their ICT systems to develop educational innovations into standardized systems, thereby further improving educational quality within their respective purviews (Ministry of Higher Education, Science, Research and Innovation, 2019).

Instructional management must transition to align with a new learning paradigm that empowers learners to independently seek knowledge, particularly through the optimal use of educational innovations and technology (Dhawan, 2020). In the 21st century, educational models prioritize the development of human potential and competencies, emphasizing active learning processes that promote creative thinking and practical application, or the use of learning management systems. Therefore, instruction must adapt to this new paradigm requiring active learning, which helps learners connect or construct knowledge themselves through hands-on practice utilizing appropriately designed media or activities. As a result, learners become capable of independent inquiry, particularly through educational technology (Adnan & Anwar, 2020; Darunee Panjarattanakorn et al., 2022).

Pre-service teachers will primarily serve as facilitators and activity designers, creating conditions that enable learners to self-assess their learning progress. These factors present a significant challenge, requiring teachers to adapt their instructional formats to match 21st-century learner characteristics by utilizing digital media to stimulate and capture attention. In essence, digital lessons function similarly to marketing communication tools that must be attractive and pique learners' curiosity. Currently, newly tailored platforms exist for 21st-century learners. The learning process integrates pedagogical methods and content related to STEM education (Science, Mathematics, Technology, and Engineering) with professional experience training curricula. This is designed to develop the teaching profession using Core Teaching Practices and Professional Learning Communities (PLC) to elevate educational quality, ensuring students achieve professional teaching competencies; this initiative is abbreviated as the Strengthening Teachers Education Program (STEP). Consequently, this research focuses on developing a platform to elevate pre-service teacher production quality, exploring the benefits and usability of the platform, as well as the factors influencing the adoption or rejection of digital platform innovations. This aims to provide a foundational database for analyzing and refining the processes involved in producing 21st-century new-era pre-service teachers, leading to continuous improvements in both the production process and the instructional platforms utilized.

However, despite the continuous growth of digital platforms in education, literature reviews and current school conditions reveal persistent research gaps and significant limitations in past platforms and learning management, primarily in three areas: Limitations of legacy platforms acting merely as data repositories: Most current learning platforms function only as one-way communication channels or document/media storage, lacking highly interactive digital spaces that truly support virtual collaboration, reflection, and co-creation of innovation.

Resource disparities and siloed integration: Past STEM education management heavily relied on the availability of costly physical laboratories and equipment. When implemented in real school contexts facing budget and equipment shortages, STEM education is restricted to single-subject integration, failing to achieve genuine cross-disciplinary integration in the physical world. The disconnect between PLC processes and professional practicum

Typical platforms have not systematically linked the PLC process with the design and actual classroom testing of pre-service teachers' lesson plans, leaving pre-service teachers to face a gap in translating theoretical knowledge from the university into classroom practice. This research aims to fill these research gaps by developing the

T-STEP platform innovation. This platform is designed to transcend past limitations by functioning as a virtual learning ecosystem that transforms the platform into a "Virtual Community of Practice." It serves as a centralized shortcut space systematically linking the PLC process, allowing pre-service teachers to collaboratively design and evaluate cross-disciplinary STEM lesson plans. Simultaneously, it functions as a virtual laboratory and exhibition space, compensating for the physical equipment and budget constraints of network schools, thereby enabling pre-service teachers to efficiently and equitably organize project-based and problem-based activities.

Research Objectives

- To study the current state of driving STEM education-based learning management in schools.
- To develop an integrated platform alongside the STEM education-based learning management
- process in schools.
- To examine the outcomes of using the integrated platform alongside the STEM education-based learning management process in schools.

Research Methodology

This study utilizes a Research and Development (R&D) methodology, divided into four operational steps:

Step 1: Study the current state of driving STEM education-based learning management in schools.

Step 2: Design a STEM education-based learning process utilizing the Professional Learning Community (PLC) approach.

Step 3: Develop an integrated platform alongside the STEM education-based learning management process in schools.

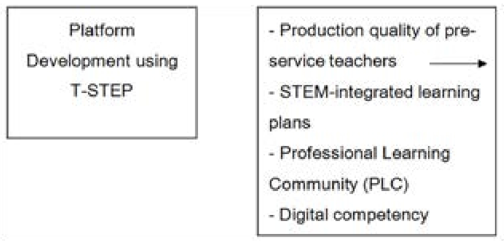
Step 4: Examine the outcomes of using the integrated platform alongside the STEM education-based learning management process in schools.

The research spans 24 months, from October 2025 to September 2027, conducted in four distinct phases. Phase 1 involves studying current operations and collecting quantitative data through foundational surveys and interviews. Phase 2 utilizes the data gathered from surveys and interviews to analytically design the STEM education-based learning process via the Professional Learning Community (PLC) mechanism. Phase 3 focuses on designing and developing the STEM learning management platform for pre-service teachers undergoing professional experience training. Phase 4 entails piloting the platform with target students taught by the pre-service teachers during their practicum, followed by summarizing the operational outcomes.

Research Report Procedures: This mixed-methods research collects and analyzes both quantitative and qualitative data. It encompasses document analysis and a survey on the current state of STEM education implementation via interviews with school administrators and teachers. The procedural steps are as follows:

- Study, analyze, and synthesize knowledge regarding policies, concepts, and theories related to integrated STEM learning management.
- Formulate a research framework and construct instruments for the development of the STEM learning management platform.
- Conduct field visits to gather in-depth data from educational institutions exhibiting best practices in digital platform-based learning management.
- Analyze and process the data to compile the final research report.

Research Conceptual Framework



Research Instruments

The study employed two main types of instruments:

A survey form to assess the current state of driving STEM education-based learning management in schools, administered via interviews with administrators and teachers.

An assessment form to evaluate the outcomes of using the integrated platform alongside the schools' STEM education learning process.

Review of Literature

This research focuses on the development of an integrated platform to elevate the production quality of pre-service teachers. The researchers reviewed relevant literature across three primary domains:

STEM Education Concepts and 21st-Century Skills: STEM Education is an instructional approach that integrates various disciplines Science, Technology, Engineering, and Mathematics—enabling learners to apply acquired knowledge to solve real-world problems (Becker, 2011). STEM-based learning management is inextricably linked to the development of 21st-century skills, particularly when deployed through learner-centered models such as Project-based Learning and Problem-based Learning. This correlates with Koehler et al. (2013), who indicated that STEM methodologies stimulate learners to apply engineering design processes in practical problem-solving contexts. Furthermore, contemporary international literature emphasizes that highly effective STEM programs must provide opportunities for learners to engage in self-directed inquiry and collaborative teamwork (Kennedy & Odell, 2022).

The Role of Digital Learning Platforms in Education: In the digital era, instructional modalities must adapt to a new paradigm that empowers learners to autonomously seek knowledge through the application of educational technology and innovation (Dhawan, 2020). Consequently, digital learning platforms transcend their traditional role as mere communication conduits, functioning instead as learning ecosystems that dismantle physical resource barriers (Falloon, 2020). Developed virtual platforms can establish highly interactive online spaces, facilitating seamless sharing of educational data and knowledge between learners and instructors. This facilitates the creation of novel learning models responsive to both national policies and global trends.

Pre-service Teacher Development via Digital Professional Learning Communities (PLC): Equipping pre-service teachers with robust STEM learning management capabilities is a significant international challenge. Research by Dong et al. (2020) indicates that pre-service teachers frequently encounter obstacles when translating theory into classroom practice. Integrating the Professional Learning Community (PLC) process with digital platforms serves as a vital mechanism to bridge this gap (Chen & Wang, 2021). Utilizing platforms as PLC spaces allows pre-service teachers to collaboratively and systematically design, exchange, and evaluate STEM lesson plans. This process subsequently elevates Technological Pedagogical Content Knowledge (TPACK), an indispensable competency for producing high-caliber new-era educators (Chai et al., 2019).

The Transition to DPaCK and Challenges of Digital Platforms in Modern Teacher Education Between 2023–2025, international educational trends emphasized upgrading TPACK to "DPaCK" (Digital Pedagogical Content Knowledge), highlighting teachers' competencies in selecting and creating digital ecosystems for participatory STEM learning (Huwer et al., 2024). However, systematic reviews by Horvath et al. (2025) and Palacios-Rodriguez et al. (2023) found that while current pre-service teachers are familiar with everyday digital technology, their competencies remain inconsistent, particularly regarding digital content creation, cross-disciplinary learning design, and collaborative problem-solving via platforms.

Addressing the Research Gap with the T-STEP Platform Max et al. (2023) and Polsue & Buaraphan (2023) agree that developing teachers' STEM competencies requires digital pedagogical makerspaces and professional networks facilitating actual practice and shared reflection. However, most current digital STEM platforms remain one-way repositories lacking high-level interactivity, failing to concretely dismantle subject silos. To fill these research gaps based on global trends and limitations, this research developed the T-STEP platform. It transforms from a general repository into a Virtual Community of Practice aligned with the DPaCK concept (Huwer et al., 2024), systematically linking the PLC process and cross-disciplinary lesson design with actual teaching practices. Furthermore, it serves as a Virtual Lab & Exhibition Space, compensating for network schools' physical and budgetary limitations, leading to equitable and sustainable digital-era STEM teaching competencies.

Population, Sample Size Calculation, and Sampling Method

Population and Sample

The population and sample group consisted of 40 third-year students majoring in Digital Technology for Education in the second semester of the 2025 academic year, selected via purposive sampling.

The key informants were teachers and educational personnel responsible for driving STEM education in 27 schools under the Secondary Educational Service Area Offices of Nakhon Sawan, Uthai Thani, and Chai Nat, as well as the Nakhon Sawan Primary Educational Service Area Offices (Zones 1, 2, and 3), selected via purposive sampling.

Content Scope The content encompasses STEM education subjects (Science, Mathematics, Technology, and Engineering) and the professional experience training curriculum aimed at developing the teaching profession. It employs Core Teaching Practices and the Professional Learning Community (PLC) process to elevate the quality of educational management, ensuring that university students attain the requisite competencies to become professional teachers.

Research Results

Current State of Driving STEM Education in Schools: Data collected from schools under the secondary and primary educational service area offices revealed that the informants were predominantly learning area teachers (14 individuals, 51.90%), followed by heads of learning areas (5 individuals, 18.50%), heads of work departments (4 individuals, 14.80%), school directors (3 individuals, 11.10%), and a deputy director (1 individual, 3.70%). STEM learning activities, integrated as annual school plans and projects, established indicators through initiatives such as STEM learning promotion projects, SMET Education projects for Grades 1-9, student academic achievement development projects, and STEM classroom activities. Support and promotion for teacher training in STEM activities were provided predominantly by the Institute for the Promotion of Teaching Science and Technology (IPST) at 51.90%, followed by various institutes/universities, private companies/publishers, and educational service area offices (11.10%). Furthermore, development units under the comprehensive teacher development project of the Office of the Basic Education Commission (OBEC) accounted for 7.40%, while 29.60% reported receiving no external organizational support. Schools primarily supported STEM activities in the Science and Technology learning area (96.30%), Mathematics (77.80%), Foreign Languages (14.80%), and Thai, Social Studies, Health and Physical Education, and Career and Technology (11.10%). The supported courses were basic courses (63.00%), additional courses/clubs/science projects (25.90%), exhibitions (14.80%), and moderate class hours, more learning hours/camps/walk rallies (11.10%). The most prevalent integration format supported by schools was within-subject integration (81.50%), whereas multidisciplinary/ cross-disciplinary integration accounted for 11.10%. Teachers implemented STEM activities through school-supported integrated lesson plans (48.10%), innovative STEM learning media/ activity sets (29.60%), integrated STEM learning units (18.50%), and Little Scientists' House camp activities (3.70%), while 22.20% reported no support. STEM was integrated with existing policies/projects such as Active Learning (48.10%), 21st-century skill development (18.50%), Independent Study (IS) within the world-class standard school curriculum (14.80%), Sufficiency Economy Philosophy and Eco-schools/Zero-waste schools (7.40%), and School Botanical Garden/Thailand 4.0/Little Scientists' House projects (3.70%), with 40.70% indicating no support. Support for media and equipment primarily occurred through standard instructional use (48.10%), school-procured equipment (18.50%), IPST STEM equipment (11.10%), and specialized kits (e.g., Lego Micro bit, experimental boards) from mentoring universities (3.70%), while 37.0% reported no media support. Internal STEM learning resources included STEM corners in school libraries (11.10%) and STEM labs/Coding and Robot learning centers (3.70%), with 37.00% reporting no such resources. Notable outcomes resulting from STEM activities included schools achieving Quality Classroom status, receiving the Little Scientists' House Royal Badge (Early Childhood Level) for the 2024 academic year, winning the TOT Smart Kids Code award, securing a Basic Robotics gold medal, and obtaining outstanding awards in educational quality development projects mentored by the Lower Northern Region Higher Education Network for Fiscal Year 2024.

Problems and Obstacles: The primary challenges encountered during the implementation of STEM learning activities pertained to insufficient budgets and personnel. While schools could function with existing budgets, increased financial resources would enable superior activity execution. Furthermore, the STEM methodology is not universally applicable to all subjects or content areas, rendering certain topics difficult to teach via this approach. Although personnel possess moderate readiness, there remains a lack of activity equipment and clear instructional guidelines. Consequently, teachers and educational personnel strongly desired continuous training (ranked highest), followed by budget allocations for equipment integrated into classroom learning. Additional requests included accessible knowledge resources, ongoing project support, teaching materials, and adequate educational budgets. The most frequent suggestion regarding STEM activity management was the need for government financial assistance, followed by the necessity for continuous activity promotion. Schools expressed a willingness to participate if contacted by relevant agencies, noting that previous projects had stalled due to the transfer of responsible teachers and a subsequent lack of follow-up from organizing bodies.

Designing the STEM Learning Process via PLC: Through the Professional Learning Community (PLC) process, 14 STEM-integrated lesson plans were systematically developed.

Lesson Plan Name	Educational Level
1. Media Literacy: Logical Fallacies	Grade 9
2. Creating Innovation using Technology	Grade 8
3. Electrical and Electronic Mechanisms	Grade 10
4. Weather Vane	Grade 7
5. Little Transport Ship	Grade 7
6. Little Kite in the Sky	Grade 7
7. Data Sorting	Grade 10
8. Good Data is Half the Battle	Grade 9
9. Algorithm Design using Draw.io	Grade 7
10. Safe and Responsible Internet Usage	Grade 9
11. Applying IoT for Creative Projects	Grade 10
12. Python Swagger	Grade 8
13. Computer Maintenance	Grade 2
14. Creating Innovation using Technology	Grade 10

Third-year students formulated 13 secondary-level plans and 1 primary-level plan, piloting them with target students over a one-month period in February 2025.

Outcomes of Using the Integrated Platform: The platform designed and developed by the students was piloted with target learners taught by pre-service teachers during their professional practicum across 14 collaborative network schools.

Evaluation Results of STEM Education Lesson Plans

The overall evaluation of the STEM Education lesson plans was at a high level (= 3.93, S.D. = 0.74) Itemized analysis revealed that the alignment of learning activities with objectives and content scored highest (= 4.14, S.D. = 0.86) followed by the appropriateness of content for the allotted time, whereas the completeness of essential components within the lesson plans scored the lowest (= 3.79, S.D.=0.89)

Assessment Items	$\bar{X}$	**S.D.**	**Level**
The learning unit is complete, appropriate, and has harmoniously aligned details	3.86	0.95	High
The lesson plan aligns with the designated learning unit	3.86	0.95	High
The lesson plan contains all essential components with correlated details	3.79	0.89	High
The core concepts are written correctly	3.93	0.77	High
Learning objectives are clear and cover the content	3.91	0.73	High
Learning objectives develop students' knowledge, process skills, and attitudes	4.00	0.75	High
Learning objectives are sequenced from simple to complex behaviors	4.01	0.78	High
Content is appropriate for the time allotted	4.07	0.83	High
Learning activities align with objectives and content	4.14	0.86	High
Learning activities align with objectives and student grade levels	3.89	0.77	High
Learning activities are diverse and practical	3.86	0.75	High
Learning activities promote students' thinking processes	3.93	0.83	High
Activities emphasize hands-on learning	3.81	0.73	High
Learning activities appropriately integrate morals and good values	4.07	0.83	High
Materials, media, and learning resources are diverse	4.07	0.76	High
Materials, media, and learning resources are appropriate for the content	3.93	0.73	High
Students use media and learning resources independently	3.91	0.74	High
Students create artifacts using knowledge and thought rather than simply following instructions	3.93	0.73	High
Measurement and evaluation align with learning objectives	3.86	0.77	High
Overall Average	3.93	0.74	High

STEM Education Integration Results

The overall evaluation of STEM Education integration was at a very high level (=2.97,S.D.=0.76) Specifically, the knowledge domains of Science, Mathematics, and Technology were at a very high level, STEM learning activity management was at a very high level (=2.93,S.D.=0.73) and measurement and evaluation were at a very high level (= 3.00,S. D=0.78)

Assessment Items	$\bar{X}$	**S.D.**	**Level**
1. Knowledge Domain			
1.1 Science	3.00	0.78	Very High
1.2 Mathematics	3.00	0.78	Very High
1.3 Technology	2.93	0.83	Very High
2. STEM Learning Activity Management	2.93	0.73	Very High

3. Measurement and Evaluation	3.00	0.68	Very High
Overall Average	2.97	0.76	Very High

Discussion

The objective of this research was to develop a platform utilizing T-STEP to elevate the production quality of new-era pre-service teachers in the 21st century. Based on the data analysis, the researchers discussed key findings in conjunction with relevant theories and concepts as follows:

Current State and STEM Integration: The research revealed that the majority of schools supported and promoted STEM activities primarily in the Science and Technology learning area (96.30%), followed by Mathematics (77.80%). The most prevalent format endorsed by schools was within-subject integration (81.50%). This aligns with the definition of STEM education proposed by Becker (2011), who described it as a learning approach that integrates Science, Technology, Engineering, and Mathematics. However, an investigation into problems and obstacles indicated that schools face significant challenges related to inadequate budgets, insufficient personnel, and a lack of instructional materials. These findings reflect that, despite efforts to integrate subjects, practical application encounters obstacles, frequently resulting in integration being confined primarily within individual subjects. Therefore, educational institutions require continuous support in both resources and training to achieve comprehensive cross-disciplinary integration. Although Becker (2011) defines STEM as the seamless integration of various disciplines, these findings expose a practical contradiction within Thai educational institutions. The persistence of within-subject integration points to structural barriers stemming from strict departmentalization, rooted in the resource and personnel deficits identified in the study. Consequently, deploying a digital platform is not merely an exercise in modernization, but a strategic attempt to establish a central "shortcut" space that mandates cross-disciplinary collaboration, which schools struggle to facilitate in the physical world.

Application of Digital Platforms to Expand Learning Opportunities: To circumvent budget and material constraints, this study developed STEM-integrated lesson plans that utilized a virtual world platform as a tool and collaborative workspace. The application of this technology is consistent with Nanthaporn Thabthimphairoj (2016), who explained that platforms function as infrastructures that seamlessly connect stakeholders by creating ecosystems conducive to learning and collaborative activities. This also aligns with Chanthip Kaewprakhon et al. (2018), who defined digital platforms as environments combining hardware and software to generate highly interactive online spaces. Developing learning platforms and exchanging artifacts via a virtual world (e.g., the "Weather Vane" lesson plan) serves as an effective innovation to address the gaps caused by physical resource scarcity. Viewed critically, the virtual innovation in this research transcends its role as a mere technological tool to act as a mechanism compensating for disparity. In contexts where network schools lack the budget to procure STEM equipment, the platform functions as a virtual laboratory and exhibition space, mitigating costs and eliminating spatial constraints. This empowers pre-service teachers to conduct Active Learning without relying on expensive physical resources.

Elevating the Learning Process toward 21st-Century Skills: The findings indicated that schools most frequently integrated STEM activities with Active Learning policies (48.10%) and 21st-century skill development (18.50%). The researchers designed a learning process via innovations that integrated scientific and technological knowledge, emphasizing Project-based and Problem-based Learning. This approach corresponds with Koehler et al. (2013), who supported the notion that STEM education promotes technical literacy and encourages learners to apply engineering design processes to resolve daily life problems. Designing activities that allow students to collaborate, engage in hands-on practice, and undergo online artifact assessments significantly reinforces self-directed learning attributes. This is a core competency required to equip new-era pre-service teachers with comprehensive skills suitable for 21st-century instruction. The PLC process facilitated the production of 14 integrated lesson plans, affirming that broad, abstract mandates like the Active Learning policy require concrete driving mechanisms to succeed. Fusing the Professional Learning Community process with the platform provides pre-service teachers with a space to exchange knowledge and design innovations based on problem and project-based learning, echoing Koehler et al. (2013) regarding the practical application of engineering design. This analysis highlights that platforms and PLCs are not mere supplementary components, but critical variables that translate theoretical policies into tangible online assessments and classroom realities.

Research Limitations

Sample and Geographic Specificity: The sample comprised 40 highly tech-literate 3rd-year Digital Technology education students. Implementations occurred in 27 specific schools across three provinces, requiring caution when generalizing to different regions or majors.

Timeframe and Scope: The 1-month trial across 14 schools primarily targeted the secondary level (13 plans), lacking longitudinal learner achievement data. Despite the platform's cost-saving design, structural constraints like poor internet stability and teacher turnover remain external challenges.

Suggestions

Based on the research regarding platform development utilizing T-STEP to elevate the production quality of new-era pre-service teachers, the researchers offer the following recommendations across two domains:

Suggestions for Practice

Integrating platforms to resolve resource constraints: School administrators should implement policies encouraging teachers to utilize virtual platform innovations as substitute laboratories or virtual exhibition spaces, offsetting the necessity to procure expensive physical equipment.

Relevant agencies and teacher training institutions should foster the establishment of cross-disciplinary Professional Learning Communities (PLCs) on digital platforms. This provides a concrete space for teachers from various disciplines to exchange knowledge and collaboratively design cross-disciplinary integrated lesson plans.

Educational institutions should allocate budgets for continuous practical training for both in-service and pre-service teachers. This will enhance their comprehension of managing STEM activities beyond merely Science and Mathematics, while simultaneously improving their digital tool proficiencies for Active Learning.

Directions for Future Research

Future research should pilot the T-STEP platform with pre-service teachers in other academic disciplines, as well as in schools with varying sizes and spatial contexts, to verify the platform's flexibility and broad efficacy.

Longitudinal follow-up studies should be conducted regarding the development of learners' 21st-century skills (e.g., critical thinking, problem-solving, and collaboration) fostered through STEM plans on the T-STEP platform to confirm sustainable learning achievements.

Subsequent research phases should consider integrating automated learner tracking and assessment systems (such as Learning Analytics or AI) into the platform. This would enable pre-service teachers to access learners' behavioral data, leading to more highly effective, personalized STEM lesson plan adaptations.

References

Azorín, C. (2020). Beyond COVID-19 Supernova. Is Another Education Coming? *Journal of Professional Capital and Community, 5*, 381-390.

Becker, H. K. (2011). Effects on integrative approached among Science, Technology. Engineering, and Mathematics (STEM) subject on student' learning: A preliminary meta- analysis. *Journal of STEM Education, 12*(5), 23 – 37.

Chai, C. S., Jong, M. S. Y., Yin, H. B., Chen, M., & Zhou, W. (2019). Validating and modelling teachers' technological pedagogical content knowledge for integrative science, technology, engineering and mathematics education. *Journal of Educational Technology & Society, 22*(3), 61-73.

Chanthip Kaewprakhon et al. (2018). Electronic Seminar Room Service Platform. Bangkok: Research and Development Institute, Chandrakasem Rajabhat University.

C..Dong, Y., Wang, C., Day, S. K., & Zhao, P. (2020). Pre-service teachers' implementation of STEM education: A systematic literature review. *International Journal of STEM Education, 7*(1), 1-17.

Chen, J., & Wang, M. (2021). Professional learning communities in the digital age: A systematic review of literature. *Computers & Education, 168,* 104209.

Dhawan, S. (2020). Online Learning: A Panacea in the Time of COVID-19 Crisis. *Journal of Educational Technology Systems, 49*, 5-22.

Falloon, G. (2020). From digital literacy to digital competence: the teacher digital competency (TDC) framework. *Educational Technology Research and Development, 68*(5), 2449-2472.

Faraclas, E., Giblin, D., Moss, D., & Kazerounian, K. (2013). The Nexus between science literacy and technical literacy: a state by state analysis of engineering content in state science standards. *Journal of STEM Education, 14*(3), 5-12.

Horvath, A., et al. (2025). Digital competence for sustainable education of pre-service teachers: A systematic literature review (2014–2024). *Frontiers in Psychology, 16*, 1710983.

Huwer, J., et al. (2024). Editorial: STEM/science teacher education for the future: "From TPaCK to DPaCK". *Frontiers in Education, 9,* 13300.

Kennedy, T. J., & Odell, M. R. L. (2022). Characteristics of highly effective STEM education programs. *Science Education International, 33*(4), 384-391.

Koehler, C., Faraclas, E., Giblin, D., Moss, D., & Kazerounian, K. (2013). The Nexus between science literacy and technical literacy: a state by state analysis of engineering content in state science standards. *Journal of STEM Education, 14*(3), 5-12.

Koehler,C., Darunee Panjarattanakorn et al. (2022). Platform Development of Online Learning for the Modern School Database using Activity-Based Learning Technique for Graduate Students. *Kurusapha Witthayachan, 4*(1), 87-104.

Max, A.-L., et al. (2023). Factors influencing the development of pre-service science teachers' technological pedagogical content knowledge in pedagogical makerspace. *Frontiers in Education, 8*, 1283921.

Ministry of Higher Education, Science, Research and Innovation. (2019). Higher Education Act B.E. 2562. Bangkok: Goods and Parcel Delivery Printing Press.

Ministry of Higher Education, Science, Research and Innovation, National Innovation Agency. (2019). Innovation for the Future.

Nanthaporn Thabthimphairoj. (2016). Interest and study business before entering business in the form of a platform. Sasin Management Consulting Article. Retrieved October 14, 2019.

Palacios-Rodriguez, A., et al. (2023). Digital competence in pre-service teacher training: A key factor for educational innovation. *Journal of Technology and Science Education, 13*(2), 415–429.

Polsue, S., &Buaraphan, K. (2023). Teaching by integrating STEM education and technological pedagogical content knowledge: New dimension for Thailand teacher 4.0. *Journal of Education Silpakorn University, 21*(1), 21–45.

Author Details

Duangjai Puttasem, *Nakhon Sawan Rajabhat University, Thailand, **Email ID**: Duangjai.p@nsru.ac.th*

Kraiwit Dee-aim, *Nakhon Sawan Rajabhat University, Thailand, **Email ID**: kraiwit.d@nsru.ac.th*