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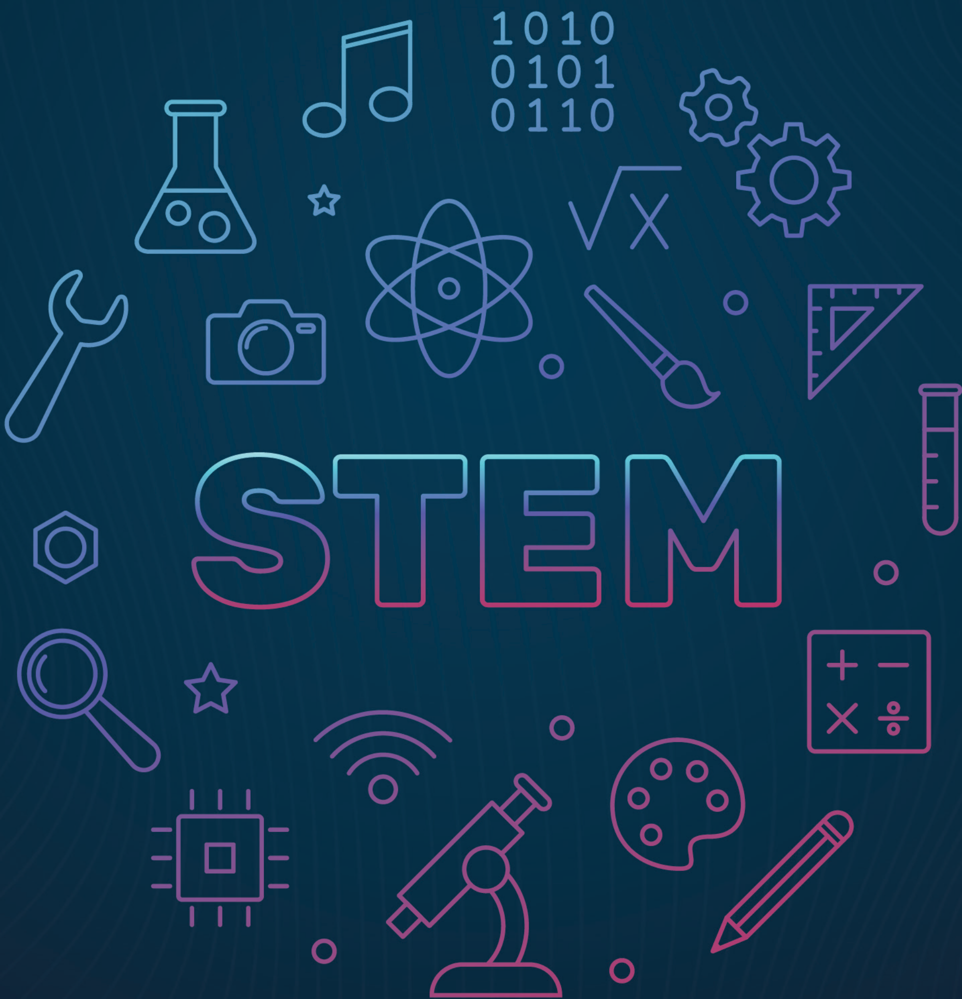
STEM Teachers' Continuous Professional Development

Opportunities, Challenges, and Policy Implications in Cambodia



Nhem Davut, Chea Sathya, and Heng Sok Mean

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Author(s) and **affiliation**(s):

Nhem Davut
Research associate, Cambodia Development Resource Institute

Chea Sathya
Research fellow, Cambodia Development Resource Institute

Heng Sok Mean
Research assistant, Cambodia Development Resource Institute

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The views expressed in this working paper are those of the authors and do not necessarily reflect the views of the Cambodia Development Resource Institute. The authors are responsible for any unintentional errors or mistakes. Corresponding author: Nhem Davut, davut_nhem124@yahoo.com.

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CDRI
56 Street 315, Tuol Kork, Phnom Penh, Cambodia
+855 23 881 701/881 916/883 603
cdri@cdri.org.kh
www.cdri.org.kh

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List of acronyms and abbreviations

CDRI	Cambodia Development Resource Institute
STEM	Science, Technology, Engineering, and Math
CPD	Continuous Professional Development
TEP	Teacher Education Programme
MoEYS	Ministry of Education, Youth and Sport
DPs	Development Partners
USESDP	Upper Secondary Education Sector Development Programme
ADB	Asian Development Bank
StepUP	Science and Technology Project in Upper Secondary Education
GEIP	General Education Improvement Project
HE	Higher Education
USSs	Upper Secondary Schools
CPD-MO	Continuous Professional Development - Mentoring Office
NIE	National Institute of Education
RSs	Resource Schools
NWs	Network Schools
NSs	Normal Schools
PjBL	Project-based Learning
PBL	Problem-based Learning
IBL	Inquiry-based Learning

Executive summary

Background of the study

In Cambodia, Science, Technology, Engineering, and Mathematics (STEM) has gained national attention due to the government's ambition to achieve a high-income status by 2050, with STEM viewed as a key driver. However, STEM education is facing challenges, as evident in several aspects. First, enrolment of students in the science track has sharply dropped from 90 percent in 2012–2013 to 34 percent in 2020–2021, while enrolment in social sciences has increased. Many students switch majors from science to social science in higher education due to poor academic performance and a lack of interest in STEM subjects. Despite the critical role of teachers, Cambodia, like other countries, faces a shortage of qualified STEM educators. However, empirical evidence on how STEM teachers engage in capacity building to enhance their knowledge and skills remains absent in Cambodia, as well as in the broader educational settings. This study aimed to investigate current continuous professional development (CPD) practices among STEM teachers in upper secondary schools and to propose strategies to address existing gaps. Specifically, it examined STEM teachers' accessibility to CPD programmes, as well as the effective characteristics of CPD activities on STEM teaching practices.

Research methodology

This study used a mixed-methods approach with an exploratory sequential design, beginning with qualitative data collection to explore STEM teachers' CPD in depth, followed by a quantitative phase to quantify the findings. The qualitative phase involved interviews with 89 participants from five provinces and Phnom Penh, including officials from the Ministry of Education, Youth, and Sports (MoEYS), development partners, provincial education leaders, school principals, and STEM teachers. Participants were selected using expert and purposive sampling, and interviews were transcribed and coded using NVivo. Insights from this phase informed the design of a national survey, which was conducted using a structured questionnaire built on KoboToolbox. The survey reached 401 teachers from 60 upper secondary schools selected through multi-stage sampling. Data were analysed using STATA, with descriptive, chi-square, and regression analyses to examine patterns and predictors of CPD participation. Below is the description of key findings, followed by policy recommendations.

Findings

STEM teacher accessibility to CPD

Teachers reported having participated in various CPD programmes, including national workshops, in-school training, technical meetings, and self-directed learning. However, only workshops and in-school training, primarily provided by MoEYS and development partners, concentrate on STEM pedagogy and material use. Notably, 79 percent of teachers have attended at least one workshop in their careers, with 48 percent doing so during the 2023-2024 academic year. Yet, the engagement in STEM-related workshops remains limited.

- Out of 401 participants who responded to the national survey, only about 50 percent engaged in Inquiry-based Learning (IBL), technology in STEM, and STEM theory, while approximately 20 percent to 30 percent were involved in Project-based Learning (PjBL), scientific material operation, assessment, experiments, and interdisciplinary learning in STEM.

- There appears to be no bias in workshop attendance based on gender or position; however, school type, together with its location, was declared a clear difference. That being said, teachers from resource schools (RSs), followed by network schools (NWs), reported benefiting more than those from normal schools (NSs). This finding suggests that STEM

CPD is mainly driven by project intervention (StepUP), raising concerns about equitable access to CPD and STEM education.

- There appears to be a paucity of cluster-based CPD on a large scale. Only school-based CPD activities, such as technical meetings, classroom observation, or peer teaching, were reported to be common yet address broader educational issues, thereby limiting the STEM focus.
- Knowledge sharing from workshops during technical meetings occurred to some extent (62 percent), yet appears to be ineffective due to limited teacher capacity and a lack of leadership support. This raises a question about the sustainability of CPD and STEM education in the long term.

Effective workshop and STEM challenges

The workshops were deemed adequate for their coverage of diverse STEM topics. Workshops were reported to cover STEM pedagogy (e.g., IBL, PjBL) and material use, positively impacting classroom practices like experiments and technology integration. Teachers were also given opportunities to engage in collaborative tasks with other fellow teachers during the workshop training.

- Nonetheless, the workshop content was reported to be too difficult for some and too easy for others, reflecting a problem with the alignment between CPD design and participant background. Furthermore, the training sometimes presented too many topics in just a few days, making it difficult for teachers to adapt them to the classroom.
- There were some follow-up activities, particularly through social media groups. After the workshop, 64.9 percent of teachers at RSs and 50 percent at NWs reported receiving post-training tasks, and 62.3 percent at RSs and 31 percent at NWs reported having some follow-up activities. Yet, activities on systematic feedback, coaching, or mentoring remained largely insufficient.
- Participation in STEM workshops seems to impact STEM education. Yet, school challenges such as insufficient resources at NSs, large class sizes, heavy curricula, mixed-ability classrooms, and an exam-oriented culture created obstacles to promoting STEM. Interdisciplinary learning is rare, with Math and ICT teachers perceiving limited STEM relevance.

Policy recommendations

Overall, STEM CPD programmes in Cambodia, primarily driven by project interventions, show promise but still face challenges in providing equitable CPD opportunities, achieving effectiveness, and ensuring sustainability. In this context, it is essential to promote collaboration within schools and school clusters through best practice sharing initiatives, thereby achieving both equity and sustainability for CPD and STEM education in the long run. Furthermore, CPD program design can be improved by better aligning CPD content with school contexts and teachers' backgrounds, providing resources to teachers in need, strengthening follow-up systems, involving leadership support, and addressing structural barriers. Reducing the scope of training content while promoting interdisciplinary learning experiences during CPD is likely to boost teachers' confidence in engaging with innovative STEM teaching practices. Finally, the MoEYS should incentivise innovation by rewarding not only CPD participation but also the implementation of innovative STEM practices and knowledge sharing efforts.

1. Introduction

In Cambodia, Science, Technology, Engineering, and Mathematics (STEM) has drawn significant national attention, following the government's declaration of its commitment to achieving high-income status by 2025 (MoEYS 2016). Central to this vision is the recognition of STEM as a vital catalyst for driving socio-economic prosperity. However, this policy goal conflicts with the current trend of STEM education in Cambodia. That said, student enrolment in the science track has plummeted from 90 percent in 2012-2013 to 34 percent by 2020-2021. Conversely, enrolment in the social science track has increased from 10 percent to 66 percent during the same period (Kao, Chea, and Song 2022). At the same time, the grade 12 national examinations have also encountered a troubling issue; for example, the passing rate during the 2016-2017 and 2017-2018 academic years was 80 percent in the social science track, compared to 50 percent in the science track (MoEYS 2021). A recent survey further revealed that 54.4 percent of the 1,338 sampled students switched their majors in higher education (HE) enrolment, with 93.1 percent from science to social science majors (Kao, Chea, and Song 2024). Although factors such as socioeconomic status and university location play a role, students' academic performance and interest in science subjects[1] significantly contribute to this trend. This evidence highlights the importance of enhancing STEM education in general education, as it can significantly impact students' major choices.

To enhance the quality of STEM education, it is undeniable that teachers are essential actors within education systems. However, a global systematic review suggests that teacher competence remains a topic of global concern (Margot and Kettler 2019). Teachers have been reported to face challenges such as pedagogical adaptation, curriculum alignment, or student background when making attempts to promote STEM education. Similarly, a shortage of qualified teachers with STEM pedagogical expertise, along with knowledge of scientific materials, significantly hinders the promotion of STEM in schools in Cambodia (MoEYS 2021). This underscores the urgent need for greater focus on teacher capacity development to enhance STEM education in the country. However, despite its essential role, research on how teacher capacity building remains limited to diverse geographical contexts, with most contributions from the US (Chai 2019; Huang et al. 2022; Surahman and Wang 2023), and some from the United Kingdom, Australia, and China (Surahman and Wang 2023). In Cambodia, although teacher capacity has drawn stronger attention, research on STEM teachers' engagement in continuous professional development (CPD) appears to be lacking at present. Therefore, this study aims to investigate CPD practices of STEM teachers in Cambodia's upper secondary schools (USSs), focusing on identifying existing gaps and proposing strategies for improvement. Two main research objectives were addressed:

1) To examine the accessibility of CPD for USS STEM teachers. It will also investigate equity in access to CPD by individual demographics (gender, age, position, specialisation, teaching track, education level, private tutoring), school types, and school location (urban/rural).

2) To explore the perceived effectiveness and challenges of existing CPD programmes on STEM education practice.

1 Science subjects include Physics, Chemistry, Biology, and Earth Science (MoEYS 2016a). However, in addition to these subjects, Cambodia's STEM education includes Math and ICT subjects (MoEYS 2022).

2. Literature review

2.1. Definitions and forms of teacher CPD

Continuous Professional Development (CPD) broadly refers to a range of ongoing activities designed to enhance teachers' knowledge of teaching and learning processes and their understanding of learners (Darling-Hammond and McLaughlin 2011), forming the conceptual foundation for the more specific discussion of STEM-focused CPD that follows. This definition aligns with Cambodia's definition (see below), emphasising the importance of teachers' capacity development through informal or formal training pursuits. Some examples of structured CPD activities include university courses, conferences, seminars, and workshops, while informal occasions encompass self-study activities and peer discussions occurring within the school context (Desimone 2011). Additionally, CPD should transcend single events, evolving into ongoing processes that involve collaboration with peers and specialists (Bergmark 2023) and has impacts on educational changes and outcomes (Guskey 2002). In this regard, CPD focuses on continuously enhancing in-service teachers' expertise in both their subject content and pedagogical knowledge, aligning with the realities of the school context, and maximising learning performance and outcomes. STEM CPD programmes can fall within the scope of this framed definition:

> … a wide variety of specialised training, formal and informal education, or advanced professional learning intended to help classroom and specialist teachers and school directors improve their professional knowledge, skills, competence, and effectiveness. (MoEYS 2019, 8)

In Cambodia, CPD can be categorised into four levels (MoEYS 2019). At the national level, teachers can participate in national-level training programmes conducted by Teacher Education Institutions (TEIs) or Non-Governmental Organisations (NGOs), with the learning content reviewed by the CPD Management Office (CPD-MO), whose primary duty is to oversee all teachers' CPD engagement. At the cluster level, CPD activities can be established in collaboration with other schools within the cluster or network, consisting of five to six schools that are geographically close to one another. At the school level, CPD activities include technical meetings, peer teaching, class demonstrations, or short training sessions. At the individual level, teachers can pursue self-learning opportunities, such as action research, extensive reading activities, or formal academic coursework, and compile these into portfolios. The CPD-MO will assess the portfolios based on two criteria: academic (formal) and non-academic (informal) systems. The former refers to teachers pursuing formal academic studies (BA, MA, or PhD degrees) at institutions recognised by the CPD-MO, while the latter pertains to teachers attending short courses, workshops, webinars, or school cluster training, which count toward the hours attended. CPD recognition might include certificates, teaching medals, cash incentives, or teacher cups.

2.2. Effective CPD in STEM

Effective CPD programmes, particularly in STEM education, require robust evaluative criteria. One study (Hubers, Endedijk, and Van Veen 2022) proposed a comprehensive framework consisting of two dimensions: content and coherence (see Table 1). The first dimension emphasises the relevance of CPD content to specific subject areas and teachers' engagement in collaborative activities. Pioneering scholars in CPD also endorse the role of teachers' active and collaborative engagement, arguing that teachers should actively engage in demonstrating new teaching activities, observing and analysing the learning process, or discussing and receiving feedback (Hubers, Endedijk, and Van Veen 2022; Sims and Fletcher-Wood 2021; Patton, Parker, and Tannehill 2015; Borko, Jacobs, and Koellner 2010; Desimone 2011). Such hands-on experiences through collaborations with peers during the CPD programmes will enable teachers to adjust the new instructional approaches to their school contexts.

Table 1: Effective characteristics of CPD in STEM

Characteristics	Explanations
Content	
Focus	STEM framework, pedagogy, technology, or learning process in STEM
Activities	Lesson planning, demonstration, observation, assessment, reflection, & feedback
Collaboration	Working with different subject teachers from the same or different schools
Coherence of the content	Alignment between the training objectives, content, & activities
Duration	Re-occurring events & follow-up meetings
Coherence	
School context	Aligning with school policy, vision, resources, facilities, and environment
Individual factors	Fitting with teachers' attitudes, abilities, or interests

Source: Adapted from Hubers, Endedijk, and Van Veen (2022)

In addition, the coherence between the learning content and learning goals should be clearly established in CPD programmes (Hubers, Endedijk, and Van Veen 2022). For instance, if the school aims to involve students in developing a software application, then the CPD programme should be tailored to support teachers in demonstrating knowledge and skills to students to realise that goal. Moreover, scholars have also reached a consensus on the sustainability of CPD programmes (duration). To be successful, CPD activities should not be a one-time training session but an ongoing process of reflection and refinement — a principle long recognised in the broader CPD literature (Hubers, Endedijk, and Van Veen 2022; Sims and Fletcher-Wood 2021; Borko, Jacobs, and Koellner 2010; Patton, Parker, and Tannehill 2015; Desimone 2011). This is understandable that, at times, teachers require some reflection, adjustment, or support during their practice.

Introducing new technologies/activities needs to be more practical and relevant to teachers' knowledge and classroom context, since teachers might not have sufficient time to explore and plan them for classroom practice (Hubers, Endedijk, and Van Veen 2022). CPD programmes should align with teachers' personal growth (Borko, Jacobs, and Koellner 2010; Hubers, Endedijk, and Van Veen 2022) and schools' visions and policies (Hubers, Endedijk, and Van Veen 2022). In this regard, CPD programmes need to pay close attention to the school context, including state/provincial district and school education reform priorities and policies, school characteristics, and individual factors, all of which contribute to the success of the delivery of the CPD programmes (Hubers, Endedijk, and Van Veen 2022). While the framework above provides insight into what constitutes effective CPD in STEM internationally, the extent to which such practices are reflected in Cambodia's educational landscape remains unclear. The following section therefore outlines the development of STEM education and teacher capacity in Cambodia to contextualise these global concepts.

2.3. A glimpse into STEM and teacher capacity development in Cambodia

STEM education in Cambodia can be traced back to the 2010 education reform, which introduced two new learning pathways in USSs: the science track and the social science track. Students entering 11th grade are required to choose one of these streams based on their interests and abilities (Pov et al. 2022). Earlier, in 2008, according to USS Resource School policy, Cambodia also established three types of USSs: resource schools (RSs), network schools (NWs), and normal schools (NSs). The policy aimed to ensure that RSs would provide better educational quality to students (Department of General Secondary Education 2008). In 2015, STEM-focused schools such as "New Generation Schools" and later "E2STEM school" were established to promote STEM education in Cambodia. The establishment of such school types is comparable to those in Singapore, the US, Australia, and the Philippines, where STEM-oriented schools are designed to attract students interested in science education (Teo 2019).

In 2016, a STEM policy was introduced, emphasising the development of policy actions such as STEM regulations, mechanisms, curricula, resources, school infrastructure, teacher capacity, gender equality, stakeholder engagement, and monitoring and evaluation systems, along with incentives for STEM initiatives (MoEYS 2016b). STEM education manuals have also become available for guiding STEM education (MoEYS 2022; Department of General Secondary Education 2018). For example, a manual on "STEM Education for Training Upper Secondary School Teachers" offers a compendium on STEM theory, frameworks, teaching approaches, and teacher training. It also includes a STEM instruction framework, consisting of four levels (0-3). At level zero, STEM subjects are taught separately, emphasising theoretical knowledge without real-life connections or hands-on practice. Level one begins to link theories to real contexts, while level two involves student engagement in practical observations. Level three integrates interdisciplinary learning, real-life connections, and hands-on learning experiences (MoEYS 2022).

Despite these STEM initiatives, upgrading teachers' formal qualifications has become the primary focus in Cambodia. In principle, USS teachers must hold a bachelor's degree in their specialised subject and attend a one-year teacher education programme (TEP) at the National Institute of Education (NIE) (BA+1 formula), implemented between the academic years 1995-1996 and 2021-2022 (NIE 2025). However, STEM disciplines in HE remain subject-isolated, theory-oriented, and teacher-centred. Inquiry-based learning (IBL) and debates are often absent from classrooms (Phirom et al. 2021). The teachers' background in STEM pedagogy largely relies on the training at NIE, rendering the STEM qualification inadequate. As highlighted in the Cambodia Secondary Education Blueprint 2030, despite having sufficient STEM materials in RSs, many teachers still could not utilise them due to their lack of knowledge regarding material operations and STEM instruction (MoEYS 2021). To strengthen teacher capacity, NIE has recently revised its TEP from BA+1 to BA+2, with a stronger emphasis on STEM within the science disciplines (NIE 2025). This reform might aim to extend the learning opportunities for pre-service teachers, potentially drawing inspiration from other countries such as Australia (Treagust et al. 2015), Singapore (Tan, Koh, and Lim 2021) or Macau (Wei 2019) that offer four-year teacher education programmes.

Over the past ten years, Cambodia has launched two phases of the Upper Secondary Education Sector Development Program (USESDP), funded by the Asian Development Bank (ADB), to improve USSs from 2017 to 2022 (USESDP-1) and from 2018 to 2025 (USESDP-2). Under this programme, the Science and Technology Project in Upper Secondary Education (StepUP) specifically targets enhancing STEM education in 50 RSs, 101 NWs, 4 general technical high schools (GTHS), and 103 NSs (ADB 2022). Cambodia has also received support from the World

Bank (WB) to implement the General Education Improvement Project (GEIP), which focuses on primary-secondary transition, student retention, school leadership, professional development, and other areas (MoEYS 2021). Despite these policy efforts, empirical studies on STEM teacher professional development remain limited. To further illuminate this gap, the next section reviews previous research on STEM-related CPD both internationally and within Cambodia.

2.4. Previous studies on CPD in STEM

Teacher CPD has increasingly been recognised as a leading strategy to assist teachers in keeping pace with the emerging trend of STEM within global education systems. This recognition can be reflected in the growing number of research publications on teacher CPD in STEM over the past twenty years. For instance, a systematic review (Huang et al. 2022) identified 76 studies in the Web of Science database, published between 2006 and 2020, across various regions, including North America (49 articles), Asia (18 articles), Europe (5 articles), and other locations (4 articles). Notably, the number of publications surged significantly only in 2017, jumping from 10 to 39 by 2020. Similarly, another review (Surahman and Wang 2023), utilising data from the SCOPUS database, found 44 studies on STEM CPD published between 2018 and 2022. This study also indicated that most of these publications originated in North America (47 percent), with the United Kingdom, Australia, and China contributing only 6.7 percent each. These reviews, however, starkly highlight a lack of evidence on CPD in diverse geographical regions, raising concerns about the availability and quality of programmes designed to enhance teachers' capacities in STEM education worldwide.

Generally, most CPD programmes appear to place a stronger emphasis on pedagogies and the use of technology in teaching STEM disciplines, which might aim to address the paucity of such training areas during teacher education programmes (Huang et al. 2022), although some programmes did not explicitly address this content relevance (Hubers, Endedijk, and Van Veen 2022). Teacher engagement in activities, such as designing lesson plans, collaborating with peers, demonstrating teaching methods, and reflecting on practices, has been incorporated into many CPD programmes (Huang et al. 2022; Surahman and Wang 2023; Hubers, Endedijk, and Van Veen 2022). However, some issues also persist. One is about the sustainability of STEM CPD, considering most CPD programmes as single events, while school leadership engagement remains limited (Surahman and Wang 2023). Coherence of CPD with the school context and teachers also poses another concern, as highlighted in another review study (Hubers, Endedijk, and Van Veen 2022). Furthermore, the evaluations of effective CPD programmes should move beyond self-assessment to product-based or performance-based assessments (Huang et al. 2022).

In Cambodia, research on teacher CPD in STEM appears to be absent at this moment, potentially due to its recent emergence in this context. This lack of evidence leaves more doubts on the opportunity and quality of CPD programmes, which have an impact on STEM education. At this juncture, the limited existing studies shows that opportunity for teachers to participate in CPD programmes remains low. A study by No and Heng (2017) on all subject teachers at different school levels has revealed that teaching requires ongoing trainings; however, many teachers still lacked access to consistent capacity building programmes as that over half of the surveyed teachers were unable to join the majority of CPD programmes. Normally, only principals, vice principals, and senior teachers joined workshops (King 2018). Even when CPD activities are planned, some teachers still cannot attend them, due to various constraints, such as road conditions, insufficient budget, time limitations, and holidays (Berkvens 2009). Research also showed that roughly half of the teachers benefited little or not at all from the several CPD programmes (No and Heng 2017), highlighting the irrelevance and quality concerns of the

CPD training. This issue can occur because sometimes CPD programmes at the school level are determined by the provincial office, where some officials may have a limited understanding of the school's and teachers' needs. Additionally, the officials' (trainers') knowledge and expertise in pedagogical approaches may justify the above issue (King 2018).

3. Research methodology

The study adopted a mixed-methods approach, utilising an exploratory sequential design. It began with qualitative data collection to explore the research topic in depth, followed by the quantitative strand to generalise the qualitative findings (Creswell 2014; Gillespie, Glăveanu, and de Saint Laurent 2024). Guided by this approach, our analysis fell into two aspects: first, mapping out CPD accessibility, and second, critically examining the effective characteristics of the CPD programme, specifically the STEM workshop, informed by the qualitative data. Furthermore, the insights from the initial qualitative phase informed the design of the quantitative instrument. Below is the description of each research strand.

3.1. Qualitative research strand

To collect data, we developed three interview protocols for key informant interviews (KIIs), school principals, and teachers. These instruments were created based on the conceptual framework of CPD and the literature review, focusing on STEM teaching, CPD opportunities, and CPD characteristics. The instruments were subsequently reviewed by peers in our research centre. The study began with conducting KIIs with relevant stakeholders. Expert sampling was initially employed to recruit participants who had a strong understanding of the issues, including representatives from MoEYS, such as the Teacher Training Department (TTD), the Department of Secondary Education, the CPD-Mentoring Office, and the National Institute of Education (NIE), as well as development partners (DPs), including UNESCO, ADB, KOICA, KAPE, and the World Bank.

Next, we employed a purposive sampling method to recruit schools and participants from five provinces and Phnom Penh city. First, we selected schools with different characteristics, such as RSs, NWs, and normal schools (NSs) in diverse geographical locations, including Steung Treng, Pursat, Banteay Meanchey, Kampong Thom, Kampong Cham, and Phnom Penh. This selection aimed to examine how teachers from different school types and locations perceived the usefulness of CPD programmes they had experienced. In each province, we selected three schools: one RS, one NW, and one NS, along with one school principal and two STEM teachers from each school, taking subject and gender diversity into account. We also interviewed directors (or representatives) of the Provincial Department of Education (PoE) to gain comprehensive insights into STEM education and CPD activities in each province.

Our fieldwork lasted from December 2, 2024, to January 13, 2025. We met with 10 representatives from DPs, 12 from MoEYS and NIE, 9 PoE personnel, 21 school principals (or representatives), and 37 subject teachers (see Table 2). The interviews, conducted individually, in pairs, or groups, lasted approximately one and a half hours. The data were transcribed and coded using NVivo software version R1 (2020). We employed both predetermined and emerging theme coding strategies during the coding process. Examples of the coding themes included "types of CPD," "context focus," "CPD activities," "context coherence," or "individual coherence." The data were ultimately reported in themes, guided by our research objectives and frameworks. Each participant was assigned a code (e.g., RT01, RT02, NT01, NT02) to conceal their identity. The letter 'F' or 'M' was added to each code, such as RT01F and NT02M, to indicate gender: female and male.

Table 2: Interviewed participants' demographics (n=89)

Items	DP (n=10)	MoEYS (n=7)	NIE (n=5)	PoE (n=9)	SP (n=21)	ST (n=37)	Total (n=89)
Gender							
Male	8	6	5	9	16	20	64
Female	2	1			5	17	25
Subject specialisation							
Math						7	7
Physics						9	9
Chemistry						6	6
Biology						6	6
Earth Science						6	6
ICT						3	3
School type							
RSs					8	11	19
NWs					6	14	20
NSs					7	12	19

3.2. Quantitative research strand

To proceed with the quantitative data collection, we constructed a questionnaire based on the conceptual framework of CPD and the qualitative data obtained in the previous phase. The questionnaire included four main sections: Participant demographics, types of CPD, CPD characteristics, and STEM practice. It was reviewed by quantitative experts and subsequently prepared on the Kobo online platform. The questionnaire was piloted with STEM teachers at a public high school in Phnom Penh on 12 March 2025. This study employed a multi-stage sampling approach, starting with the selection of 11 provinces and Phnom Penh[2] (see Appendix 1), followed by schools, and then recruiting teachers for participation. Within each province, four types of schools were randomly selected – RSs, NWs, NSs, and non-StepUP schools[3] – to capture variations in CPD access and STEM practice. This selection is guided by the concept of equity (Levinson, Geron, and Brighouse 2022), referring here to the provision of different CPD to schools and teachers with varying needs, so that they strive for equal excellence. A total of 60 out of 581 schools participated in the survey. The data collection took place from 17 March to 2 April 2025.

The data were analysed using STATA software. Descriptive statistics were used to summarise CPD participation, frequency, and characteristics across demographic groups. To explore predictors of CPD participation, the ordered logistic regression analysis was employed. The raw variable on workshop participation was captured as a numeric count. However, the continuous

2 Phnom Penh, Kampong Cham and Banteay Mean Chey were selected in both data collection phases, yet different schools participated in the study except one school in Banteay Meanchey.

3 There are three types of USSs in the StepUP project: RSs, NWs, and NSs. Other USSs are non-StepUP schools.

count did not offer a meaningful interpretation. Therefore, for substantive interpretability, the count was converted into ordered participation bands (0 / 1–3 / 4–6 / >6). This created an outcome that is ordinal in nature. This approach is also consistent with other dependent variables in the study, which are measured in categorical/ordered forms, including private tutoring engagement, gender, position, specialisation, teaching track, levels of education, school type, and location. Thus, ordered logistic regression was selected because the dependent variable is ordered rather than interval-scale, and because this model aligns with the substantive interpretation of "higher levels of workshop participation. All statistical analyses were conducted using Stata 17.0. Significance levels were set at $p < .1$ for marginal effect and $p < .05$ for significant effect.

Table 3 shows the demographics of the teachers who responded to our national survey. The data indicates that many participants were male teachers (67.83 percent). This might be affected by the limited number of female STEM teachers in the USS. Age distribution shows that 50 percent of respondents were within the 31–40 age group, while those under 30 and those aged 41–50 each represented approximately 20 percent. The majority had a bachelor's degree (77 percent), with only 15 percent holding a master's degree. The number of teachers and technical team leaders was comparable, suggesting that both roles had similar opportunities for involvement. Among the six STEM subjects represented, mathematics teachers made up the largest group at 20.7 percent, followed closely by teachers of physics, chemistry, and biology, who had similar participation rates. Earth science and ICT teachers constituted a smaller segment, likely reflecting their lower representation in many schools.

The majority of the teachers taught in the science track, which was our target group, and around half of all participants were engaged in offering private supplementary tutoring. The classification of school types indicates that 51.68 percent of teachers were from non-StepUP schools, with 28.43 percent from RSs, NWs, and NSs, each accounting for roughly 10 percent. However, NWs and NSs within the StepUP project show minimal disparities and may be grouped together. While these data suggest a biased distribution, they likely represent the actual population, as non-StepUP schools outnumber RSs and others in the StepUP project in Cambodia. Additionally, in our efforts to promote diversity, approximately 37.16 percent of teachers from rural schools were also included in the survey.

Table 3: Surveyed participants' demographics (n=401)

Items	Frequency	Percentage
Gender		
Male	272	67.83
Female	129	32.17
Age group		
Below 31	70	17.46
31–40	215	53.62
41–50	79	19.7
Over 50	37	9.23
Level of education		
Associate degree or lower	28	6.99
Bachelor's degree	310	77.31
Master's degree	60	14.96
None of the above	3	0.75

Position		
Teacher	218	54.36
Deputy technical team leader	38	9.48
Technical team leader	128	31.92
School principal	17	4.24
Specialisation		
Math	83	20.7
Physics	66	16.46
Chemistry	68	16.96
Biology	69	17.21
Earth science	48	11.97
ICT	39	9.73
Social science	28	6.98
Teaching track		
Science	316	78.80
Social science	85	21.20
Private tutoring		
Yes	222	55.36
No	179	44.64
School type		
RSs	114	28.43
NWs	42	10.47
NSs	38	9.48
NSs (Non-StepUP)	207	51.62
School location		
Urban	252	62.84
Rural	149	37.16

3.3. Reliability

To establish the credibility of the findings, our team employed various strategies such as data triangulation and member checking (Korstjens and Moser 2018). First, we analysed diverse data sources from different stakeholders, ranging from the national level to individual schools and other DPs. Using multiple sources allowed us to incorporate different perspectives into the data analysis, resulting in more robust evidence and a solid conclusion on the topic. In collaboration with the Department of Policy, MoEYS, we also held a validation workshop on 28-29 July 2025, in Kampong Cham Province, involving 48 school principals and teachers from schools representing various regions of Cambodia. During the workshop, participants anonymously shared their views on the key findings via a brief Likert-scale survey before engaging in group discussions centred around three themes: CPD opportunity and equity, quality of STEM workshops, and recommendations. They responded by indicating their agreement or disagreement or by adding comments on sticker notes, which they then placed on flipcharts. Afterwards, a representative from each group presented their feedback to the entire audience, while our assistants took notes of the verbal presentations. The workshop results were generally positive and constructive, along with a few suggestions for improvement.

4. Findings

4.1. CPD opportunity and equity

4.1.1. STEM teachers' accessibility to CPD

In this study, CPD refers to the various ways in which STEM teachers pursue ongoing professional development to enhance their knowledge and teaching practices. This includes formal pathways such as academic degree programmes, as well as informal efforts like self-study. It also encompasses participation at various levels, from national to cluster-based CPD, school-based initiatives, as well as individual efforts, including personal reflections, reading, and discussions. Our findings indicate that Cambodian STEM teachers have participated in various CPD programmes, including workshops, in-school training, technical meetings, formal academic coursework, and self-directed study.

Workshop

Based on our interviews, at the national level, CPD workshops, typically conducted over three to five days, focused on scientific experiments, STEM education theories, and instructional strategies (See quotes below). These workshops were held in provinces such as Takeo, Kampong Speu, Kampong Chhnang, and Kampong Cham. The participants generally identified MoEYS or the National Institute of Education (NIE) as the primary providers of these programmes, occasionally in collaboration with Non-Governmental Organisations (NGOs). Nevertheless, some respondents also expressed uncertainty regarding the specific organisers. KIIs further underscored the collaborative efforts of various NGOs and agencies, such as VSO, JICA, KOICA-EMCAST, and KAPE, together with donors (e.g., ADB, UNICEF, and World Bank), in supporting STEM education in Cambodia.

> Experimental workshops are held fairly regularly—about once a year—but occur in other provinces. Only science teachers are invited, as the focus is on teaching techniques and conducting experiments. These sessions are organised by the ministry [MoEYS]. (A female earth science teacher, RT06F)

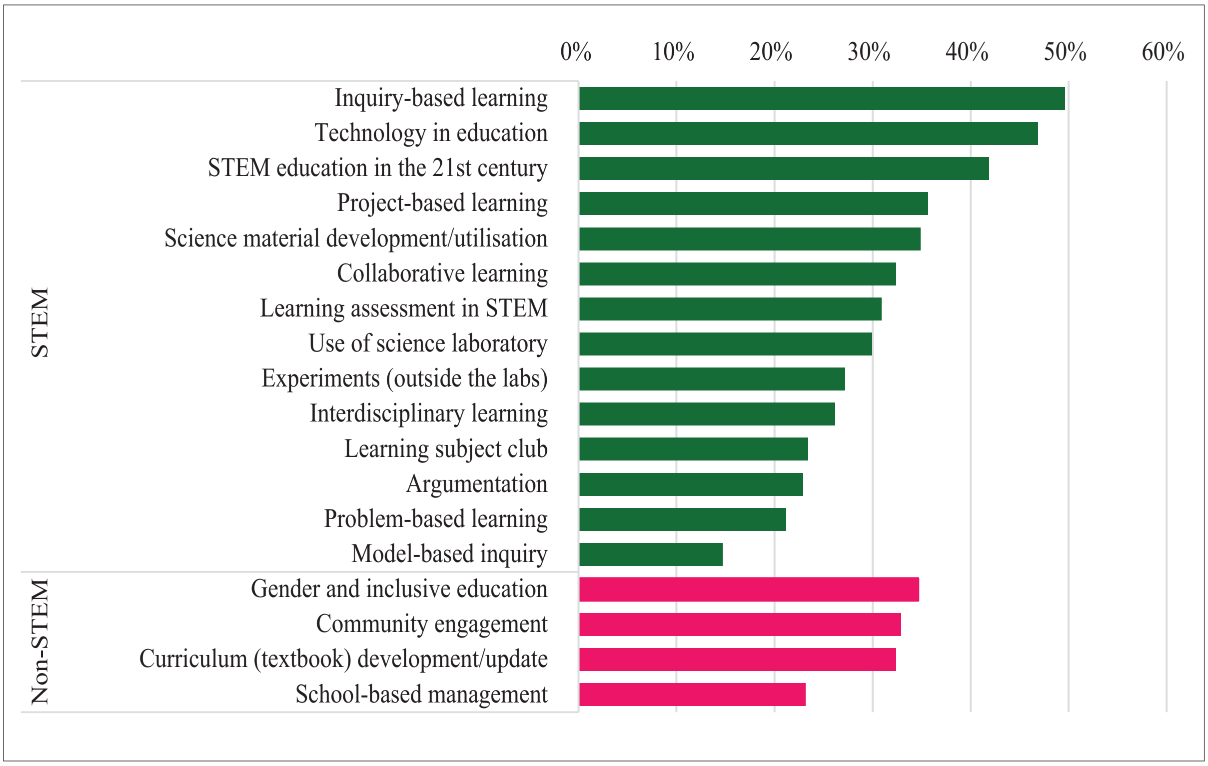
> We joined a short training workshop on STEM. It was not about experiment, but about how to interlink between subjects and lessons, for example, linking math to physics or physics to chemistry. (A male math teacher, NT05)

Our quantitative data also indicate that 79 percent of the surveyed teachers have attended at least one training workshop since the start of their teaching careers, with 67 percent doing so in the last five academic years and 48 percent in the most recent academic year (2023-2024). Teachers from RSs, followed by NWs and urban areas, were more likely to have participated in workshops than those from other backgrounds (see Figure 1). However, approximately 50 percent of the sampled teachers (n=401) received training in STEM topics such as IBL, technology, and STEM theory. This was followed by training in PjBL, scientific material operation, assessment in STEM, experiments, and interdisciplinary learning, which each accounted for between 20 percent and 30 percent of the training (see Figure 2). The majority of those workshops were conducted outside the province (50.19 percent), followed by those held within the province (20.45 percent) and at the teachers' own schools (19.7 percent). The primary providers of the last training attended were the MoEYS (39.41 percent) and NIE (26.02 percent). Regarding the selection for training, most teachers were appointed by their school directors (56.88 percent) and training providers (30.48 percent) (see Appendix 2).

Figure 1: Workshops received by groups (n=401)

Items		N	Ever Attended	Past 5 Years	Past Year
All		401	79%	67%	48%
Gender	Female	129	73%	63%	44%
	Male	272	82%	69%	50%
Position	Teacher	218	72%	62%	46%
	TTL	166	87%	72%	49%
	Others	17	82%	82%	59%
School	Resource	120	97%	95%	75%
	Network	44	81%	81%	55%
	Normal	51	66%	32%	18%
	Non-STEPUP	186	71%	56%	37%
Location	Rural	252	71%	55%	36%
	Urban	149	92%	88%	68%

Figure 2: Topics of workshops in the last 5 years (n=401)



Cluster and school-based CPD

The qualitative data show that instances of cluster-based CPD programmes – where schools within a network collaborate or share training opportunities – were notably rare. For example, a male chemistry teacher (RT05M) said, "*Last year, a network school also came to ask us to help with chemicals and experiments*." In another case, network schools were invited to attend training sessions hosted by a resource school. However, participation was minimal, and engagement was limited. As one male vice principal (ND03M1) recounted, "*Two teachers and I went there, but we did not have a chance to do any experiment tests. We just listened* *to what the ministry officials had to say*." School-based CPD programmes are more common but consist of short-duration training sessions and technical meetings. The former, primarily organised by MoEYS (as they were unsure about NGOs' involvement), is designed to enhance teachers' competencies in STEM instructional methods and the operation of STEM-related materials. These training sessions, usually spanning one to two days, are tailored to individual schools' specific needs and contexts, particularly RSs or NWs (See a quote below). In this case, all teachers at the targeted schools were given the opportunity to participate.

> Last year, a trainer from NIE came to our school and taught us about PjBL. Teachers from various subjects, such as math, chemistry, physics, etc., joined the training. (A female earth science teacher, RT01F1)

Technical meetings, typically held for two or three hours, represent the most frequent form of school-based CPD and gather teachers within their respective subject areas at least once a month. The quantitative data also confirms this qualitative finding, highlighting that 53.12 percent of participants have attended at least 4-9 technical meetings, with 27.18 percent more than 10 times, in the last academic year (see Table 4). Notably, technical meetings appear to be more frequently held at RSs and rural schools. However, while not solely focused on STEM education, these meetings provide a platform for addressing a broad range of pedagogical and administrative matters, such as new academic-year planning, new teaching techniques, instructional alignment across classes, student learning challenges, and other ongoing challenges in the school context, consistent with the quantitative data (see Figure 3). As a physics teacher (NT06M1) explained, "*It depends on each month. Sometimes, we focus on sharing the teaching techniques, and sometimes, we focus on the students' performances*."

Both qualitative and quantitative data also share a similar pattern in that a few teachers share the knowledge they have acquired from workshops with their respective subject groups. The survey shows that 62 percent of moderately frequent occurrences of such knowledge sharing take place, with higher rates at RSs (see Table 4). However, this form of dissemination, often called the *cascade model*, was perceived as irregularly effective, consistent with previous studies in Cambodia (King 2018; Wedell 2005). Several challenges were identified, including teachers' limited capacity to disseminate knowledge and the lack of interest among both teachers and students (see quotes below). This finding was also emphasised during the validation workshop, as some teachers cited teachers' commitment as the key factor. Additionally, the absence of reinforcement from the management team might contribute to the scarcity of this sharing, as revealed in an expert group interview "[…] there is no monitoring system and those responsible have the freedom to not implement the policy. In terms of management, when a policy is created, there should be enforcement, such as incentives for those who do well and punishment for those who do not implement it. (ED1)". Other forms of school-based CPD, such as class observations, peer or team teaching, and demonstrations, are reported to be moderately frequent, as shown in the survey (see Figure 4).

> We discussed the teaching and training programmes that were provided. We offered them documents we received from training programmes so that other teachers can review and practice on items based on the documents. If we have any questions, we can ask one another during the technical meetings. (A female chemistry teacher, NT01F1)

> We tried, but they said it was difficult. They said they did not understand, and it was difficult, so they did not do it. We can teach students by ourselves, but it is hard to explain it to them because of our limited knowledge. (A male physics teacher, NT05M2)

Table 4: Technical meetings and knowledge sharing in the 2023-2024 academic year (n=401)

Freq.		**All (n=401)**		**Location**		**School type**			
				Urban	**Rural**	**RSs**	**NWs**	**Ns**	**Non-StepUP**
		%	**%**	**%**	**%**	**%**	**%**	**%**	
Technical meetings	0 time	25	6.23	8	92	4	32	0	64
	1-3 times	54	13.47	37.04	62.96	27.78	12.96	9.26	50
	4-6 times	63	15.71	50.79	49.21	31.75	11.11	3.17	53.97
	7-9 times	150	37.41	34	66	26.67	8.67	17.33	47.33
	More than 10 times	109	27.18	40.37	59.63	34.86	6.42	4.59	54.13
Knowledge sharing	Never	31	7.73	32.26	67.74	12.9	12.9	9.68	64.52
	Rarely	42	10.47	33.33	66.67	19.05	2.38	11.9	66.67
	Sometimes	155	38.65	40.65	59.35	30.97	9.03	10.97	49.03
	Often	92	22.94	46.74	53.26	42.39	9.78	9.78	38.04
	Always	51	12.72	33.33	66.67	25.49	11.76	7.84	54.9
	None	5	1.25	0	100	20	0	0	80
	Missing	25	6.23	8	92	4	32	0	64

Figure 3: Topics of technical meetings (n=376)

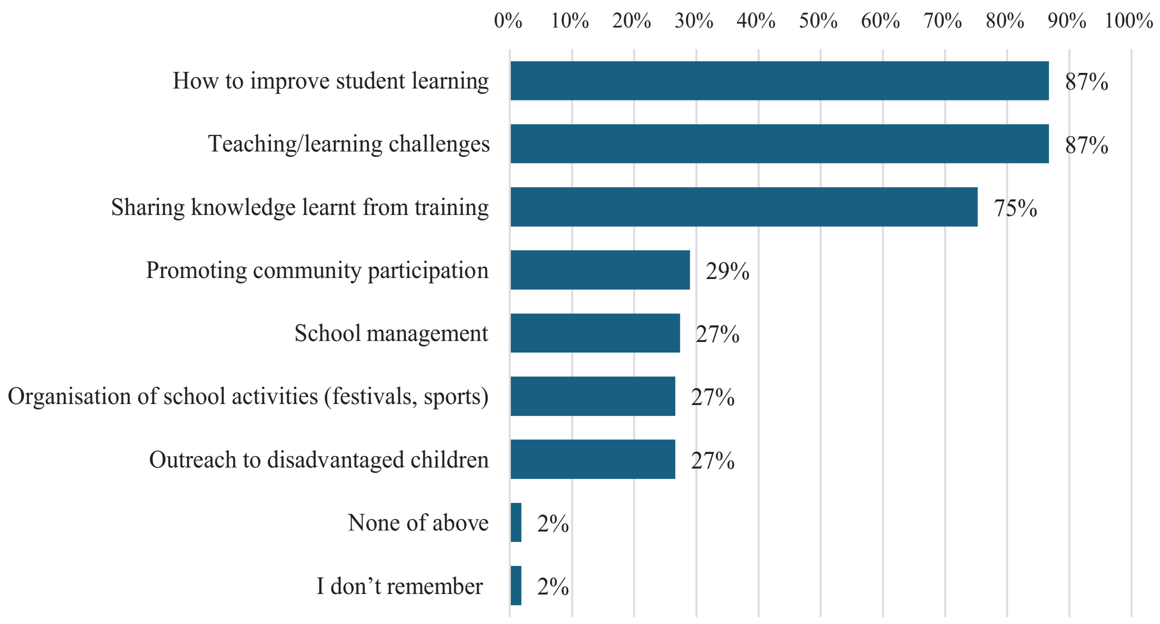
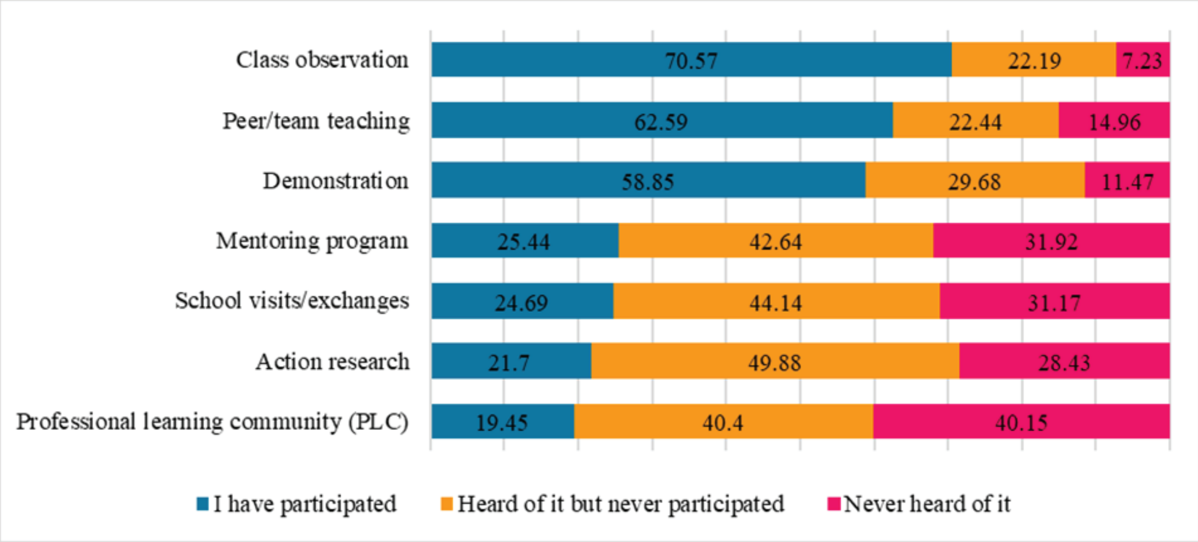


Figure 4: Other school-based CPD activities (n=401)



Self-directed learning and others

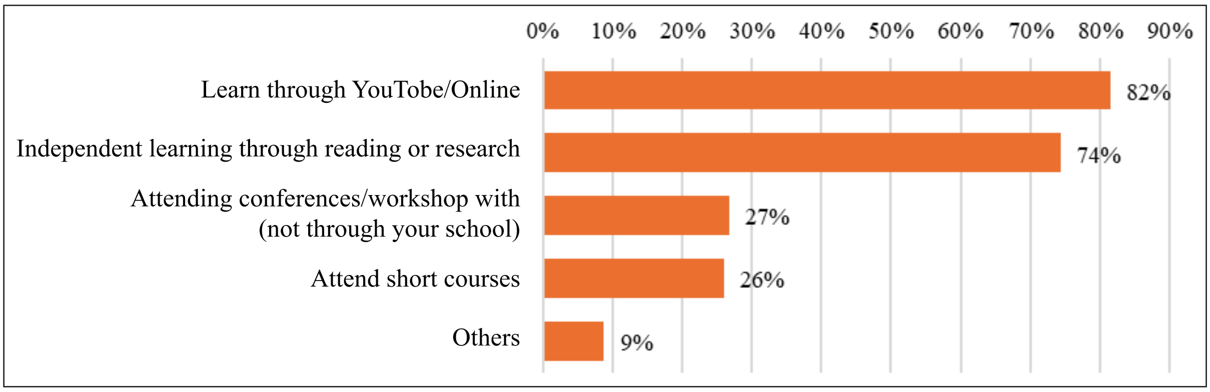
The qualitative data indicate that self-directed learning pursuits exist in the form of formal academic programmes (e.g., BA or MA) and personalised learning activities. Some teachers have pursued further studies, utilising their financial resources or university-funded scholarships. Our survey shows that half of the participants have pursued a formal degree after becoming teachers. Of those (n=201), 61 percent undertook a bachelor's degree and 32 percent a master's degree. Additionally, 17 percent of the sample (n=401) participated in a formal degree programme under the GIEP project (see Table 5). This means that, according to our qualitative data, teachers whose schools participated in the GEIP project have the opportunity to enrol in the Teaching Upgrading Programme offered by a leading national university in Phnom Penh. Those teachers engaged in online learning sessions on weekends while occasionally attending in-person classes in Phnom Penh. The programme covered all expenses related to travel and accommodation. However, this academic initiative, along with other self-funded programmes, did not concentrate on STEM education but rather encompassed a broad spectrum of educational management and teaching-learning activities (See a quote below). Both qualitative and quantitative data share a similar pattern that personalised learning activities, such as reading books and exploring lessons on websites or YouTube, have appeared to be common (see Figure 5) and proven effective. Teachers were able to acquire new knowledge and skills that match with their interests and needs. However, language barriers, particularly with English-language videos and written documents, appear to be challenging for some teachers, based on our interviews.

> Basically, they just taught us about teaching techniques, as required by the GIEP project, including how to assign classwork to students and motivate them to engage in self-learning. Moreover, they also taught us how to use Google Classroom, for example, to assign work and install the application. (A female biology teacher, GT02F)

Table 5: Pursuing a higher degree after becoming a teacher (n=401)

Items	N	Freq	%
Teacher upgrading programme	401	68	17
Obtain higher degree	401	201	50
Associate degree	201	3	1
Bachelor's degree	201	122	61
Master's degree	201	64	32
None of above	201	12	6

Figure 5: Informal self-study activities (n=401)



Our interviews reveal that action research, while theoretically advocated for schoolteachers, remains largely unfamiliar to many teachers in Cambodia. Very few have heard of research or action research during their university or teacher training programmes. As one female teacher (NT06F1) remarked, "*But I heard about this [action research] since I studied at a private university. There was one teacher who specialised in research*." Some teachers referred to conducting experiments in their subject studies or searching for more information. This perception of action research may align with that referenced by 21.7 percent of teachers in our survey (see Figure 4). A female earth science teacher (RT05F) stated, "*We only follow the basic textbooks. Sometimes, we don't have time to research or follow other things*." Another teacher was uncertain, attributing this to the fact that his education was completed long ago. During his STEM project implementation, an expert interviewee highlighted that only 3 out of 83 teachers were aware of action research, and that awareness may correlate with teachers' age and graduation year. He emphasised the need for revisiting action research in teacher training programmes to better equip pre-service teachers with essential research skills (see the quote below from D05). However, this finding is not unusual, as the research culture in Cambodia continues to be relatively underdeveloped (Heng et al. 2023; Eam 2015).

> … when I spoke to the teachers at one particular project that I did, I've got 83 teachers, for example, and I asked them whether they'd heard of action research, which is one of the big things that everybody talks about being important to try and improve things. And three teachers out of 83 said they'd heard of action research. (DO5)

The findings presented above indicate that Cambodian teachers can access CPD programmes on STEM education, primarily from MoEYS, in the form of national workshops and in-school training. In this regard, considering its dominant role, the STEM workshop will be fully elaborated in the following sections. School-based CPD, such as technical meetings, classroom observations, peer teaching, and class demonstrations, can be frequently visible in many schools. Personal self-study efforts tend to concentrate on a broader spectrum of education. However, since STEM education is still relatively new to teachers, individual and peer teaching pursuits in STEM may be limited, depending on the individuals' capabilities and commitments. Other forms of CPD, such as mentoring and professional learning communities (PLCs), are observed on a very small scale. KAPE has established a mentoring programme to train mentors to support teachers in New Generation Schools (NGSs) and potentially other resource schools. VSO focused on PLCs, inviting cluster teachers to attend a series of both physical and online sessions. However, this type of CPD was project-based and has since concluded.

4.1.2. Equity in access to CPD

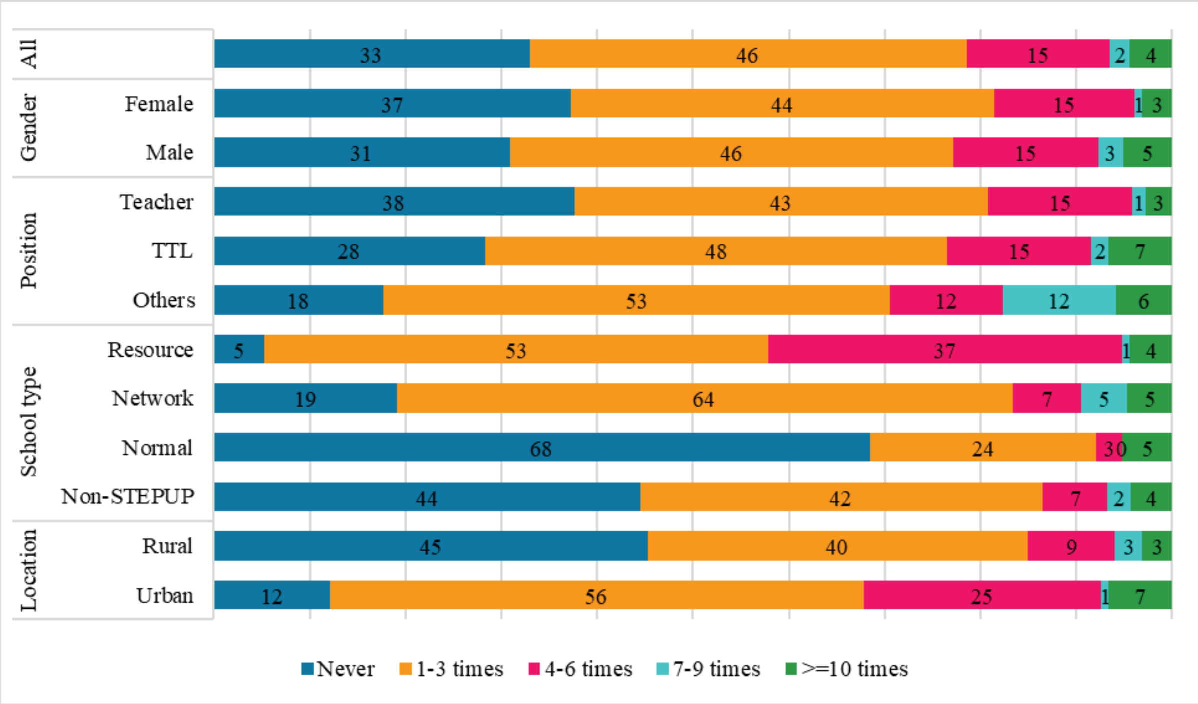
Our qualitative analysis shows that accessibility to STEM CPD, particularly workshops, varies among school types and teacher positions. Many teachers from the six RSs, followed by some NWs, have received noticeable training on STEM education. Some teachers attend at least one STEM-related workshop per year (See a quote from RT01M below). However, it is essential to note that technical team leaders are more frequently invited to join workshops or training, as they are expected to share their knowledge with their team upon returning from the training. Additionally, short training sessions are often conducted within their school campus. Unfortunately, such opportunities appear less common for teachers at normal schools (see quotes from GT02F and GT06F below). They may sometimes attend training on other aspects of school or student learning improvement. This evidence is consistent with data obtained from an expert group interview, revealing that Cambodia's effort to train teachers on STEM education remains exclusive, only available to some schools, particularly 50 RSs and 87 NWs. This finding highlights the limited access to STEM education in different schools and possibly locations.

> As a technical group leader, I have joined short courses [workshops] every year, about two to three times per year. However, there aren't any this year, 2024. …. I joined courses in Kampong Cham, Prey Veng, Kampong Chhnang, and more. (A male math teacher, RT01M)

> But personally, I have been teaching for 12 years already and have never received any workshops to upgrade my capacity and skills. (A female biology teacher, GT02F)

> I've only attended two workshops after the CAP project: one in 2015 in Skun on creating a new study programme, and another in 2020 in Kampong Cham, where they taught us about the 5E model and compass. (A female biology teacher, GT06F)

Figure 6: Number of workshops attended within the last 5 years (n=401)



Our survey reveals that there is no difference in workshop participation based on gender or position; yet, the parity is more pronounced by school type and location (see Figure 6). Around 53 percent of teachers at RSs and 64 percent at NWs have received workshops between 1-3 times in the past five years, apparently higher than those at NSs, where 68 percent at NSs and 44 percent at NSs in non-STEP-UP had no workshop training. Additionally, 37 percent of teachers at RSs attended workshops 4-6 times, which is apparently higher than the rate for other school types. Around 45 percent of teachers at schools in rural areas reported no attendance at the workshop, whereas this lack of opportunity was only 12 percent at schools in urban locations.

It is worth noting, however, that among the 401 respondents, only 249 (about 62 percent) reported having attended a workshop with at least one of the STEM topics above in the last 5 years. An ordered logistic regression analysis was conducted to examine how various background variables – such as gender, age group, and position – affect the probability of teachers attending STEM workshops (see Appendix 3). The analysis showed that no statistically significant relationship was found among gender, age groups, and the learning track in STEM workshop attendance (Number of observations = 401; Wald χ^2 (21) = 157.69, $p < .001$; Pseudo R^2 = 0.18). However, the differences among various factors, such as tutoring engagement, education level, position, school type, and school location, appeared to be statistically significant. For example, teachers offering private tutoring are less likely to frequently attend workshops compared to their non-tutoring peers (B = -0.51, $p <.05$), suggesting that tutoring may limit CPD opportunities.

Additionally, teachers holding bachelor's and master's degrees are more likely to attend workshops than those with less education (Bachelor: B = 0.73, $p <.1$; Master: B = 1.05, $p <.1$). Deputy technical team leaders also have higher odds of attending workshops than teachers (B = 1.31, $p <.001$). Teachers at NWs, NSs, and non-STEP-UP NSs attend workshops less frequently than those in RSs, with the strongest negative association at NSs (B = -2.67, p <

0.001). Lastly, urban teachers attend workshops more often than rural teachers, with marginal significance (B = 0.74, p = 0.052).

4.2. Effectiveness of STEM workshop

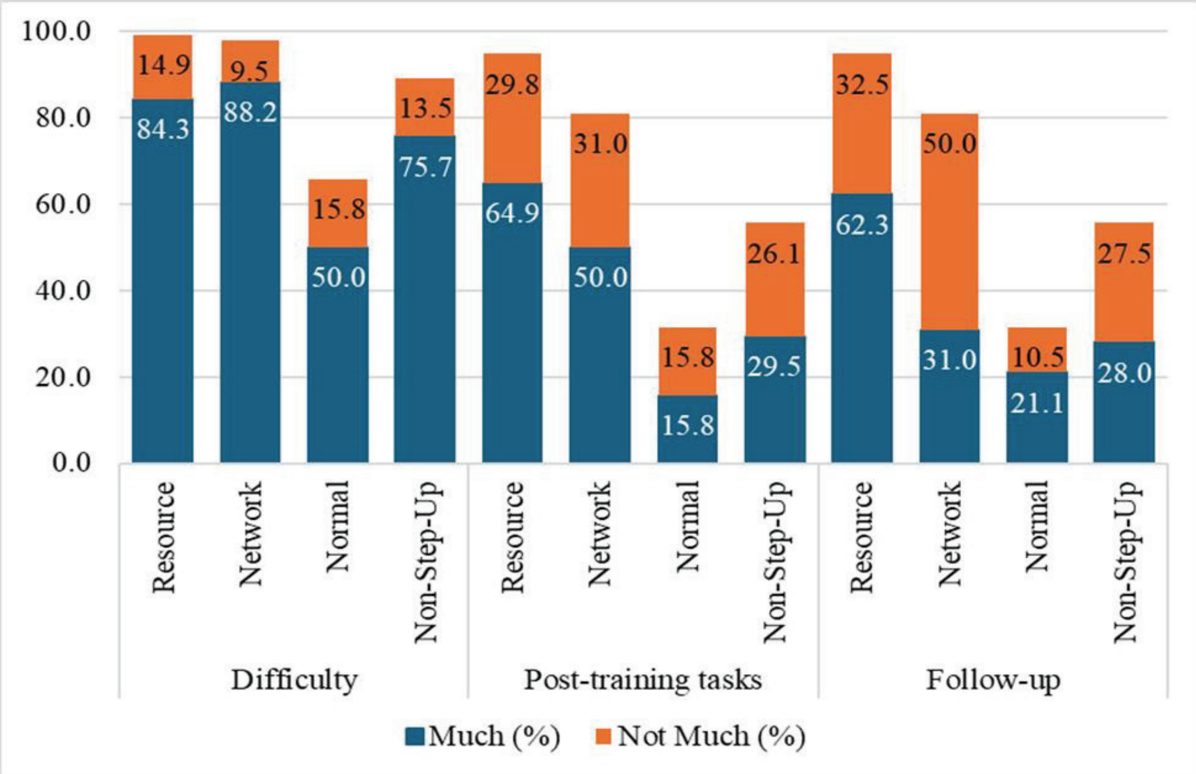
4.2.1. Contents and activities

The qualitative data indicate that STEM workshops prioritise STEM pedagogical knowledge (STEM-PK), whereas in-school training emphasises scientific material utilisation, occasionally touching on STEM-PK. Participants, despite some forgetting the content, recalled many examples of STEM training content, including core concepts of STEM education, such as interdisciplinary learning, STEM frameworks, and STEM instructional levels, as well as teaching approaches, such as Inquiry-based learning (IBL), Project-based Learning (PjBL), Problem-based Learning (PBL), constructivism teaching, student-centred classrooms, and flipped classroom (also see Figure 2). These examples demonstrate that STEM CPD programmes aim to provide teachers with relevant STEM knowledge and various teaching methods, although the actual classroom practices still permit further investigations. In-school training assists teachers in using experimental materials or equipment, enabling them to incorporate these into the aforementioned teaching methods. However, although not emerging during the interviews, our document analysis raises doubts about the scope of the content, which appears to be overwhelming. For example, a participant shared with us a 185-page training manual on PjBL for a few-day training. It covers major components, including guidelines for training, theory, sample practice, and evaluation. This point was also discussed during the validation workshop, with some agreeing and others rejecting this evidence, citing individual teachers' commitment to learning and applying their knowledge. This disagreement further emphasises the importance of individual differences in CPD.

> They demonstrated once, then allowed us to conduct the experiments ourselves. We selected lessons from a textbook provided and transformed them into STEM-integrated lessons. We were divided into groups of four to create slides and present our findings. (A female biology teacher, RT06F)

> When I joined the workshop, our trainers taught us about the topic. Once they finished it, both the science [lesson] and the lesson plan. They let us do the presentation or actual practice. (A male physics teacher, NT02M)

Figure 7: Workshop activities (n=269)



Notes: RSs (n=108); NWs (n=34); NSs (n=12); Non-STEP-UP (n=115)

Teachers have also engaged in various learning tasks during workshops, including group work, lesson design, and lesson implementation (see some quotes above). They were assigned to different groups based on their specialised subjects and teaching grades. They collaborated to create a new lesson plan by selecting a topic from a public-school textbook. In this way, teachers can support one another in applying what they have learned from the training. They could also get to know each other and exchange ideas about their school contexts, as they came from different schools. Afterwards, some groups were chosen to conduct a teaching demonstration for all the workshop attendees. Training assessments were also carried out before and after the training to evaluate the attendees' understanding of the topic. However, there is a discrepancy regarding this evaluation system. Some teachers appreciate seeing their scores regarding their knowledge of the training content, allowing them to reflect on their understanding before and after the training (see teacher quotes below). From the training provider's perspective, some teachers might take a neutral stance by reporting low correct responses, hoping to receive more training (see a quote from ED1 below). Yet, our survey revealed that many teachers, particularly those at RSs (84 percent) and NWs (88 percent), found the workshop content to be somewhat challenging (see Figure 7). This potentially suggests a higher engagement or more advanced content delivery of workshops at RSs and NWs.

> For the first time, I failed the test since I did not know much about PjBL. So, the score was not good. However, after the training, I gained a better understanding of the PjBL. The test was like multiple-choice questions, and we had to select the correct answers. After that, I got a better score. (A male physics teacher, NT06M1)
>
> From what I've seen when conducting the post assessment, many teachers still don't understand. I think they are being lazy, saying they don't understand, so that trainers can train them over again. And even after training, they still don't follow. (ED1)

The qualitative data show that some teachers reported sharing their practice in a follow-up Telegram group. This finding is consistent with the data from the national survey (see Figure 7), indicating that 64.9 percent of teachers at RSs and 50 percent at NWs received post-training tasks, and 62.3 percent at RSs and 31 percent at NWs had some follow-up activities, which is higher than for other school types. However, based on our interviews, it seems they did not receive any concrete observations or feedback from the trainers, leaving them unsure about the effectiveness of their practice (see a quote from NT05 below). In this context, STEM CPD resembles a one-time event, lacking follow-up meetings or sessions that would enable teachers to reflect on their practice and obtain feedback from peers and experts. Furthermore, although teachers were encouraged to implement new knowledge and skills in the classroom, this important idea is not mandatory, and support at the school level is virtually non-existent, allowing some teachers to go on with their old teaching routines. This evidence was also confirmed and emphasised by the participants during the validation workshop.

> After training, we were asked to make a lesson plan for STEM at least four times a year and send it to a Telegram group. We did prepare and teach based on the lesson plan, but we have not received any follow-up visits for two years since the training ended. They said they would visit us and observe our teaching, but they have not come for three years, including this year. (A physics teacher, NT05R2)

> It seems no. We just sent the report back to them, which included the students' activities on experiments. And if the experiments failed, they asked us to try to do it again. (A female teacher, NT06F1)

4.2.2. Context coherence

School reality and adaptability

To be successful, CPD training should align with the school context, including school resources, teacher abilities, and the interests of both teachers and students. However, both our qualitative and quantitative analyses yield inconsistent findings regarding the relevance and adaptability of the training content. That said, the adaptability of STEM education varied based on school contexts and teacher characteristics. According to our interview data, some teachers reported applying what they had learned from the training, making adjustments to fit their classroom contexts. They attempted to connect theories to real-world phenomena or practice by demonstrating concepts and assigning students to conduct group experiments (see some quotes below). Our national survey indicates that approximately 40 percent of teachers from all school types typically relate their teaching content to real-life social realities (see Figure 8). The validation workshop also emphasised this point, highlighting the lack of time to connect all the content to real-life situations. However, it remains unclear how the learning content connects to real-life situations. This might occur through theoretical links to social phenomena.

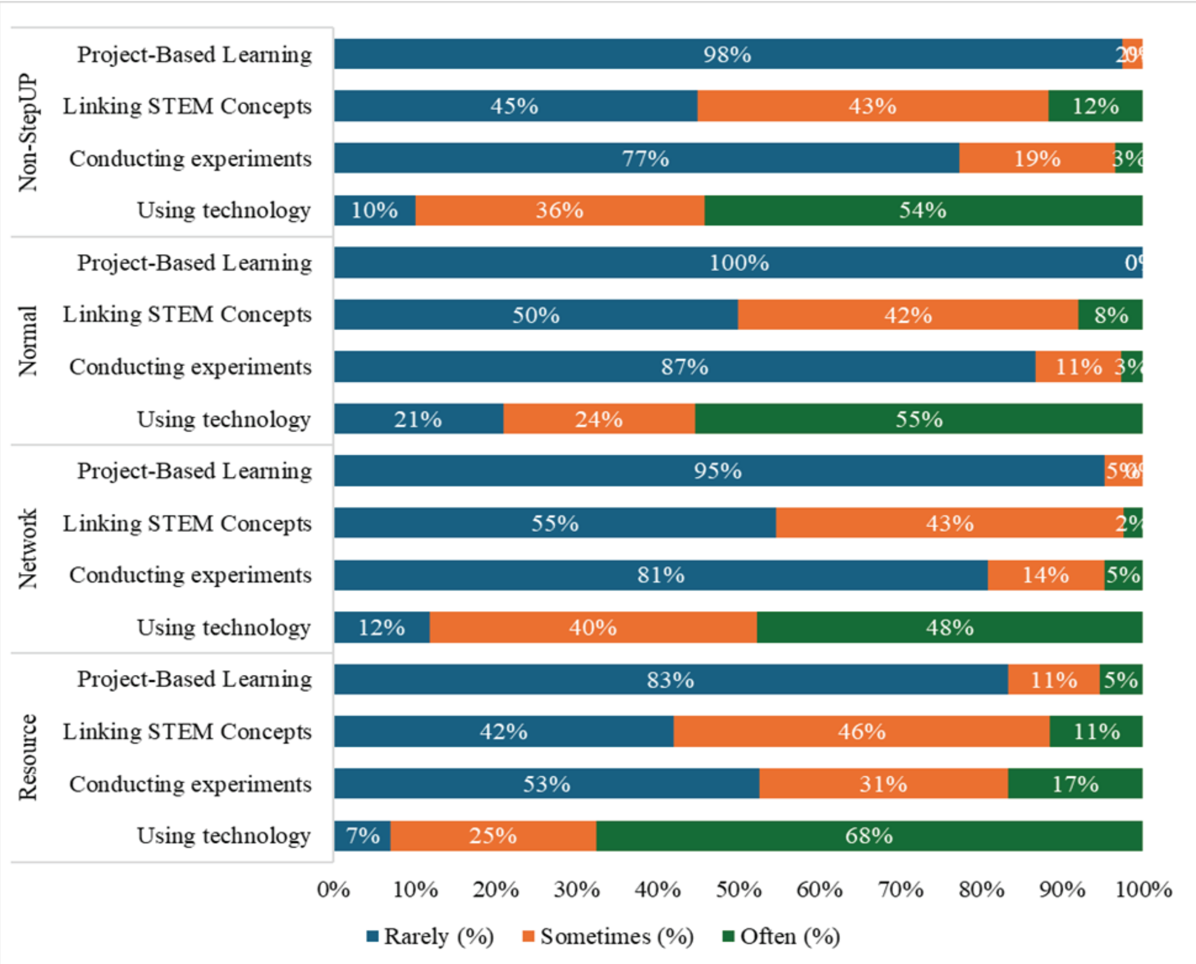
Additionally, some teachers utilise online application tools that provide simulations of lessons. For instance, a male physics teacher (NT01M) from a network school uses a PHET application to demonstrate and assign students to perform experiments in his class. Such engaging sessions were observed to be motivationally stimulating for students compared to theory-oriented sessions. Furthermore, some schools, particularly RSs and NWs, also engaged students in STEM projects led by groups of students and showcased their outputs at school events. The survey also reveals a similar pattern, where STEM projects and experiments were highly frequent at RSs compared to other school types. The use of technology in the classroom appears to be similar at both RSs and NWs (see Figure 8). However, during the validation workshop, some teachers also questioned the procedures of PjBL.

When we join the workshop, we receive knowledge and experience from the workshop. Thus, we prepare lesson plans that align with what we learned from the workshop. Then, we teach students. (A male physics teacher, NT02M)

I went to Kampong Cham for training, where they had a bottle filled with explosives, but there was no mound to create the mountain. When I returned to school, I had the students buy soil to form the mound and cut branches to make trees. Then, I filled the setup with explosives to make it explode like a real volcano. (A female earth science teacher, RT05F)

The qualitative analysis further explains that other teachers at some schools, especially at NSs, find it challenging to use new teaching methods due to inadequate equipment and materials. This finding is consistent with our survey results, which reveal that a large proportion of teachers rarely conducted experiments during the 2023–24 academic year: 77.3 percent at non-StepUp schools, 86.8 percent at NSs, and 81.0 percent at NWs, compared to 52.6 percent at RSs (see Figure 8). In this regard, teachers can perform some simple experiments that require materials available in their schools, at home, or in the market. Conversely, a few teachers at schools with more resources complain about the lack of technical knowledge concerning material operations. They explained that some equipment is too complicated or advanced to operate, and the knowledge they gained during their BA degree programme is somewhat outdated. Some schools, although they received training on material utilisation, complain that the training sessions focused on basic experimental tools that some teachers were already familiar with. Chemistry teachers are particularly concerned about the risks of using chemical substances, which can potentially harm students.

Figure 8: STEM practices across school types (n = 401)



I got new knowledge, but it is difficult to put it into practice because the training was quite short, and the STEM-based lesson design is also complicated. So, it is not easy. In practice, if any lesson is applicable, we conduct experiments to show students. We conduct easy experiments, and we need to buy equipment for difficult ones. (A male math teacher, NT05)

One more thing is about the equipment and materials. So, they gave us these materials, so there should be a training programme on how to use these things. Personally, as I mentioned earlier, I have already forgotten those processes, for example, the microscope installation, I do not know how to do that since I have already forgotten. (A female biology teacher, GT02F)

For the mathematics subject, it is hard to find lessons that relate to STEM education. It is easy for the physics and earth subjects to tie STEM through experiments. This is my opinion. (A female math teacher, NT04F)

The findings above highlight not only the irregular alignment of STEM training with school-related factors but also teachers' backgrounds, such as limited knowledge of scientific tools and experiments, which prevent them from applying innovative STEM teaching methods in the classroom. In this regard, it is further evident from our qualitative data that some teachers struggled to adapt to concepts and related pedagogies (see quotes below). A few teachers noted that the training content was new, requiring more time for learning; thus, some could apply around 50 percent of what they had learned. Some teachers, particularly in math and IT, felt their subjects had limited relevance to STEM education, which they associated primarily with hands-on experiments. However, the collected materials clearly show that there are also examples related to these subjects. During the validation workshops, teachers also acknowledged their uncertainty about STEM education, which is often limited to experiments requiring materials, without a full understanding of the importance of addressing real-life situations. Moreover, many teachers often lack experience in interdisciplinary learning or are unsure about how to integrate multiple STEM subjects. This challenge may stem from the structure of training sessions, which typically group teachers by subject area (see the above section). Such an approach may limit their exposure to interdisciplinary learning and leave them uncertain about how to design interdisciplinary STEM lessons. This evidence highlights the inconsistency in how the STEM workshop aligns with schools' and teachers' backgrounds, resulting in varied adaptability to STEM education. The validation workshop further identified the recruitment of different teachers for the STEM workshop series, which created a knowledge gap among the participants and thus compromised the quality of STEM training.

For me, I joined those workshops, and I received good insights, but it is not adequate. If MoEYS provides more training, I and other teachers in high schools will join. (A male physics teacher, NT02M)

One more thing is that the training is very short, and we are not able to absorb everything. You see, this thick book, and we only studied it for one day. (NT06F1)

Constraints in STEM adaptation

Our interviews also revealed cultural and structural constraints that further exacerbate STEM practices in schools. The majority of participants pointed to examination-oriented learning culture as one of the primary constraints. They mentioned that students in the applied science track would appreciate it if teachers focused on lessons and exercises that helped them succeed in examinations, particularly the national exams (Grade 12). Conversely, students in the social science track appear to be less committed to STEM subjects, most of which are not included in the national examinations. This learning culture reduces teachers' enthusiasm for applying engaging and collaborative learning approaches acquired from their training sessions. Additionally, large class sizes, limited instructional hours, and mixed student abilities present pressing challenges for teachers. For instance, many teachers complain of having up to 70 students per class, with some students lacking basic science knowledge and skills.

> In my grade 12 class, there are 40-50 students per class; in my grade 11 class, there are 60 students; and in grade 10 classes, there are 60-70 students. We can't control the STEM teaching with this number; practising exercises alone takes one hour. (A female math teacher, RT02F)

> Yesterday, two students requested that I allow them to study in the social science track, so I agreed. I did not stop them because I feared they might fail the national examination. If they were to fail the examinations, it could be my fault. (A male vice school principal, ND03M1)

Table 6: Constraints in applying knowledge gained from workshops (n=269)

Constraint description	Resource (%)	Network (%)	Normal (%)	Non-StepUP (%)
Limited understanding of training content	27	29	0	18
Exam-oriented culture impact	39	26	50	34
Lack of school resources	24	53	33	54
Lack of student interest	32	35	25	34
Lack of personal preparation time	26	15	8	22
Excessive curriculum content	41	32	42	30
Large class sizes	44	29	42	40
Training not matching curriculum	7	12	25	6
Lack of teacher/school support	10	12	17	10
Insufficient technical knowledge	36	32	50	34

Notes: RSs (n=108); NWs (n=34); NSs (n=12); non-StepUP (n=115)

Our survey confirmed these patterns. Exam orientation culture was more pronounced at NSs (50 percent), followed by 38.89 percent at RSs, 33.91 percent at non-StepUP schools, and NSs (26.47 percent). Approximately 40 percent of teachers at RSs and NWs regarded the curriculum content as somewhat overwhelming. Besides, the paucity of school resources was more concerning at NWs (52.94 percent) and non-StepUP schools (53.91 percent). Large class size was also an obstacle in all school types. Teachers' understanding of the training content, as 26.85 percent at RSs and 29.41 percent at NWs, blamed their insufficient comprehension as the barrier to applying what they had learned. The validation workshop also emphasised time constraints and teacher workload, leaving little time and energy devoted to creative teaching approaches, particularly STEM practices. Internet access in some rural areas remains an obstacle, while the shortage of teachers specialising in STEM subjects, together with teacher willingness, was also discussed during the validation workshop.

5. Discussion

5.1. CPD accessibility: Equity and sustainability

Our data analysis reveals a diverse range of CPD programmes for USS teachers in Cambodia. These programmes span from national initiatives, such as workshops, to school-based activities like in-school training, technical meetings, class observations, and peer teaching. Individual learning pursuits, including online searches and formal degree programmes, also play a role. However, these CPD pursuits serve different purposes. Only workshops and in-school training sessions have emerged as the primary CPD activities, designed to equip teachers with STEM knowledge and skills. The survey indicates that the majority of teachers attended at least one workshop during their teaching careers, with approximately half of the participants doing so in the 2023-2024 academic year. Nonetheless, their participation in STEM workshops has remained largely limited, with only about 50 percent participating in IBL, technology in STEM, and STEM theory, and perhaps 20-30 percent involved in PjBL, scientific material operation, assessment, experiments, and interdisciplinary learning in STEM. This finding highlights the scarcity of CPD opportunities to enhance STEM competence among teachers, ultimately affecting the quality of STEM education in Cambodia.

The accessibility of STEM CPD also varies based on individual characteristics, school type, and location. Teachers from RSs, followed by NWs, and technical team leaders (senior teachers) appear to have participated in more workshops compared to other teacher characteristics. This disparity can be understood through a project-based perspective, as most teachers participating in STEM workshops were from RSs under the StepUP project, which is also evident in an ADB report (ADB 2022). Factors such as involvement in private tutoring and education level further contribute to this accessibility gap. However, the school location, although contributing to the disparity, can be attributed to the presence of RSs in 25 provinces, as only urban schools where RSs are located have more STEM workshops. As this finding points out, the accessibility to STEM CPD observed more frequently in RSs and NWs, is primarily driven by project interventions, particularly the StepUP project. This poses a significant challenge to the sustainability of STEM education, considering the inertia of STEM sharing culture within schools and school clusters (see the below paragraph), and when the interventions are withdrawn. This allocation of STEM resources and support to certain schools, particularly in RSs, resulting in inequitable opportunities for teachers and students across different geographical areas, despite RSs being located in 25 provinces. This finding highlights an issue of equity in which STEM is offered to certain groups, ignoring those in disadvantaged areas (Levinson, Geron, and Brighouse 2022). However, it could be noted that this development trajectory may be inspired by the selected-STEM school model, as observed in Singapore, the US, or Australia (Teo 2019), aiming to balance cost-effective investment with the 2050 vision, while navigating the dilemma between equity and socio-economic development. In light of this context, sharing best practices within schools and school clusters is undoubtedly a feasible approach to sustaining CPD and promoting equitable access to STEM education.

School-based and individual CPD activities are also popular among teachers, yet these CPD pursuits predominantly address broader educational challenges. Some teachers do share knowledge gained from STEM workshops during technical meetings; however, the effectiveness of this knowledge transfer is often hampered by teachers' abilities and varying interests among teachers (also see King 2018), alongside laissez-faire leadership, an absence of leadership initiatives (Skogstad et al. 2007), resulting in an ad hoc occurrence of knowledge sharing within schools. In-school training offers specific content tailored to individual schools, yet only occurs in some StepUP-project schools (e.g., RSs or NWs). Mentoring, although becoming more familiar among teachers, is not widely practised in Cambodia. Self-directed learning activities are viable; yet language barriers, such as difficulty understanding English-written documents, often subjugate such efforts. Pursuing master's degrees is limited in scope, and their relevance to STEM remains questionable due to the scarcity of specialised science education programmes in Cambodia, unlike in other developed countries such as Australia (Treagust et al. 2015) or Singapore (Teo and Tan 2021). Overall, the evidence suggests a project-driven approach, with little bottom-up initiative in STEM CPD. However, this issue can be justified by the unappealing nature of the teaching profession in Cambodia, where salaries (Tandon and Fukao 2015) and working conditions might potentially discourage innovation.

5.2. Optimising workshop design for STEM integration in schools

Analysing through the lens of our framework (see Table 1), the study suggests that the design of workshop content and activities is notably more comprehensive, covering essential STEM topics, technologies, and the operation of scientific tools. This may enable teachers to apply their new knowledge and skills in the classroom. Consistent with the literature (Hubers, Endedijk, and Van Veen 2022; Sims and Fletcher-Wood 2021; Patton, Parker, and Tannehill 2015; Borko, Jacobs, and Koellner 2010; Desimone 2011), our result shows that teachers had the opportunity to design lesson plans, collaborate in groups, and demonstrate their knowledge through practical applications, supported by some follow-up activities. Such engaging experiences can equip teachers with hands-on experiments that enhance their knowledge of new STEM pedagogies and skills. Our quantitative data confirm this assertion, showing that participation in STEM workshops likely influenced teaching practices. Teachers who attended more STEM workshops, particularly those from RSs, engaged in STEM activities, such as experiments, PjBL, or technology, more frequently in their teaching. However, it is also a concern that classroom observations may provide different perspectives, which are limited in this study.

However, the workshop design still has some room for improvement. First, aside from its relevance, the content still requires greater attention. Evidence suggests that CPD programmes often cover too many topics at once, posing challenges for some teachers to apply all the new activities while feeling uncertain about their adaptability in the classroom. In addition, as Hubers, Endedijk, and Van Veen (2022) argued, the content should allow for easy replication with minimal modification for the classroom practice. Despite STEM being viewed as an interdisciplinary approach (Margot and Kettler 2019), many teachers expressed difficulty in linking their subject content to other STEM disciplines, due to the paucity of such interdisciplinary learning experiences. Many noted that they have worked exclusively with colleagues from their subject areas during CPD. More interestingly, some conceptualised STEM as primarily involving projects and experiments that require readily available materials, overlooking the need to address real-life challenges. Most Math and ICT teachers, in particular, viewed their subjects as less relevant to STEM, citing minimal connections to experiments. This evidence reveals that many teachers still struggle to translate STEM into their classroom practice, requiring more relevant (interdisciplinary) training that can be applied across STEM subjects.

Second, aligning the CPD programme with the realities of the school context is more than essential (Hubers, Endedijk, and Van Veen 2022). Some teachers cited barriers to STEM adoption, including insufficient materials, large class sizes, heavy curricula, and an examination-oriented culture, similar to previous literature, highlighting teachers' incapacity to deal with structural constraints in STEM education (Margot and Kettler 2019). Therefore, the CPD programme should not only introduce new activities but also demonstrate how these can be integrated into various school contexts. As previously mentioned, the programme should facilitate teachers' adaptation of new activities with minimal effort and creativity. Additionally, follow-up activities to support STEM practices at the school level are imperative (King 2018; Surahman and Wang 2023), yet appear to be deficient in Cambodia. School leaders should monitor the implementation of new activities in classrooms, and ongoing discussions and reflections with school leaders and trainers should continue until teachers feel confident in their new skills. In addition, a consecutive training approach, in which a series of sessions are held at different intervals, can be more practical because it offers space for reflection on practice, after which teachers can acquire a new skill (King 2018).

Finally, individual characteristics cannot be overlooked in CPD programmes (Borko, Jacobs, and Koellner 2010; Hubers, Endedijk, and Van Veen 2022) because the diverse demographics of participants, such as individual capabilities and commitments to CPD, can vary. The qualitative data reveal that some teachers attribute their inability to conduct effective STEM instruction to inadequate knowledge of material utilisation. Additionally, some found the training to be overly simplistic, while others perceived the content as too advanced, requiring more time for mastery. Therefore, the participant selection should not solely be based on decisions made by school principals or the MoEYS, but rather on their respective abilities and commitment to fully engage in CPD and apply their learning. This means that although school principals are likely to select potential teachers from their pool, that does not always correspond to the training content. Our expert interview also revealed that while trainers were involved in designing and delivering the training, they lacked awareness of the participants' backgrounds. In this regard, it is vital to establish criteria for recruiting teachers who are capable of implementing and sharing new knowledge and skills, thereby achieving an effective investment.

In a nutshell, this study highlights the progress of STEM education in Cambodia, achieved through enhanced CPD and material support to schools under the funded project. Our study reveals many features of effective CPD in this educational setting, meanwhile highlighting emerging areas in effective CPD design. While the literature typically emphasises the importance of content relevance in STEM (Chai 2019; Hubers, Endedijk, and Van Veen 2022), our study highlights the scope of content and its concise connections to interdisciplinary fields. The study endorsing the literature (Hubers, Endedijk, and Van Veen 2022), also draws attention to context coherence and individual background in CPD design and delivery, identifying context-bound issues in Cambodia.

6. Conclusion and policy recommendations

This study examines the opportunities of CPD programmes for USS teachers in Cambodia, illuminating how STEM education is enhanced in this context. Our analysis indicates a range of CPD activities, yet STEM-focused CPD programmes are primarily driven by projects funded for certain schools, raising concerns about the equity and sustainability of STEM CPD and education. STEM CPD pursuits at the school cluster, school, and individual levels occur on a limited scale, which can be attributed to individual capacity and interest, the minimal engagement of leadership, and challenging working conditions. In addition, as suggested by the literature (Huang et al. 2022), our study emphasises not only the effective characteristics of CPD programmes but also their impact on various STEM education activities in schools. The study highlights explicitly areas for improving the current design of the CPD programme, particularly workshops, as well as other school challenges that hinder the smooth progress of STEM education in Cambodia. In particular, two critical areas require further attention to ensure the success of this STEM initiative in Cambodia. First, the current CPD programme needs enhancements in content scope, contextual and individual coherence, and a robust follow-up system. Second, addressing the cultural and structural challenges within schools is essential for promoting STEM education.

However, some limitations in this study should not be overlooked. Due to the limited scope of the study, we were unable to evaluate the relevance of all forms of CPD engagement, including school-based and individual CPD pursuits. That said, although identified in the study, they did not receive critical examinations due to the diverse designs of those CPD activities, which is far from practical to detail them sufficiently in a single study. For example, mentoring, technical meetings, or academic programmes deserve more empirical examination, potentially offering insights into STEM education in Cambodia. Next, although our study shows progress in STEM education, likely influenced by STEM CPD, the quality of STEM instruction still warrants further investigation, as this aspect was not within the scope of this study. In this context, a closer examination of classroom practices and student experiences offers valuable insights into STEM education in Cambodia. Despite potential limitations, this study employed a robust methodology that yields reliable data for enhancing CPD and STEM education. Therefore, the study aims to offer some recommendations for policy and practice improvements in Cambodia and beyond.

Enhancing STEM workshop design

1) Aligning CPD with teachers and school contexts

Recognising the diverse capabilities and contexts of educators, CPD programmes should move away from a one-size-fits-all approach (also see King 2018). At the recruitment of participants step, a thorough assessment of teachers' current capacities should be performed, not to exclude but to categorise them into groups with similar needs, interests and level of knowledge. This diagnostic phase ensures that CPD content is meticulously tailored, aligning with teachers' existing knowledge with the specific objectives of the training, ultimately making the learning applicable within their school environments. Also, selecting the same participants for the training series is important, as this ensures they have the necessary background knowledge. Furthermore, CPD programmes should be designed to explicitly address contextual challenges prevalent in Cambodian upper secondary schools, such as large class sizes, varied student abilities, and limited resources. This means designing and delivering training that not only introduces innovative instructional activities but also demonstrates their pragmatic implementation in resource-constrained settings, minimising additional effort and burden on teachers.

2) Small-scope training with cross-subject relevance

Current CPD programmes often present an overwhelming number of topics at once, making it challenging for teachers to apply all the learned concepts effectively. Many educators struggle to connect their subject to STEM teaching. Therefore, it is important to refine training content by reducing the number of topics while incorporating more practical examples into each subject. This approach would enable teachers to adopt STEM teaching and practices to their specific school contexts with minimal effort. Additionally, since teachers are still new to the concept of connecting their subject to other STEM disciplines, they should be given ample opportunities to practice and apply interdisciplinary concepts during the training, fostering a deeper understanding and integration of STEM subjects.

3) Providing materials to teachers

It is evident that some teachers were unable to apply new teaching methods due to the scarcity of materials available at their schools (also discussed above). In this regard, providing relevant materials to teachers whose school facilities are limited is necessary to help them apply the new knowledge or engage in teaching activities. This suggestion aligns with the previous one, which emphasises the importance of identifying teachers' backgrounds and schools' characteristics before selecting participants for STEM workshops.

4) Consecutive training as moving back and forth

Implementing a training series, rather than one-off sessions, would better track teacher growth and the sustained application of learned concepts (also see King 2018). As suggested above, each training session should concentrate on a single new topic or skill, allowing teachers to apply it, followed by discussions and reflection, before moving on to the next topic. In this context, a consecutive approach to CPD can be practically undeniable. For instance, a training session can be held at the start of the first semester of a new academic year, and the second session, possibly at the beginning of the second semester, aims to provide a platform for reflection on practice, after which teachers can move on to learning a new skill or knowledge. Furthermore, school management should actively monitor and provide necessary support to teachers as they integrate new STEM concepts into their school environment.

5) Follow-up and leadership support

School leaders play a vital role in supporting the implementation of new knowledge or teaching methods in schools and assist teachers in this process (also see King 2018). However, empirical evidence suggests that teachers primarily rely on support from trainers, while ongoing discussions with peers and school leaders appear to be limited. In this context, school leaders can talk with teachers about how to integrate new teaching activities into the classroom and address existing challenges. Both parties can negotiate how to monitor and evaluate progress at specific intervals. This also encourages a bottom-up approach to STEM CPD.

6) STEM CPD during semester breaks

The validation workshop recommends scheduling STEM CPD during semester breaks, citing teachers' limited time to manage the heavy curriculum. Our data shows that teacher workload is one of the factors that leaves little time for teachers to design STEM activities for the classroom. Given these challenges, it is preferable to hold CPD activities during semester breaks, which do not interfere with teaching time and instructional preparation.

CPD for equity and sustainability in STEM

7) Cluster-based CPD for equity and sustainability in STEM

The current opportunity to access STEM CPD is primarily project-driven, supporting specific schools, such as RSs, NWs, or NSs, within the StepUP project. To promote STEM across school contexts, it is essential to establish policies and guidelines that encourage teachers to share knowledge within schools and school clusters, as outlined in the Teacher CPD Framework 2019. School leaders should follow up and monitor this process. Creating this type of sharing will encourage teachers to pay greater attention to their training. Additionally, schools and teachers who support other schools or teachers within their respective educational contexts should receive rewards or recognition. In this way, CPD programmes can be cost-effective and promote a bottom-up, sustainable, and equitable approach to capacity development.

8) Mentorship programmes

Mentoring has gained popularity in theory but remains distant from practice in Cambodia. Although KAPE has been attempting to implement this approach in NGSs, it is still largely ignored by many schools. In this context, having a more experienced teacher work with a less experienced one to co-design STEM instructional activities can be more practical and sustainable in Cambodia. This collaborative approach enables teachers to combine their expertise into cohesive, relevant learning experiences for students while also developing their own professional skills. By working together, teachers can share knowledge, explore new teaching strategies, and deepen their understanding of related disciplines. This approach also helps address common challenges such as heavy curriculum content and time constraints by making planning and teaching more manageable. For teachers who may be hesitant to lead initiatives alone, this process offers a supportive environment to build confidence and grow professionally.

9) Incentive systems for CPD and STEM initiatives

It is essential to develop a motivating system that counts not only teacher engagement in CPD programmes but also innovative practices that yield positive educational outcomes. This means that providing incentives or recognition should not be based solely on a strong record of CPD participation, but also on changes in teaching-learning performance. Therefore, the motivating system would motivate teachers to engage in CPD activities that benefit their students' learning.

10) Addressing structural challenges

Addressing the above-mentioned areas is not enough to promote CPD and STEM practices in schools. STEM education is just a part of the broader education programme, and the success of its implementation depends on the entire education and school system. In this context, it is vital to examine whether the education system climate, school resources, and classroom environment can facilitate STEM education in schools. For instance, factors such as large class size, mixed-ability students, or an examination-oriented culture remain premier barriers for many teachers to design STEM education activities in their schools.

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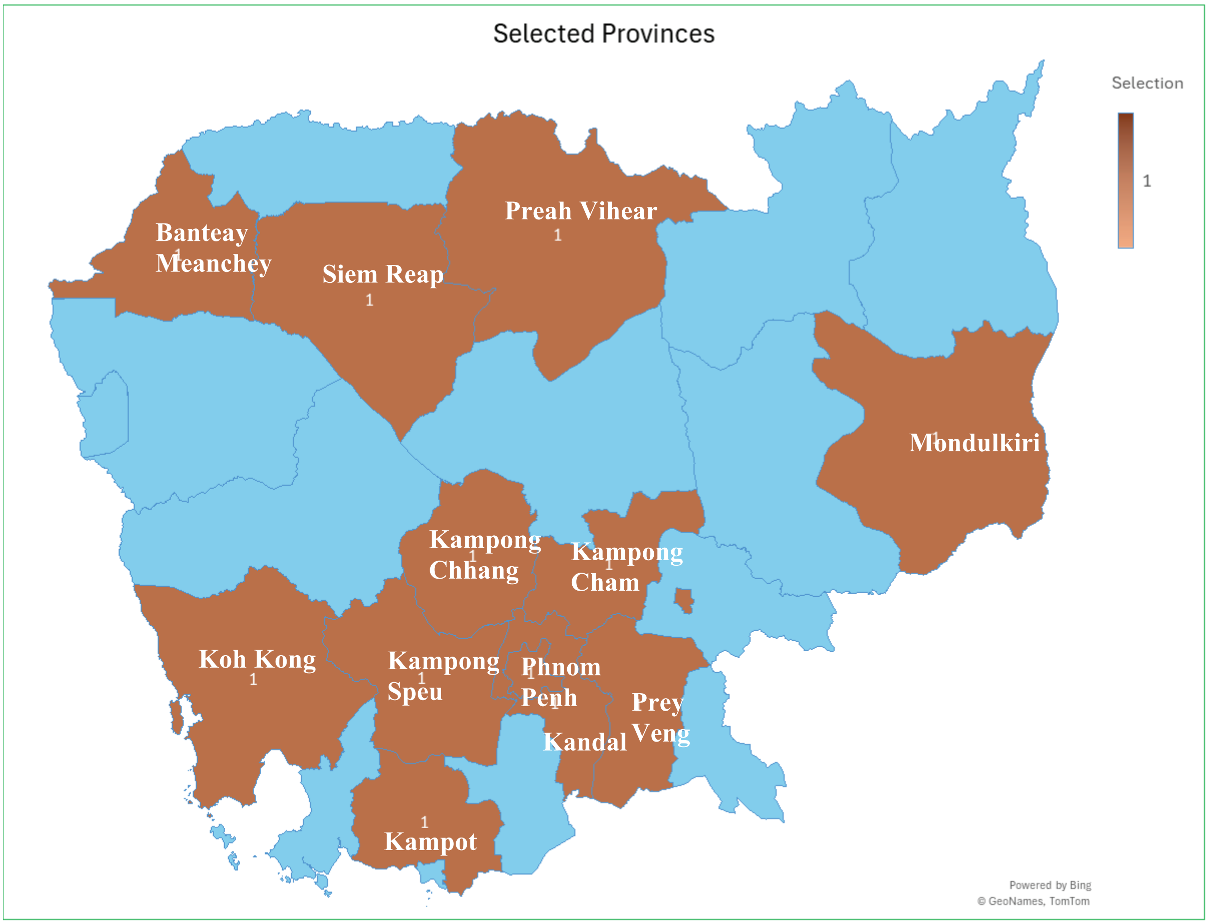
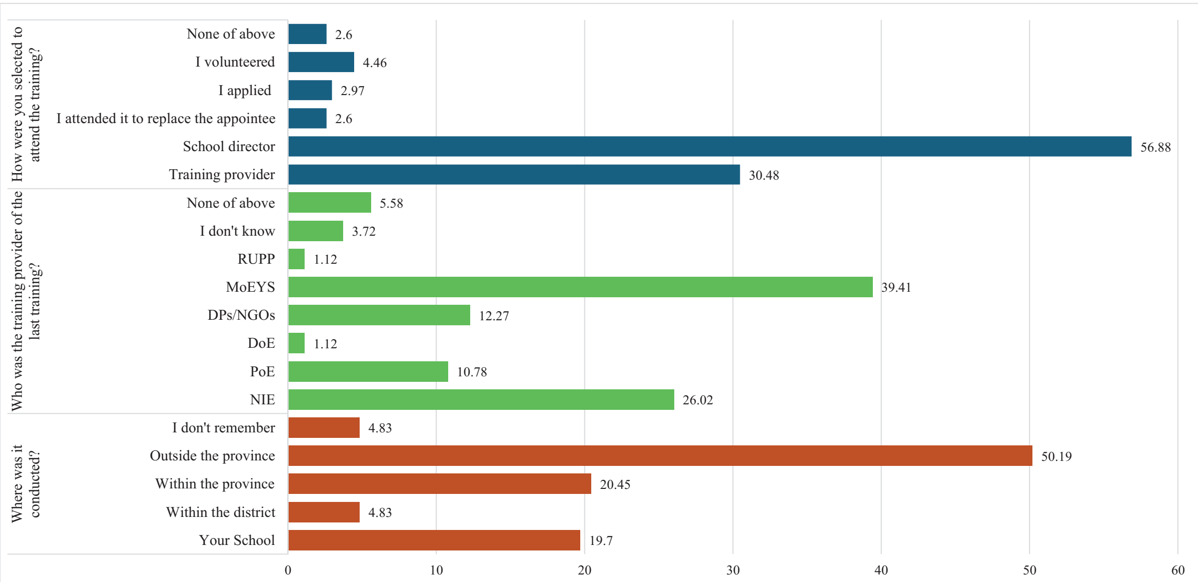
Appendices

Appendix 1: Selected research sites by province in quantitative phase (n=12)



Appendix 2: Providers and locations (n=269)



Appendix 3: Ordered Logistic Regression on workshop participation (n=401)

Predictor	Coefficient (B)	SE	Z	P	95% CI Lower	95% CI Upper
Tutoring (Yes)	-0.51	0.24	-2.10	0.036*	-0.99	-0.03
Gender (Female)	-0.34	0.32	-1.04	0.297	-0.97	0.30
Urban (Urban)	0.74	0.38	1.95	0.052†	-0.01	1.49
Position						
Deputy	1.31	0.40	3.25	0.001**	0.52	2.10
Technical	0.38	0.23	1.64	0.102	-0.07	0.83
Manager	1.13	0.87	1.29	0.197	-0.58	2.84
School type						
Network	-1.24	0.49	-2.54	0.011*	-2.19	-0.28
Normal	-2.67	0.47	-5.72	0.000**	-3.59	-1.76
Non-StepUp	-1.64	0.43	-3.78	0.000**	-2.49	-0.79
Specialisation						
Physics	0.10	0.41	0.26	0.799	-0.69	0.90
Chemistry	0.00	0.38	0.01	0.994	-0.75	0.76
Biology	-0.19	0.38	-0.50	0.618	-0.92	0.55
Earth Science	-0.01	0.43	-0.02	0.983	-0.86	0.84
ICT	1.37	0.57	2.39	0.017	0.25	2.49
Age group						
31–40	-0.08	0.36	-0.21	0.831	-0.79	0.63
41–50	0.09	0.45	0.19	0.849	-0.80	0.97
Over 50	-0.54	0.57	-0.94	0.348	-1.66	0.58
Sci-track (no)	-0.06	0.30	-0.18	0.853	-0.65	0.54
Education						
Bachelor	0.73	0.42	1.72	0.085†	-0.10	1.56
Master	1.05	0.57	1.84	0.066†	-0.07	2.16

Notes: Reference categories are: Tutoring = no, gender = Male, urban = rural, position = teacher, school_type = resource, specialisation = Math, age_group = Below 30, scitrack = yes, education = less than bachelor. Robust standard errors clustered by q0_2. *p < .05; **p < .01; †p < .10.

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