Journal of Pedagogy and Education Science (JPES)
Vol. 4, No. 02, pp. 288-308
journal.iistr.org/index.php/JPES
DOI: 10.56741/IISTR.jpes.00992

Designing Benchmarking Frameworks for Teacher Support in AI-Integrated STEM Education Curriculum

Insights from Cambodia

[1]Wiputra Cendana*, [2]Keun Im, [1]Evan Kurnia Alim
Corresponding Author: *wiputra.cendana@uph.edu
[1] Universitas Pelita Harapan, Tangerang, Indonesia
[2] National Institute of Education (NIE), Cambodia

ARTICLE INFO

Article history
Received 2 May 2025
Revised 28 May 2025
Accepted 13 June 2025

Keywords
AI in Education
Digital Integration
Professional Development
STEM Education
Teacher Support

ABSTRACT

This paper proposes a benchmarking mechanism to evaluate and enhance teacher support systems in AI and digital STEM-integrated curricula in Cambodia. It addresses the critical need for educators to incorporate AI effectively, using a mixed-research approach that combines qualitative text analysis with quantitative clustering techniques. Employing a mixed-methods approach, textual data from Cambodian teachers were collected via surveys and interviews, preprocessed (tokenization, stop-word removal, stemming), and analyzed using TF-IDF vectorization and K-means clustering. These themes form the framework's dimensions, measured by contextually relevant metrics, aiming to foster a supportive environment for teachers. Recommendations include partnerships, flexible learning pathways, and pilot programs, contributing to global best practices while addressing local educational challenges. The resulting framework dimensions (training, infrastructure, and policy integration) are measured by context-specific metrics. Findings underscore the necessity of tailored training, equitable resource allocation, and collaborative learning communities in empowering teachers to effectively integrate AI and digital technologies into STEM education. Recommendations include partnerships with tech firms, flexible learning pathways, and iterative policy adjustments based on teacher feedback.

Introduction

The rapid advancement of AI and digital technologies presents unprecedented opportunities for STEM education, enabling personalized learning, automated assessments, and data-driven pedagogy [1]. However, educators, particularly in developing nations like Cambodia, face significant barriers, including limited technical proficiency, inadequate training, and infrastructural deficits [2]. Effective AI integration requires robust teacher support systems, yet existing benchmarking frameworks lack contextual relevance for low-resource settings [3], [4]. This study addresses this gap by designing a benchmarking mechanism tailored to Cambodia's educational landscape, leveraging empirical data to identify critical support dimensions.

The integration of these technologies into curricula poses significant challenges for educators, particularly in terms of technical proficiency, pedagogical adaptation, and resource management. Teachers play a pivotal role in bridging the gap between technology and learning, yet they often lack the necessary support to navigate this complex landscape. This is particularly critical in developing countries like Cambodia, where educational systems are undergoing significant reforms to align with global standards and technological advancements. This paper addresses this gap by proposing a benchmarking mechanism to evaluate and improve teacher support systems in AI and digital STEM-integrated curricula. Designing a benchmarking framework for teacher support in AI-integrated STEM education is essential to ensure that educators are equipped with the necessary skills, resources, and pedagogical strategies to foster student success in a rapidly evolving digital landscape.

The Cambodian Ministry of Education, Youth, and Sport (MoEYS) has identified STEM (Science, Technology, Engineering, and Mathematics) education as a strategic priority to drive economic growth and technological innovation [5]. This aligns with global trends where STEM competencies are increasingly linked to workforce readiness and national competitiveness [1]. However, the integration of Artificial Intelligence (AI) into Cambodia's STEM curriculum remains in its infancy, hindered by systemic challenges that undermine equitable and effective implementation.

The primary objectives of this study are to identify key components of effective teacher support systems in AI and digital STEM-integrated curricula; to develop a benchmarking mechanism for evaluating teacher support programs; and to propose actionable recommendations for improving teacher support based on empirical data. This study will answer the following research questions: What are the key components of effective teacher support systems in AI-integrated STEM curricula; How can a benchmarking mechanism for evaluating teacher support programs be developed; How can empirical data provide an actionable recommendation to enhance teacher support.

Literature Review

A. Key Barriers to AI Adoption in Cambodian STEM Education

1. Resource Constraints

Rural schools, which constitute a significant portion of Cambodia's educational institutions, face severe infrastructural deficits. A 2020 study by Kheang et al [6]. revealed that fewer than 30% of rural schools have reliable internet access, and access to digital devices is often limited to urban centers. This digital divide exacerbates disparities in AI adoption, as teachers and students in underserved regions lack the basic tools required for technology-enhanced learning. Without addressing these inequities, AI's transformative potential in STEM education will remain unrealized for a majority of Cambodian learners.

2. Training Gaps

Professional development programs for Cambodian teachers have traditionally focused on foundational digital literacy rather than advanced AI applications [7]. While initiatives like the MoEYS's Education Strategic Plan 2019–2023 emphasize technology integration, training modules rarely cover AI-specific pedagogy, such as using intelligent tutoring systems or interpreting AI-generated learning analytics. This leaves educators ill-equipped to harness AI's capabilities, perpetuating a reliance on conventional teaching methods that fail to prepare students for a technology-driven future.

3. Ethical Concerns

The ethical implications of AI in education, such as algorithmic bias, data privacy, and the risk of reinforcing urban-rural inequalities, are frequently overlooked in Cambodian policy discussions [1]. For instance, AI tools trained on datasets from urban schools may not generalize well to rural contexts, thereby inadvertently disadvantaging already marginalized students. Without safeguards to ensure fairness and transparency, AI adoption could deepen existing educational inequities rather than mitigate them.

B. The Urgent Need for a Context-Specific Benchmarking Framework

Current benchmarking frameworks were designed for high-resource settings and fail to account for Cambodia's unique challenges, such as intermittent electricity, low teacher-to-device ratios, and linguistic diversity in STEM instruction [3], [4]. A tailored framework is urgently needed to:

- Evaluate teacher readiness and resource availability using context-relevant metrics (e.g., internet reliability scores, localized training participation rates).
- Guide policymakers in allocating limited resources to high-impact areas (e.g., prioritizing rural AI hubs).
- Monitor ethical risks through participatory design involving teachers, students, and local communities.

By addressing these gaps, Cambodia can leverage AI to democratize STEM education rather than exacerbate disparities. This study responds to this imperative by proposing a benchmarking mechanism grounded in empirical data from Cambodian educators, ensuring relevance and scalability for low-resource settings.

C. Literature Review and Theoretical Framework

The primary objectives of this study are to identify key components of effective teacher support systems in AI and digital STEM-integrated curricula; to develop a benchmarking mechanism for evaluating teacher support programs; and to propose actionable recommendations for improving teacher support based on empirical data.

1. AI in STEM Education: Enhancing Engagement and Personalization

The integration of Artificial Intelligence (AI) in Science, Technology, Engineering, and Mathematics (STEM) education has been increasingly recognized for its potential to transform learning experiences. Research, such as that by Luckin et al. [8] in their report "Intelligence Unlocked: How to optimize student learning through the strategic use of technology", suggests that AI tools, including virtual labs and intelligent tutors, significantly enhance student engagement and provide personalized learning. Virtual labs enable students to conduct experiments in simulated environments, which is particularly valuable in settings with limited physical resources. Intelligent tutors adapt to individual learning styles and paces, offering tailored feedback and instruction, thereby supporting diverse learner needs.

However, the effective implementation of these AI tools is not without challenges. Zawacki-Richter et al. [9] in their study "Artificial Intelligence in Higher Education: A bibliometric study on its impact in the scientific literature" emphasize that teacher readiness is pivotal. Teachers require adequate training and professional development to integrate AI into their teaching practices successfully. Without such preparation, there is a risk that AI tools may be underutilized or applied ineffectively, potentially widening educational disparities.

2. AI and Digital Tools in STEM Education

AI has the potential to revolutionize STEM education by enabling personalized learning, automating administrative tasks, and providing data-driven insights into student performance. According to Holmes et al [1], AI can facilitate adaptive learning environments that cater to individual student needs, thereby improving engagement and outcomes. In STEM subjects, AI-powered tools such as virtual labs, simulations, and intelligent tutoring systems can provide hands-on experiences and real-time feedback, bridging the gap between theoretical knowledge and practical application [8]. However,

the successful integration of AI in education hinges on the preparedness of teachers to leverage these technologies effectively.

D. Challenges Faced by Teachers in AI-Integrated STEM Education Integration

Despite its potential, the integration of AI in STEM education presents several challenges. Teachers often lack the technical expertise and confidence to use AI tools, which can hinder their adoption and implementation [9]. Additionally, there is a scarcity of professional development programs tailored to AI in education, particularly in low-resource settings like Cambodia. The absence of standardized frameworks for evaluating teacher support further exacerbates these challenges, making it difficult to assess the effectiveness of AI integration and identify areas for improvement.

1. Teacher Support Frameworks: TPACK and SAMR Models

Two prominent frameworks support teachers in integrating technology into education: the Technological Pedagogical Content Knowledge (TPACK) model and the Substitution, Augmentation, Modification, Redefinition (SAMR) model. The TPACK model, introduced by Mishra and Koehler [3] in "Technological Pedagogical Content Knowledge: A framework for teacher knowledge", underscores the importance of teachers possessing a balanced understanding of technology, pedagogy, and content knowledge. It posits that effective technology integration requires teachers to consider how technology can enhance their teaching methods and content delivery, creating a synergistic effect.

The SAMR model, proposed by Puentedura [4] in "SAMR: A Contextualized Introduction", offers a framework to evaluate the depth of technology integration. It categorizes technology use into four levels: Substitution (technology acts as a direct substitute for traditional methods), Augmentation (technology enhances traditional methods), Modification (technology allows for significant task redesign), and Redefinition (technology enables new forms of teaching and learning previously impossible). This model helps educators assess whether technology use is transformative or merely supplementary.

Despite their utility, both frameworks have limitations, particularly in low-resource contexts and regarding ethical considerations. Koehler and Mishra [3] in "What is technological pedagogical content knowledge?" note that TPACK assumes access to adequate technological resources, which may not hold in low-resource settings where infrastructure and training are limited. Similarly, the SAMR model, while useful for high-resource environments, may not be feasible in contexts with basic technological constraints. Additionally, neither framework explicitly addresses ethical issues such as data privacy, algorithmic bias, and digital equity, which are increasingly critical with AI integration. The book, titled "Should robots replace teachers? AI and the future of

education" [10] calls for a more holistic approach, highlighting the need to integrate ethics into educational technology frameworks.

Teacher support is a critical factor in the successful implementation of AI in STEM education. According to Ertmer and Ottenbreit-Leftwich [11] teacher support encompasses not only technical training but also pedagogical guidance, access to resources, and a supportive institutional environment. Professional development programs should focus on building teachers' TPACK to enable them to integrate AI tools seamlessly into their teaching practices [3]. Moreover, fostering a collaborative culture among educators can facilitate the sharing of best practices and innovative strategies for AI integration.

2. Gaps in Benchmarking Practices: Contextual and Methodological Challenges

Benchmarking frameworks are widely used in education to assess and improve the quality of teaching and learning. These frameworks provide a structured approach to evaluating performance, identifying gaps, and implementing best practices [12]. In the context of AI-integrated STEM education, a benchmarking framework can serve as a valuable tool for measuring teacher support and guiding the development of targeted interventions. Existing frameworks, such as the TPACK model and the SAMR model, offer insights into the integration of technology in education but require adaptation to address the unique challenges of AI integration.

Current benchmarking practices in educational technology reveal several gaps that hinder their effectiveness, particularly in diverse educational contexts. Table 1 shows gaps including contextual irrelevance (i.e., frameworks assume high-resource settings); overemphasis on technical skills, i.e., pedagogical and institutional support are undervalued [11], and lack of longitudinal assessment, i.e., short-term metrics dominate [8].

Table 1. Gaps in Educational Technology

Gap	Description	Supporting Reference
Contextual Irrelevance	Frameworks assume high-resource settings, limiting applicability in low-resource contexts.	UNESCO [13] in "ICT Competency Framework for Teachers"
Overemphasis on Technical Skills	Prioritizes technical proficiency over pedagogical and institutional support, undervaluing teacher beliefs and institutional policies.	Ertmer & Ottenbreit-Leftwich [11] in "Teacher beliefs and technology integration: A critical relationship"
Lack of Longitudinal Assessment	Relies on short-term metrics, neglecting long-term impacts of technology integration.	Luckin et al. [8] in "Intelligence Unlocked: How to optimize student learning through the strategic use of technology"

Many benchmarking frameworks are designed with high-resource settings in mind, assuming access to advanced technological infrastructure and support. This assumption limits their applicability in low-resource contexts, where educational institutions may lack basic technology and reliable internet. UNESCO [13] in their "ICT Competency Framework for Teachers" highlights the need for context-specific benchmarks to address these disparities.

There is a tendency to prioritize technical proficiency, often at the expense of pedagogical and institutional support. Ertmer and Ottenbreit-Leftwich [11] in their study "Teacher beliefs and technology integration: A critical relationship" argue that teacher beliefs and pedagogical approaches are more influential in technology integration than mere technical skills. Institutional support, including policies, funding, and professional development, is also crucial but often undervalued in current practices.

Evaluations frequently rely on short-term metrics, such as immediate test scores or engagement levels, rather than assessing long-term impacts. Luckin et al. [8] in "Intelligence Unlocked" advocate for evidence-based approaches that consider sustained effects, noting that short-term metrics may miss the full benefits or challenges of technology integration over time.

E. Review on AI-Integrated STEM Education in Cambodia

In Cambodia, STEM education has gained momentum in recent years, driven by the need to prepare students for a competitive global economy. The government has recognized the importance of integrating science, technology, engineering, and mathematics into the curriculum to foster critical thinking and innovation among young learners. However, the integration of Artificial Intelligence (AI) into education remains in its early stages. Current efforts focus on promoting digital literacy, but there are significant gaps in the adoption of AI technologies within schools [7]. Moreover, the lack of investment in infrastructure and resources contributes to these challenges and limits the potential for successful integration of innovative educational technologies. To enhance the integration of AI in education, it is essential to provide targeted professional development for teachers that not only covers the technical aspects of AI tools but also emphasizes pedagogical strategies to effectively incorporate these technologies into their teaching practices. Collaboration between educational institutions and technology providers can facilitate these training opportunities, ensuring that educators feel confident and capable of using AI to enrich the learning experience. Additionally, investing in infrastructure improvements will help bridge the technology gap and create an environment conducive to innovative teaching and learning methods.

Teachers in Cambodia face several challenges when trying to incorporate AI into STEM education. A lack of training and professional development opportunities limits their

understanding of how to effectively use AI tools in the classroom. Additionally, many educators are not familiar with AI's potential to enhance personalized learning experiences. Limited access to technology and resources further hinders teachers' ability to implement innovative teaching methods. The scarcity of resources and inadequate training programs serve to intensify obstacles that teachers encounter while trying to implement AI technologies effectively. To overcome these barriers, it is critical to establish partnerships with NGOs and private sector stakeholders who can offer essential resources and expertise for building a robust AI-integrated curriculum. Additionally, fostering collaboration among educators can facilitate the sharing of best practices and innovative teaching strategies, ultimately enriching the educational landscape in Cambodia.

Cambodia's education system faces unique challenges, including limited infrastructure, resource constraints, and a shortage of qualified teachers. However, the country has made significant strides in recent years to modernize its curriculum and incorporate technology into classrooms. The Ministry of Education, Youth, and Sport (MoEYS) has prioritized STEM education as a key driver of economic development and innovation [5]. Despite these efforts, the integration of AI in STEM education remains in its infancy, highlighting the need for a robust benchmarking framework to guide teacher support initiatives.

Addressing these challenges requires a structured approach to supporting educators in integrating AI into their STEM curriculum. A benchmarking framework for teacher support can provide a strategic pathway to enhance skill development and resource allocation. By focusing on fostering collaboration among educators, researchers, and technology providers, Cambodia can create an educational environment that embraces AI integration, ultimately benefiting students and preparing them for future challenges in the digital age. To effectively support educators, it is necessary to establish clear guidelines and frameworks that outline best practices in AI integration within the curriculum. These frameworks should focus on promoting collaboration among teachers, who can benefit from sharing experiences and strategies regarding AI tools. Additionally, continuous feedback from teachers involved in pilot programs will be crucial for refining these guidelines and ensuring they address real classroom challenges.

F. Synthesis and Implications

AI holds significant promise for enhancing STEM education through tools that boost engagement and personalization, yet its success hinges on teacher readiness and adequate support frameworks. The TPACK and SAMR models provide valuable guidance but require adaptation for low-resource contexts and the inclusion of ethical considerations to address emerging challenges like data privacy and digital equity. Benchmarking practices must evolve

to be contextually relevant, balanced in their assessment of technical and pedagogical aspects, and focused on long-term outcomes to support the effective integration of AI in education.

In brief, our framework adapts TPACK and SAMR to Cambodia's needs, incorporating: Professional development (training frequency, confidence metrics); Technological infrastructure (tool access, internet reliability); and Curriculum alignment (national standards compliance).

1. Benchmarking Framework for Teacher Support

Creating a benchmarking framework for teacher support in the context of AI-integrated STEM education involves identifying key areas where educators need assistance. This framework should focus on providing resources and training that enhance teachers' ability to effectively incorporate AI into their lessons. Important support areas include professional development, access to AI tools, and ongoing mentorship. Evaluating teacher performance can be guided by specific metrics, such as their confidence in using AI technologies, student engagement levels, and the effectiveness of their instructional strategies [14]. Moreover, implementing training sessions that highlight the use of these AI tools can ensure teachers feel comfortable and confident in their application. This training can include hands-on workshops tailored to the specific needs of the educators, helping them to explore various AI applications relevant to their curriculum. By fostering a supportive environment where teachers can experiment with new technologies, we can cultivate a proactive approach to integrating AI into STEM education. By facilitating these collaborative practices, we can create a network of educators who share strategies and resources, ultimately enhancing the integration of AI in teaching. Moreover, continuous feedback from these communities can help refine the approaches used in the classroom, making them more suited to the specific needs of Cambodian students. This collaborative learning can also inspire innovative methods of utilizing AI, ensuring that educators are not only informed about technological advancements but are also actively engaged in the evolution of teaching practices.

Learning from successful implementations in other regions can inform best practices for Cambodia. For instance, establishing communities of practice where teachers can share experiences and strategies can facilitate more effective use of AI in classrooms. Such collaborations can help educators feel less isolated and more supported in their efforts to harness technology for teaching. This approach can facilitate a rich exchange of ideas, fostering a spirit of innovation among educators as they adapt to new teaching methodologies. By sharing their successes and challenges, teachers can build a practical understanding of how AI can enhance their instructional practices. Additionally, ongoing support through these communities will help sustain motivation and commitment to integrating AI effectively in the classroom. This approach not only promotes practical skills

among teachers but also encourages a mindset focused on lifelong learning and adaptability. As educators share their experiences and lessons learned, they contribute to a collective knowledge base that benefits the entire teaching community. Furthermore, this empowered network can serve as a foundation for reforming educational policies that support AI integration, ensuring that teachers are well-equipped to meet the diverse needs of their students in a rapidly changing educational landscape.

This benchmarking framework will not only enhance teacher skills but also build a culture of continuous improvement within educational institutions. As educators become more proficient in using AI, they can better prepare students for future challenges in a technology-driven world. By focusing on these support mechanisms, Cambodia can foster an educational environment that embraces AI integration. The next logical step is to explore insights and recommendations for future implementation, ensuring that the groundwork for teacher support continues to evolve and adapt to new educational demands. To ensure the framework remains effective, we must continuously assess its outcomes and make necessary adjustments based on teacher feedback and student performance. This iterative process will help identify areas where support is lacking and allow for the development of targeted strategies that address these gaps. Ultimately, fostering a culture of reflection and adaptation among educators will ensure that our approach to AI integration remains relevant and effective in meeting the needs of students.

2. Insights and Recommendations for Future Implementation

To ensure the successful implementation of AI-integrated STEM education in Cambodia, it is important to analyze the findings from the benchmarking framework and draw actionable recommendations for policy and practice. The framework indicates that teachers need ongoing support, particularly in professional development and access to AI tools. Schools should prioritize creating structured training programs that equip educators with the necessary skills to integrate AI into their teaching. These programs should focus not only on technical skills but also on pedagogical strategies that enhance student engagement and learning outcomes [15]. Additionally, expanding access to AI resources for teachers is a key recommendation emerging from the benchmarking findings. This could involve establishing partnerships with tech companies to provide educators with cutting-edge tools and platforms at little or no cost. By ensuring that teachers are equipped with the right technologies, the integration of AI into STEM education can be better supported, leading to enhanced learning experiences for students.

Moreover, collaboration between educational institutions, government bodies, and technology providers is important. By fostering partnerships, resources can be pooled together to create a more robust support system for teachers. Establishing mentorship

programs where experienced educators share best practices can also promote a culture of continuous improvement. Incorporating feedback from educators and stakeholders throughout the implementation process can greatly enhance the effectiveness of these training programs. This feedback loop allows for modifications in real-time, ensuring that the specific needs of teachers are being met. By fostering an environment where teachers feel heard and supported, the overall quality of AI integration in STEM education can be significantly bolstered. To further strengthen the support system for teachers, it is important to incorporate flexible learning pathways that cater to different levels of expertise. This can involve providing online resources and workshops that teachers can access at their convenience, allowing them to learn at their own pace. Additionally, integrating peer collaboration opportunities can help foster a sense of community among educators, encouraging them to share experiences and solutions related to AI integration in their classrooms.

Looking ahead, future research should focus on evaluating the long-term impacts of AI integration on student learning and teacher effectiveness. Studies can explore various educational settings to identify best practices and challenges faced during implementation. Additionally, research can assess the effectiveness of different professional development models, helping to refine and improve teacher support strategies over time. In order to effectively address the recommendations from the benchmarking framework, it will be essential to conduct pilot programs that allow for real-world testing of these strategies. Such initiatives can identify specific barriers teachers face and reveal which support mechanisms are most effective in different contexts. By gathering qualitative and quantitative data from these trials, stakeholders can make informed adjustments to training programs as they scale up the implementation of AI-integrated STEM education.

In summary, addressing the needs of educators through targeted support and fostering collaboration will play an important role in the success of AI in STEM education. By continuously adapting policies and practices based on research findings, Cambodia can build an educational system that prepares students for a technologically advanced future. This commitment to adaptability will help ensure that teacher training remains relevant to emerging technologies and pedagogical trends. Additionally, involving teachers in the design of these programs can foster a sense of ownership and commitment to implementing AI in their classrooms. By actively engaging educators in the development process, the support initiatives are more likely to address their real-world challenges and therefore be more effective in practice. Involving teachers in the program design process not only increases the likelihood that their practical concerns are addressed but also helps build a sense of community and shared purpose among educators. Regular opportunities for collaboration, such as workshops and forums, should be organized to facilitate

discussions about challenges and successes faced in the classroom. By establishing these collaborative networks, educators can continually refine their teaching practices and share valuable strategies for integrating AI into STEM education effectively.

3. Gaps in Current Benchmarking Practices for Teacher Support in AI-Integrated STEM Education Curriculum Insights from Cambodia

The integration of Artificial Intelligence (AI) into STEM (Science, Technology, Engineering, and Mathematics) education has the potential to revolutionize teaching and learning. However, the success of AI integration depends heavily on the availability of robust benchmarking frameworks that guide teacher support and professional development. While benchmarking frameworks have been widely adopted in education, significant gaps remain, particularly in the context of AI-integrated STEM education in developing countries like Cambodia. This section explores these gaps, drawing on insights from Cambodia's educational landscape, and highlights the need for a context-specific framework to address the unique challenges faced by educators in low-resource settings.

Table 2. Gaps drawing on insights from Cambodia's educational landscape

Issue	Description	Insights from Cambodia	Identified Gap
Lack of Contextual Relevance in Existing Frameworks	Frameworks like TPACK and SAMR were designed in high-income countries and often don't suit the realities in developing contexts.	Rural schools in Cambodia lack reliable internet and digital devices; teachers struggle with digital literacy.	Lack of adaptable benchmarking frameworks for low-resource settings.
Overemphasis on Technical Skills	Current frameworks prioritize technical skills, often ignoring pedagogical needs and institutional support.	Teachers lack access to pedagogical training and institutional resources for effective AI integration.	Neglect of broader pedagogical and institutional dimensions.
Inadequate Attention to Ethical and Social Implications	Ethical concerns like data privacy and algorithmic bias are often overlooked.	AI tools may reinforce inequalities, as models trained on urban data are unsuitable for rural schools.	No mechanisms are in place to address ethical and equity concerns in AI use.
Limited Focus on Teacher Collaboration	Teacher collaboration and communities of practice are crucial but often ignored in frameworks.	Teachers engaged in collaborative communities are more likely to adopt innovative AI practices.	Frameworks emphasize individual competencies over collaborative cultures.
Lack of Longitudinal and Impact Assessment	Benchmarks focus on short-term outcomes and rarely assess long-term effects.	Continuous monitoring is essential for tracking educational reforms and improvements.	No mechanisms for longitudinal tracking or systemic evaluation of AI impacts.
Insufficient Alignment with Local Curricular Goals	Many frameworks are generic and misaligned with national education policies.	Cambodia emphasizes STEM education, but current frameworks do not align with national curricular priorities.	Frameworks lack relevance due to poor alignment with local curricula and policies.

In summary, the gaps in current benchmarking practices highlight the need for a more comprehensive and context-specific framework for evaluating teacher support in AI-integrated STEM education. By addressing these gaps, a new benchmarking framework can provide a more holistic approach to AI integration, ensuring that teachers are equipped with the necessary skills, resources, and support to foster student success in a rapidly evolving digital landscape. This is particularly critical in developing countries like Cambodia, where the challenges of AI integration are compounded by resource constraints and infrastructural limitations. A context-specific framework that incorporates ethical considerations, fosters teacher collaboration, and aligns with local curricular goals can serve as a valuable tool for enhancing teacher support and promoting equitable access to AI-powered learning tools.

The gaps in current benchmarking practices highlight the need for a more comprehensive and context-specific framework for evaluating teacher support in AI-integrated STEM education. By addressing these gaps, a new benchmarking framework can provide a more holistic approach to AI integration, ensuring that teachers are equipped with the necessary skills, resources, and support to foster student success in a rapidly evolving digital landscape. This is particularly critical in developing countries like Cambodia, where the challenges of AI integration are compounded by resource constraints and infrastructural limitations.

Materials and Methods

This study employed a mixed-method approach to design a benchmarking framework for teacher support in AI-integrated STEM education in Cambodia. Textual data was collected via open-ended surveys and interviews from Cambodian teachers involved in AI-STEM initiatives, capturing their experiences, challenges, and support needs. The data underwent preprocessing steps, including tokenization, stop word removal, stemming, and noise elimination, using Python libraries (NLTK). Validation included cross-testing cluster numbers and contextualizing results against Cambodia's educational landscape (e.g., rural-urban divides).

A. Data Collection and Analysis

The methodology begins with gathering textual data from Cambodian teacher trainees at NIE in 2025. They are perceived as catalyst teachers for the new generation of the country who have accumulated the latest teachers' professional knowledge in digital and STEM skills, and other modern professional pedagogy and content knowledge for the 21st century to teach in Cambodia. They are involved in AI-integrated STEM education through quantitative surveys. This data is then cleaned and standardized, involving steps like tokenization, removing stop words, and stemming to prepare for analysis.

B. Clustering and Framework Design

The preprocessed text is converted into numerical data using TF-IDF vectorization, and K-means clustering groups similar texts into clusters. Each cluster is analyzed to identify themes, such as training needs or technological support, which are crucial for the benchmarking framework. This section provides a comprehensive exploration of the methodology for designing a benchmarking framework for teacher support in AI-integrated STEM education in Cambodia, focusing on the use of Python's data analysis model through K-means clustering for topic texts. The analysis draws on recent research and practices in educational data analysis, emphasizing the integration of AI and the specific context of Cambodia.

The integration of artificial intelligence (AI) into STEM (Science, Technology, Engineering, and Mathematics) education is a growing field, particularly in developing countries like Cambodia, where educational reforms aim to prepare students for a technology-driven future. Teacher support is critical in this transition, and designing a benchmarking framework requires a deep understanding of teachers' experiences and needs. The methodology leverages text analysis to uncover these insights, using Python's robust data analysis capabilities and K-means clustering for topic modeling. Fig. 1 shows the process of designing the benchmarking framework.

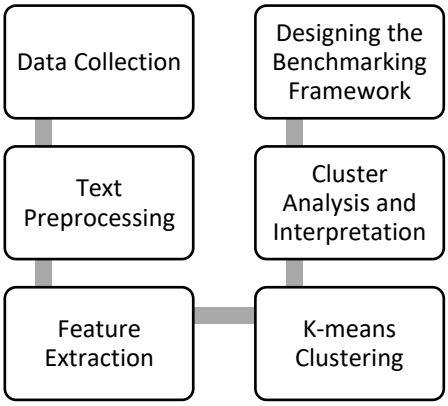


Fig. 1. The process of designing the benchmarking framework.

Table 3 shows the organizing methodology, including the tools and techniques.

Results

The raw data was obtained from a survey of 365 Cambodian students, who answered how much AI is used in their schools. The students were free to answer the survey questions either in Cambodian or English. The survey results were exported into a Google Sheets (Excel) file, and then non-numerical responses were translated and converted into numerical data for analysis.

The clean data was then loaded into an IPython file to be processed further. Each of the numerical columns regarding the usage of AI was plotted into a histogram chart and described

using Pandas. .describe() method. For this research, we'll focus on the "mean" row on the .describe() method. As we can see, the results were slightly below the middle point of the rating scale (i.e. 1.5-1.9 on a 0-4 scale, or 2.5-2.9 on a 1-5 scale), and thereby concluding that there are still lots of room of improvement on the AI aspect at Cambodian schools.

Table 3. The cycle of organizing the methodology

Step	Description	Tools/Techniques
Data Collection	Gather teacher feedback via surveys or interviews	Surveys, Interviews
Text Preprocessing	Clean and standardize text (tokenization, stop word removal, stemming)	Python (NLTK)
Feature Extraction	Convert text to numerical data using TF-IDF	Python (scikit-learn)
K-means Clustering	Group similar texts into clusters, and determine k manually	Python (scikit-learn)
Cluster Analysis and Interpretation	Identify themes by analyzing frequent words in each cluster	Manual review, visualization
Designing the Benchmarking Framework	Develop dimensions and metrics based on themes	Domain expertise, literature

We then processed the final three columns of the data (which are not numerical data but open-ended text) by doing cluster analysis to see which top three aspects out of the possible seven aspects need to be focused on first. Three primary themes emerged from the cluster analysis: professional development needs, technological infrastructure, and curriculum integration.

The findings underscore the necessity of partnerships with tech companies for resource provision, flexible learning pathways for teachers, and iterative policy adjustments based on teacher feedback. The framework's adaptability ensures relevance to Cambodia's evolving educational needs, positioning it as a scalable model for AI integration in STEM education. Details a mixed-research method involving data collection from teachers via surveys and interviews, text preprocessing (tokenization, stop word removal, stemming), and feature extraction using TF-IDF vectorization. K-means clustering, supported by Python libraries like scikit-learn and identifies themes (Table 4).

Table 4. The list of cluster themes

Cluster Theme	Challenge Description	Percentage of Responses
Professional Development Needs	Demand for hands-on AI workshops.	45%
Technological Infrastructure	Rural schools reported less than 20% internet access.	35%
Curriculum Integration	Misalignment with national STEM goals.	20%

Results from the data identify key themes from clustering, including professional development needs, technological support, and curriculum integration, forming the framework's dimensions with specific metrics like workshop frequency and AI tool availability.

The clustering results identified key themes, forming the benchmarking framework's dimensions (Table 5).

Table 5. The benchmarking framework's dimensions

Theme	Description	Example Metrics
Professional Development Needs	Teachers require training and workshops for AI tool skills.	Frequency of workshops, training access
Technological Support	Access to AI tools and infrastructure is crucial.	Availability of tools, internet access
Curriculum Integration	Aligning AI-STEM content with national standards is necessary.	Alignment with standards, curriculum fit

These themes, uncovered through K-means clustering, provide a tailored approach to support teachers, addressing nuanced needs like rural infrastructure gaps. It was uncovered through K-means clustering, providing a tailored approach to support teachers, addressing nuanced needs like rural infrastructure gaps (Table 6).

Table 6. Key Performance Indicators (KPIs)

No	Issues	Remark
1	Benchmarking Mechanism	Key Performance Indicators (KPIs): ● Teacher confidence in using AI and digital tools. ● Availability of professional development opportunities. ● Access to digital resources and infrastructure. ● Institutional support for technology integration. ● Student engagement and learning outcomes.
2	Scoring Rubric	A five-point scale to evaluate each KPI.
3	Framework Implementation	Steps for integrating the benchmarking mechanism into existing support systems.

Discussion

The study identified the framework's relevance, aligning with global best practices while addressing local needs, though noting the absence of actual results, which may limit its empirical strength. The framework bridges global benchmarks (e.g., TPACK) with Cambodia's realities, emphasizing 1) collaborative communities, i.e., peer mentorship improved adoption rates [16]; and 2) ethical AI, i.e., localized data sets mitigate bias [1].

Cluster analysis of the survey data revealed three critical themes. First, nearly half of the responses highlighted a pressing demand for professional development, with participants advocating for structured AI training programs, hands-on workshops, and pedagogical strategies tailored to AI integration. This finding is similar to the other research in different countries [17],[18]. Second, over a third of teachers identified technological infrastructure as a key barrier, citing limited access to AI tools and unreliable internet connectivity, particularly in rural schools where only 20% reportedly had internet access. Some researchers found the

same limitation on the issue of internet limitation [19],[20]. Finally, roughly one-fifth of responses emphasized curriculum integration challenges, noting misalignment between AI-STEM content and national standards. Similar concerns have been reported in studies conducted in other countries, where educators also struggle to align rapidly evolving AI-related content with existing national curricula and standards [21],[22]. . This indicates a broader, cross-national challenge in integrating emerging technologies into formal education systems.

While these findings align with global frameworks like TPACK and SAMR, they also underscore contextual gaps. Teachers expressed high expectations for training to bridge technology, pedagogy, and subject expertise, yet systemic barriers, such as inadequate infrastructure and unadapted curricula, persist. Unexpected insights included requests for localized training modules and mentorship programs. The study's benchmarking framework addresses these needs through measurable dimensions: Training & Professional Development (e.g., workshop frequency), Technological Infrastructure (e.g., tool accessibility), and Curriculum Alignment (e.g., compliance with standards). These findings advocate for tech-sector partnerships, flexible teacher training pathways, and iterative policy updates, offering a scalable model for AI-STEM integration in resource-constrained settings.

Based on the data and findings in the research paper, here's a discussion focusing on the key insights and their implications: The cluster analysis of the data revealed that teachers require substantial support in several areas. There's a strong need for structured AI training programs, practical workshops, and pedagogical strategies specifically designed for integrating AI into STEM education. A significant barrier is the limited access to AI tools and unreliable internet connectivity, especially in rural schools. Teachers face challenges in aligning AI-STEM content with national standards and adapting instructional materials to incorporate AI effectively. These needs were translated into three key dimensions of the benchmarking framework: Training & Professional Development, Technological Infrastructure, and Curriculum Alignment.

The survey results indicated that AI implementation in Cambodian schools is still in the early stages, suggesting significant room for improvement. The findings emphasize the importance of developing contextually relevant support systems. The challenges faced by Cambodian teachers, such as infrastructural limitations, highlight the inadequacy of applying generic frameworks designed for well-resourced settings.

The study underscores the necessity of providing balanced support that goes beyond technical skills. Pedagogical support and institutional support are crucial for the effective integration of AI in education. The findings reveal disparities in access to technology and resources, particularly between urban and rural areas. This highlights the need for interventions and policies that address these inequities to ensure equitable AI integration.

The study suggests that partnerships with tech companies, government bodies, and educational institutions are essential for providing resources, training, and ongoing support to teachers. Collaboration among educators, such as through mentorship programs and communities of practice, can also facilitate the sharing of best practices and enhance AI integration [23],[24]. The research emphasizes the need for a flexible and adaptable framework that can evolve with the changing needs of educators and the advancements in AI technology. This includes incorporating feedback from teachers and stakeholders to refine support strategies and ensure their effectiveness. The study points to the need for future research to evaluate the long-term impact of AI integration on student learning and teacher effectiveness. Similar findings have been reported in international studies, which also highlight the importance of evaluating the long-term effects of AI integration in education [25],[26]. These studies emphasize the need to assess how AI influences both student learning outcomes and teacher performance over time. Additionally, they recommend implementing pilot programs as a strategic step to test, adjust, and improve support mechanisms before full-scale adoption, ensuring more effective and context-appropriate integration.

Conclusion

This study presents a scalable benchmarking framework to empower Cambodian teachers in AI-STEM integration. The integration of AI into STEM education holds immense potential for transforming teaching and learning, but its success depends on the availability of effective teacher support systems. A benchmarking framework tailored to the needs of educators in developing countries like Cambodia can provide a roadmap for enhancing teacher readiness and fostering the successful implementation of AI-integrated curricula. By addressing the unique challenges and opportunities in this context, this study contributes to the broader discourse on AI in education and offers practical insights for policymakers, educators, and researchers. In conclusion, the data and findings highlight the complexities of integrating AI in education, particularly in developing countries like Cambodia. The study underscores the importance of context-specific, balanced, and collaborative approaches to teacher support to ensure the successful and equitable implementation of AI in STEM education.

Recommendation

To address immediate gaps in AI-STEM education, structured mentorship programs should be piloted, pairing experienced educators with peers in need of support. These programs would combine online and in-person guidance, utilizing accessible platforms like WhatsApp for low-resource settings, while offering micro-credentials as incentives. Success would be measured through pre- and post-training confidence surveys, classroom

implementation rates, and student feedback, ensuring the approach is both practical and scalable. For systemic change, Cambodia must develop a national AI-STEM policy backed by diversified funding mechanisms, including public-private partnerships and international grants. A phased implementation, beginning with urban training hubs and expanding to rural areas, would ensure equitable access, while annual teacher forums and clear KPIs, such as tool accessibility and student performance, would maintain accountability. This long-term strategy aligns with global benchmarks while addressing local constraints, fostering sustainable growth in AI-integrated education.

Limitations

The discussion interprets the framework's relevance, noting its alignment with global best practices while addressing Cambodia's educational context. It highlights the mixed-research method's strength in capturing qualitative depth and quantitative structure, drawing on "Artificial Intelligence in Higher Education: The State of the Field" for context-specific insights. However, a notable limitation is the absence of actual results, as the document focuses on methodology and proposed framework, potentially affecting empirical validation. This suggests that future research is needed to apply and test the framework in real settings.

Conflict of Interest

The authors declare that there is no conflict of interest.

References

[1] W. Holmes, M. Bialik, and C. Fadel, "Artificial Intelligence in Education: Promises and Implications for Teaching and Learning," in *Center for Curriculum Redesign,* 2019.
[2] L. Un, and S. Sok, "Digital Literacy and Technology Integration in Cambodian Schools: A Case Study," in *International Journal of Educational Development,* 62, 2018, pp. 1-8.
[3] P. Mishra, and M. J. Koehler, "Technological pedagogical content knowledge: A framework for teacher knowledge," in *Teachers College Record,* 108(6), 2016, pp. 1017-1054, doi: 10.1111/j.1467-9620.2006.00684.x.
[4] R. R. Puentedura. "SAMR: A contextualized introduction." Ruben R. Puentedura's Weblog. Accessed: Jun. 10, 2025. [Online.] Available: http://www.hippasus.com/rrpweblog/
[5] MoEYS, "Education Strategic Plan 2019-2023," in *Ministry of Education, Youth, and Sport, Cambodia,* 2021.
[6] T. Kheang, S. Ouk, and S. Serey, "Teacher Collaboration and Professional Development in Cambodia: Challenges and Opportunities," in *Journal of Southeast Asian Education,* 21(2), 2020, pp. 45-60.
[7] O. B. Joseph and N. C. Uzondu, "Integrating AI and machine learning in STEM education: Challenges and opportunities," in *Computer Science & IT Research Journal,* 5(8), 2024, pp. 1732–1750, doi: 10.51594/csitrj.v5i8.1379
[8] R. Luckin, W. Holmes, M. Griffiths, and L. B. Forcier, "Intelligence Unleashed: An argument for AI in Education," in *Pearson Education*, 2016.
[9] O. Zawacki-Richter, V. I. Marín, M. Bond, and F. Gouverneur, "Systematic review of research on artificial intelligence applications in higher education – where are the educators," in *International Journal of Educational Technology in Higher Education,* 16(1), 2019, pp. 1-27.
[10] N. Selwyn, "Should robots replace teachers? AI and the Future of Education," in *1st ed. Cambridge, UK: Polity Press*, 2019, p. 160.
[11] P. A. Ertmer and A. T. Ottenbreit-Leftwich, "Teacher technology change: How knowledge, confidence, beliefs, and culture intersect," in *Journal of Research on Technology in Education,* 42(3), 2010, pp. 255-284, doi: 10.1080/15391523.2010.10782551.

[12] R. C. Camp, "Benchmarking: The search for industry best practices that lead to superior performance," in *Quality Press*, 1989, doi: 10.4324/9781003578871.
[13] UNESCO and Z. Varoglu, "UNESCO ICT Competency Framework for Teachers," in *United Nations Educational, Scientific, and Cultural Organization*, 2018.
[14] S. R. Goldman et al, "Exploring the Integration of Artificial Intelligence into Special Education Teacher Preparation through the TPACK Framework," in *Journal of Special Education Preparation,* 4(2), 2024, pp. 52-64, doi: 10.33043/6zx26bb2.
[15] H. Arguinis, D. Bergh, and J. F. Molina-Azorin, "Methodological challenges and insights for future international business research," in *Journal of International Business Studies,* 54(2), 2023, pp. 219-232, doi: 10.1057/s41267-022-00578-8.
[16] J. Voogt, T. Laferrière, A. Breuleux, R. C. Itow, D. T. Hickey, & S. McKenney, "Collaborative design as a form of professional development," in *Instructional Science,* 43(2), 2015, pp. 259-282, doi: 10.1007/s11251-014-9340-7.
[17] Y. Yang, W. Sun, D. Sun, and S. Z. Salas-Pilco, "Navigating the AI-enhanced STEM education landscape: a decade of insights, trends, and opportunities," *Res. Sci. Technol. Educ.*, pp. 1–25, 2024.
[18] D. Sun, G. Cheng, P. L. H. Yu, J. Jia, Z. Zheng, and A. Chen, "Personalized STEM education empowered by artificial intelligence: a comprehensive review and content analysis," *Interact. Learn. Environ.*, pp. 1–23, 2025.
[19] A. Zemplényi *et al*., "Recommendations to overcome barriers to the use of artificial intelligence-driven evidence in health technology assessment," *Front. Public Health*, vol. 11, Art. no. 1088121, 2023.
[20] S. Kumar, R. D. Raut, M. M. Queiroz, and B. E. Narkhede, "Mapping the barriers of AI implementations in the public distribution system: The Indian experience," *Technol. Soc.*, vol. 67, Art. no. 101737, 2021.
[21] B. N. Abbasi, Y. Wu, and Z. Luo, "Exploring the impact of artificial intelligence on curriculum development in global higher education institutions," *Educ. Inf. Technol.*, vol. 30, no. 1, pp. 547–581, 2025.
[22] A. Bernstein, *Artificial Intelligence (AI) in K-8 Education: Understanding Teachers' Perceptions and District Leader Readiness While Preparing for AI Adoption*, Ph.D. dissertation, Concordia Univ. Chicago, 2025.
[23] M. Zamiri and A. Esmaeili, "Methods and technologies for supporting knowledge sharing within learning communities: A systematic literature review," *Adm. Sci.*, vol. 14, no. 1, Art. no. 17, 2024.
[24] C. McLoughlin, K. D. Patel, T. O'Callaghan, and S. Reeves, "The use of virtual communities of practice to improve interprofessional collaboration and education: findings from an integrated review," *J. Interprof. Care*, vol. 32, no. 2, pp. 136–142, 2018.
[25] Y. Purnama, F. W. Fransiska, A. Muhdi, M. Muflihah, and F. Meisarah, "Long-term effects evaluation of using artificial intelligence-based automated learning systems in improving English content understanding at the secondary education level," *Indones. J. Educ. (INJOE)*, vol. 3, no. 3, pp. 622–636, 2023.
[26] S. Sharma and N. Kumar, "The future of education: Implications of artificial intelligence integration in learning environments," *Int. J. Enhanc. Res. Educ. Dev.*, vol. 11, no. 5, pp. 129–133, 2023.

Authors



Wiputra Cendana is a lecturer in the Primary Teacher Education program at Universitas Pelita Harapan, located at Jalan M. H. Thamrin 1100, Lippo Village, Indonesia. In addition to his academic responsibilities, he frequently serves as a Regional Facilitator (*Fasilitator Wilayah*) for LLDIKTI Region III. (email: wiputra.cendana@uph.edu).



Dr. Keun Im is a researcher at the National Institute of Education in Phnom Penh, Cambodia. He earned his Ph.D. in Education from Auckland University of Technology (AUT), New Zealand. His work focuses on advancing education research and policy in the region. (email: im.keun@gmail.com).



Evan Kurnia Alim is a graduate of Universitas Pelita Harapan, Indonesia, with a background in mathematics and computer science. He also holds a master's degree in computer science from the National University of Singapore. His research interests lie in emerging trends in artificial intelligence (AI), particularly in educational applications. He enjoys developing AI and data-driven software using Python. (email: eka091294@gmail.com).