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Enhancing pre-service teachers' TPACK through the integrating of community of practice and lesson study

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ABSTRACT

This study explores the impact of a combined community of practice (CoP) and lesson study (LS) approach on fostering technology pedagogical content knowledge (TPACK) in student teachers. TPACK encompasses various knowledge areas, including technological knowledge (TK), content knowledge (CK), pedagogical knowledge (PK), pedagogical content knowledge (PCK), technology content knowledge (TCK), and technology pedagogical knowledge (TPK). The study employs combined CoP-LS practices in two distinct CoPs: CoP A characterized by varied experiences, and CoP B comprising members with comparable experiences. Data gathered through questionnaires and group discussions. The findings reveal that the CoP-LS activities effectively enhance TPACK among student teachers, leading to improved confidence in designing learning activities. Both CoP A and CoP B show overall enhancements in TPACK, with CoP A exhibiting superior development across all dimensions. Further analysis demonstrates that CoP A exhibits greater advancements in PK and PCK, transitioning from the adapting level to the advancing level. Moreover, TCK and TPK demonstrate progress from the exploring level to the advancing level within CoP A. In contrast, CoP B showcases advancements in TK from the exploring level to the advancing level, while no notable changes are observed in CK, PK, PCK, TCK, and TPK.

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1. INTRODUCTION

In the present era, it is indisputable that technology holds a substantial influence over our everyday existence, encompassing the field of education as well. The impact of the COVID-19 pandemic has further emphasized the importance of technology, making its significance even more apparent. The convenience and variety of learning resources that teachers have learned from using technology in teaching and learning during the COVID-19 pandemic have led to a shift in teachers' thinking and beliefs [1]. This has led teachers to design blended learning, which emphasizes students as the creators of knowledge through both face-to-face and technology-enhanced learning systems. As a results, effective teaching now necessitates a combination of technological expertise and pedagogical understanding to craft compelling and meaningful learning encounters for students. Technological pedagogical content knowledge (TPACK) is a framework that integrates three types of knowledge: content knowledge (CK), pedagogical knowledge (PK), and technological knowledge (TK) to help teachers integrate technology in their teaching practices [2]. The TPACK framework has been widely

recognized as a valuable tool to help teachers achieve this goal. Aspiring pre-service teachers must acquire TPACK proficiency to deliver high-quality education in the digital age.

Therefore, educational institutions responsible for teacher preparation cannot ignore the crucial importance of fostering the development of TPACK and adequately equipping prospective teachers with the necessary competencies to maximize educational effectiveness. An exemplary institution in this regard is the Faculty of Education at Mahasarakham University, highly regarded for its excellence in teacher training in Thailand. The faculty places significant emphasis on the comprehensive integration of TPACK across various subject areas within its curriculum. Currently, the faculty is undergoing a transitional phase, transitioning from a 5 year undergraduate program to a 4 year program. Notably, both curricula share parallel structures, particularly evident in core subject clusters and resource sharing among students. However, in the 4 year program, there is an increased integration of professionalization aspects to align with the limited timeframe. This change may potentially impact the amount of time dedicated to cultivating professional experiences during teacher training. Nevertheless, the unprecedented circumstances brought about by the COVID-19 pandemic have heightened pre-service teachers' awareness of the critical significance of TPACK. They have come to recognize the essential role of technology in their own learning and instructional practices. To effectively utilize technology, pre-service teachers must consider the diverse contextual factors and influential determinants that shape the integration of technology within instructional settings. However, many pre-service teachers still lack the necessary TPACK to integrate technology into their teaching practices effectively. As such, there is a need for effective professional development approaches that can help pre-service teachers acquire TPACK [3]. Through scholarly investigation, it is discerned that both communities of practice (CoP) and learning sciences (LS) stand as efficacious conceptual paradigms adept at fostering self-efficacy and facilitating the development of educators in the context of teaching practice placements. Additionally, these frameworks demonstrably contribute to the effective cultivation of pedagogical skills in learning design. Henceforth, it may be asserted that CoP and LS are two approaches that have been shown to be effective in professional development including teachers' TPACK [4]–[7].

Communities of practice refers to a collection of individuals who share a mutual involvement in a particular endeavor and interact with others to enhance their proficiency in it [8]–[11]. CoP is grounded on the belief that learning is a social phenomenon that transpires through active participation within a community of like-minded individuals who share a common interest or field. CoP underscores the significance of social interaction and collaborative engagement among its members as a means to foster the cultivation of knowledge and competencies. In the context of teacher education, a CoP serves as a valuable platform for pre-service teachers, offering them a supportive and collaborative environment [12], [13]. Within this setting, aspiring the pre-service teachers have the opportunity to share their experiences and knowledge, engage in peer learning, and receive valuable feedback from experienced educators. CoP establishes a social learning environment, facilitating interactions between pre-service teachers who share similar interests and objectives. Through active participation in this community, pre-service teachers engage in meaningful discussions, exchange ideas, and reflect upon their experiences, thereby fostering the development and deepening of their TPACK [5], [14], [15].

In addition, learning sciences is another approach that has been shown to be effective in promoting the development of TPACK among pre-service teachers [16]–[19]. Lesson study is an instructional approach driven by teachers themselves, where they collectively establish a specific objective for their teaching and rigorously analyze their practice through careful planning and implementation of lessons. This teacher-centered and teacher-led practice highlights the active engagement of educators within a community as they collaboratively reflect on and enhance their instructional techniques [7], [20]–[23]. In other words, LS is a collaborative professional development model which provides pre-service teachers with the opportunity to collaborate with other teachers in planning, observing, analyzing, and reflecting on lessons to improve their teaching practices [20], [24], [25]. Another perspective reveals that lesson study can further cultivate a collaborative culture among teaching teachers, fostering a sense of unity through shared work and problem-solving. Additionally, it instills confidence in designing instructional activities that can enhance the effectiveness of efficient teaching management. It has the potential to develop well-rounded learning outcomes for students [26]. Therefore, it can be asserted that lesson study is another effective concept for enhancing the teaching profession.

Nevertheless, an examination of the extant literature reveals the efficacy of incorporating the LS framework into professional development initiatives. This pedagogical approach has demonstrated remarkable effectiveness in fostering the enhancement of teachers' competencies, encompassing the cultivation of pedagogical knowledge and its adept application within the instructional setting. Moreover, it has concurrently facilitated the establishment of a robust teacher learning community or community of practice of the teachers [27]. As a potential avenue for teacher professional growth, LS has the capacity to bolster initiatives led by teachers, such as learning communities or community of practice, in contrast to conventional workshops led by experts that may lack real-world classroom connections. Learning

communities hold the promise of empowering teachers in diverse ways, potentially resulting in enhanced student learning outcomes [28]. In these communities of professional learning or CoP, teachers are afforded the chance to shape the trajectory of their own professional development and enhance their teaching practices within a collaborative and supportive setting [29]. The studies conducted, it is evident that the development of a professional community is identified as one of the key conditions for supporting successful LS [30]. Especially if it involves establishing a learning community within the same context, with similar characteristics of issues, it enhances the collaborative efficacy of teachers following the LS approach. It can be asserted that the school context is also a powerful influence in LS [31]. This implies that applying the LS concept through a learning community or a community of practitioners within the same context is likely to yield highly effective outcomes. An examination of extant literature reveals the amalgamation of the LS and CoP frameworks in the professional development process, indicating that the integration of CoP and LS constitutes a potentially effective approach for augmenting teachers' knowledge, encompassing the teaching competency [24], [32]–[34].

A substantial research gap exists in the concurrent application of CoP and LS frameworks for TPACK, especially for student teachers with diverse backgrounds. The researchers aim to empirically assess the efficacy of integrating both frameworks in fostering TPACK among student teachers. CoP involve exchanging valuable knowledge, fostering collective learning, and cultivating a shared understanding of TPACK among pre-service teachers. LS provides opportunities for pre-service teachers to observe experienced educators, gaining insights and constructive feedback. The integration of these approaches offers a collaborative professional development experience, refining TPACK competencies. Additionally, the study delves into how distinct characteristics in the formation of CoPs influence the development of TPACK among student teachers.

The purpose of this paper is to explore the use of CoP combined with LS (CoP-LS) as a professional development activity to promote pre-service teachers' TPACK. The study will investigate the effectiveness of this guideline in enhancing pre-service teachers' TPACK. Additionally, the study will examine the challenges and benefits of implementing CoP-LS in the pre-service teacher training program particularly, the study focuses on examining the formation of CoP characterized by distinct attributes and characteristics. The findings of this study will contribute to the existing literature on TPACK, CoP, and LS providing valuable insights for teacher educators, educational policymakers, and researchers. The results will help to inform teacher education programs and professional development initiatives aimed at enhancing pre-service teachers' TPACK and their teaching practices in the digital era.

2. METHOD

The research design employed in this study is characterized by a convergent parallel mixed methods design [35]. This methodological framework seamlessly integrates both quantitative and qualitative data collection methods. Additionally, it involves the simultaneous application of quantitative and qualitative analysis approaches, facilitating a comprehensive and multifaceted exploration of the research subject.

2.1. Participants

The study involved purposefully selecting 8 student teachers from Mahasarakham University's General Science Program, encompassing both 4-year and 5-year tracks. This targeted approach aimed to capture diverse perspectives relevant to the research focus on science education. The participants, under the supervision of the researcher throughout the study, offer unique insights into the intersection of pedagogy, content knowledge, and practical experiences. This purposive selection ensures contextual relevance and enhances the depth of qualitative inquiry [36]. All participants are integral to both quantitative and qualitative data collection methodologies. The selection of participants is rooted in their demonstrated capacity to furnish elaborate responses and intricate descriptions [37].

2.2. Research instruments

The framework employed in this study to combine the community of practice with lesson study was based on Cojorn and Sonsupap [34]. It was carefully modified to suit the specific context of pre-service teachers undergoing practical teaching experiences and the unique characteristics of the practitioner. The CoP formed by these pre-service teachers who shared similar interests and backgrounds in terms of knowledge and experiences. The learning process consisted of four distinct stages: eliciting, designing, implementing, and reflecting as shown in Table 1. In the execution of CoP-LS activities, the process will unfold in cycles following the learning process, encompassing all four stages as depicted in Figure 1. A panel of five esteemed experts evaluated the instructional activity, resulting in an outstanding suitability rating of 4.98. This score attests to the activity's effectiveness and alignment with objectives and educational context. The involvement of expert reviewers enhances the credibility and reliability of the evaluation process and findings.

Table 1. Description of the activity guideline based on CoP-LS

CoP plus LS	Activity
Eliciting	The student teachers who teach the same subject in the same educational context and face similar problems come together to share their knowledge, experiences, and effective teaching techniques.
Designing	The group members of CoP engage in a process of sharing thoughts and viewpoints, and then work collaboratively to create learning activities.
Implementing	The individual utilizes the learning activities created by the community of practitioners and incorporates them into their own classroom while also observing the classes of fellow group members.
Reflecting	The CoP members are working together to examine the results of designing learning activities and enhancing them as a group to make them more comprehensive.

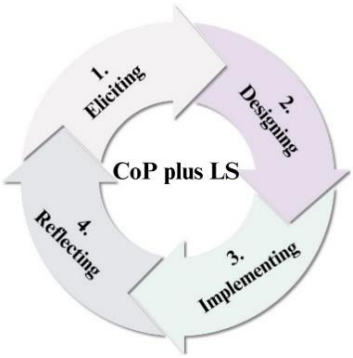

Figure 1. CoP-LS learning activity

The TPACK questionnaire, based on Schmid *et al.* [38], was developed using a 5-point rating scale. This questionnaire assesses all seven dimensions of TPACK, including TK, CK, TPK, and TPACK. Each dimension consists of four items. The experts determined that the content validity of the questionnaire was 0.95, and the item appropriateness ranged from 4.88 to 5.00.

A record of a focus group discussion was created based on three main discussion topics: i) the benefits of the CoP-LS activity; ii) the experiences and emotions associated with using the CoP-LS activity; and iii) the challenges encountered when using the Cop-LS activity. The researcher analyzed the quality of the instrument used in the interview by consulting with five experts to assess the content validity of the interview items. The experts found the content validity to be 1.00, while the appropriateness of the items ranged from 4.80 to 5.00.

2.3. Data collection

The researchers have provided guidelines for creating a community of practice in education through lesson plans to inform the research participants. An assessment of TPACK was conducted in the first semester of the academic year. Two distinct forms of CoP could be created depending on the school field experience context which are: i) CoP A is a CoP comprising 4 student teachers who come from different programs, namely, 4 year and 5-year programs; and ii) CoP B is a CoP consisting of 4 student teachers who are members of the same program. Both CoPs conducted teacher professional development through the guideline of community of practice combined lesson study, with the researchers who were instructional coaches providing guidance, supervision, and assistance in carrying out the activities according to the guideline. After completing the teaching activities in the second semester, a subsequent TPACK evaluation was performed, and group discussions were held with both CoPs.

2.4. Data analysis

The data collected through the questionnaire to assess the TPACK level of student teachers during their field experience was analyzed by calculating the mean and standard deviation (S.D.). These statistical measures were then interpreted according to Niess *et al.* [39]. The criteria for analysis can be summarized by mean score ranges 4.21–5.00 refers to the level of advancing, 3.41–4.20 refers to the level of exploring, 2.61–3.40 refers to means the level of adapting, 1.81–2.60 refers to the level of accepting, and 1.00–1.80 refers the level of recognizing. Regarding the analysis of data from the focus group discussion, the researcher classified the responses and put them into an order before carrying out the content analysis. The results of the analysis were presented through descriptive presentation. Furthermore, the TPACK development of student teachers is assessed by calculating relative gain score (RGS), considering the changes in scores between the two assessments. This methodology is in accordance with the framework suggested by Kanjanawasee [40].

Relative gain score (RGS)=((X2–X1)/(Y-X1))×100 (1)

Where, X2=score of post-evaluation; X1=score of pre-evaluation; and Y=full score of the evaluation.

3. RESULTS

The investigation into TPACK among members of CoP A, comprising student teachers from diverse academic programs such as the 4 year and 5 year Science Education programs, yielded insightful outcomes. A parallel examination was conducted within CoP B, where the members are exclusively student teachers from the same program. The comprehensive findings of this TPACK study, meticulously illustrated in Table 2, provide a comparative analysis delineating the nuances in TPACK development between student teachers from distinct and homogeneous academic program backgrounds within the respective CoPs.

Based on the data presented in Table 2, a comprehensive analysis reveals that the TPACK of student teachers within CoP A has demonstrated developmental progress, transitioning from the adapting stage to the exploring stage. Specifically, PK and PCK progressed from adapting to advancing, while TCK and TPK advanced from exploring to advancing. Conversely, no significant changes have been observed in TK and CK. Concurrently, it was discovered that an examination of the overall TPACK of student teachers in CoP B revealed a progression from the adapting stage to the exploring stage. Upon closer scrutiny of the individual dimensions, it is evident that TK exhibits advancement from the exploring stage to the advancing stage. Conversely, no significant alterations are observed in CK, PK, PCK, TCK, and TPK.

In order to examine the progression of TPACK among pre-service teacher students during the first and second academic semesters, an analytical approach was employed. This involved the computation of RGS for individuals within the distinct cohorts of CoP A and CoP B. Subsequently, a comprehensive comparative assessment was undertaken, delving into the specifics of the data related to the relative gain scores of teacher students associated with CoP A and CoP B. The detailed findings of this comparative analysis are elucidated in Figure 2.

Drawing upon the data presented in Figure 2 of the TPACK development study involving teacher students within CoP A and CoP B, a discernible pattern emerges. Notably, both overall TPACK and its constituent subcomponents exhibit a congruent trend. More specifically, teacher students belonging to CoP A demonstrate demonstrably superior development in comparison to their counterparts within CoP B. Based on the extensive group discussions conducted with participants from both CoP A and CoP B, a myriad of significant themes surfaced, offering a nuanced understanding of the collective perspectives. These emergent themes, reflective of the participants' insights and experiences, can be distilled into several salient points. The ensuing summary encapsulates the key findings gleaned from the rich discourse within the two distinct CoPs.

Table 2. TPACK Level of CoP member

TPACK	CoP A.						CoP B.					
	First semester			Second semester			First semester			Second semester		
	Mean	S.D.	Level	Mean	S.D.	Level	Mean	S.D.	Level	Mean	S.D.	Level
TK	3.96	0.80	Exp	4.08	0.78	Exp	4.00	0.36	Exp	4.25	0.44	Adv
CK	3.67	0.78	Exp	4.17	0.72	Exp	3.67	0.78	Exp	4.08	0.79	Exp
PK	3.20	0.80	Adapt	4.46	0.51	Adv	3.50	0.60	Exp	3.71	0.62	Exp
PCK	3.00	0.80	Adapt	4.50	0.58	Adv	3.80	0.60	Exp	4.00	0.82	Exp
TCK	3.75	0.50	Exp	4.25	0.50	Adv	4.25	0.50	Adv	4.25	0.50	Adv
TPK	3.72	0.74	Exp	4.30	0.60	Adv	3.92	0.60	Exp	4.00	0.60	Exp
TPACK	3.30	0.50	Adapt	3.80	0.50	Exp	3.30	0.50	Adapt	3.50	0.60	Exp

*Adv=advancing, Exp=exploring, Adapt=adapting

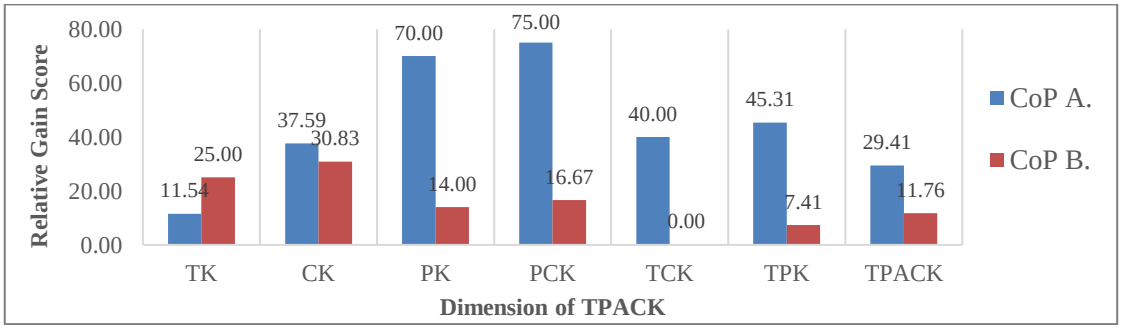

Figure 2. The progression of TPACK among pre-service teacher students between CoP A and CoP B

Learning through peer collaboration, peer assistance, and mentoring by senior members has played a pivotal role in instilling self-assurance and confidence among individuals engaged in designing instructional activities. The significance of this influence becomes evident through a dialogue excerpt that follows. The exchange highlights the tangible impact of collaborative learning and mentorship on the development of the participants' skills and self-assurance in the realm of instructional design.

> "*During the initial stages of the experience-sharing activities, there was a sense of hesitation, particularly when interacting with senior members. However, as we became more familiar with each other, we gained the courage to speak up and share more. I have learned so much from the fifth-year seniors, such as teaching techniques like Think Pair Share and Gallery Walk.*" (Member 1: CoP A)
> "*In sharing experiences where we narrate our own successful encounters, I believe it greatly benefits our peers to listen. I find it immensely advantageous, as it allows us to collect various teaching methods and techniques to adapt and apply them extensively to our own instructional activities.*" (Member 4: CoP A)
> "*Having friends to exchange ideas with, design activities together, and solve problems collaboratively, has made me more confident in designing activities and willing to incorporate new media into my teaching, especially when my friends agree with my ideas.*" (Member 2: CoP B)

The collective endeavor of collaboratively designing learning activities and participating in analytical discussions before their implementation has yielded the creation of impactful learning experiences. This outcome is substantiated by the subsequent discourse that ensued. The dialogue serves as a testament to the effectiveness of the collaborative design process in enhancing the quality and efficacy of learning experiences.

> "*Participating in this activity has been highly beneficial for me, especially in facilitating the process of designing learning activities more easily and effectively. The collaborative analysis conducted prior to implementation has increased my confidence and assurance, as it allows for collective brainstorming and critical thinking.*" (Member 2: CoP A)
> "*The presence of someone to review and evaluate the proposed activities before implementation has instilled a sense of confidence and relaxation, alleviating concerns when applying them in real situations.*" (Member 4: CoP B)

Engagement in these instructional activities affords a nuanced and encompassing framework for lesson design, surpassing egocentric perspectives. This manifestation is discernible in the subsequent discourse that transpires. The ensuing dialogue serves as empirical substantiation for the broader and more inclusive perspectives cultivated through active participation in these pedagogical endeavors.

> "*In previous lesson design activities, I used to prioritize my own ideas. However, participating in this activity with peers and friends has expanded my perspective. I have realized that what I perceive as good may not be suitable for learners. For instance, I had a strong preference for using pickles, but my peers advised me that it could be challenging to implement and suggested using quizzes instead. This experience has taught me the importance of selecting the right media and considering the context for effective teaching.*" (Member 1: CoP A)
> "*Collaborating with friends in the lesson design activity has provided valuable insights into aspects that I may have overlooked or not considered. For instance, choosing assessment methods that enhance children's enjoyment of learning. Their input has been greatly appreciated.*" (Member 1: CoP B)

Within the realm of knowledge exchange within a CoP, the indispensability of proficient experts or seasoned individuals is underscored. Their role encompasses not only providing guidance but actively engaging in the intricate dynamics of knowledge exchange, as evidenced by the ensuing conversation. This dialogue serves as a tangible illustration of the significance of experienced contributors in fostering a conducive environment for effective knowledge dissemination within a CoP.

> "*This kind of activity will yield great results if the group members consist of experts or individuals with extensive experience. For example, in our group, we have senior members who have previously conducted teaching experiments in schools. They can share their experiences, such as which activities are effective, how to manage a chaotic classroom, or what precautions to take. If we only have inexperienced members, we wouldn't know what to contribute or exchange.*" (Member 2: CoP A)

"*I agree with my friend. For example, in reflecting on the outcomes and improving our activities, it would be beneficial to have senior members who can provide insights on what adjustments should be made and in which direction to proceed. If we only have inexperienced members, we might feel that our efforts are not yielding results, but figuring out how to make effective adjustments would require substantial thought and consideration.*" (Member 3: CoP A)
"*At the beginning of our experience exchange with friends, I was uncertain about what to share because we had all encountered similar situations. If there were others who possessed more knowledge and experience than us, it would likely enhance the quality of our exchanges.*" (Member 3: CoP B)
"*Given that we have had similar experiences since our early years of education, it becomes difficult to find distinct topics to exchange. I believe having someone with different perspectives and insights from ours would greatly improve the exchange process.*" (Member 2: CoP B)

The efficacy of group activities hinges upon foundational principles such as trust, openness, acceptance of others, and a commitment to engage in critical analysis. These constituent elements assume a pivotal role in cultivating a collaborative learning environment, a phenomenon clearly evidenced in the subsequent dialogue. The discourse serves as empirical validation of the critical contribution of these factors to the establishment of an effective and cooperative learning milieu.

"*In my opinion, trust and openness are essential for achieving successful results in these activities. It is important to approach feedback from both friends and senior members with an open mind, without assuming that they are blaming us. We should be willing to learn from their diverse perspectives. At first, I felt disheartened when my meticulously planned activity did not produce the desired outcomes. However, upon carefully listening and reflecting on the feedback provided by a senior member, I recognized the validity of their remarks. Therefore, maintaining an open-minded attitude is crucial.*" (Member 1: CoP A)
"*I agree with you, as even though I am a senior member, there are areas where I perceive things differently from others. It would be challenging to conduct activities if I solely considered myself as superior with more experience and dismissed the input of others. Embracing an open mind allows us to learn new things that we may have overlooked.*" (Member 4: CoP A)
"*Having the courage to speak up, to express opinions directly, is both a strength and a weakness. Offering suggestions is crucial, and those who listen must respect and be open-minded enough to accept different perspectives.*" (Member 3: CoP B)

4. DISCUSSION

The study demonstrated positive outcomes when combining the community of practice approach with lesson study to enhance the student teachers' TPACK. The results showed significant improvements in student teachers' TPACK levels, particularly in two different CoP groups: CoP A, comprising members with diverse experiences and CoP B, consisting of members with similar experiences. Both groups progressed from the adapting level to the exploring level in terms of overall TPACK development. The process of eliciting and designing activities allowed pre-service teachers to extract valuable knowledge and experiences in effective teaching practices. This knowledge was then collaboratively utilized to design and improve teaching activities. As a result, the pre-service teachers were able to enhance their TPACK by combining their own knowledge and understanding with shared perspectives and experiences during the design and collaborative reflection processes. This facilitated the development of PCK and the ability to make appropriate adjustments, contributing to the overall advancement within the TPACK framework.

The study highlighted the significance of a learning community that emphasizes the exchange of effective experiential practices, providing a secure and supportive environment where all members feel empowered to think and take action [41], [42]. In this context, student teachers are able to engage in collaborative and effective teaching and learning experiences within a secure and supportive peer environment. The essence of peer assistance and cooperation cultivates an atmosphere conducive to lesson study, which facilitates joint design of learning activities, their implementation in the classroom, and collective reflection to identify viable strategies for improvement. Consequently, student teachers experience substantial learning and progress in their teaching practices, thereby fostering a climate of learning, skill development, and the enrichment of teacher knowledge and TPACK through practical engagement.

Notably, scholarly investigations have consistently demonstrated that the utilization of lesson study effectively promotes the establishment of proficient teacher communities of practice. By harnessing the power of dialogue and the exchange of experiences within a community of practitioners, adhering to the principles of lesson study, the process of collaborative activity design, planning, and reflective analysis exhibits notable

efficacy in professional growth. Ultimately, this approach enhances teachers' content knowledge and refines their pedagogical practices [24], [43], [44].

In examining the TPACK development of teacher students within the realms of CoP A and CoP B, discernible disparities emerge. CoP A, characterized by heterogeneous member experiences, manifests a notably superior TPACK evolution compared to its counterpart, CoP B, evident across both holistic and subdimensional analyses. A more granular exploration exposes that CoP A substantiates heightened advancements in the number of dimensions pertaining to the teacher students' TPACK, in stark contrast to CoP B. Particularly, CoP A showcases pronounced developmental strides in PK, PCK, TCK, and TPK, with notable transitions observed from Adapting to Advancing in PK and PCK, and from Exploring to Advancing in TCK and TPK. Conversely, CoP B demonstrates advancements solely in the TK dimension, shifting from Exploring to advancing, while dimensions such as CK, PK, PCK, TCK, and TPK exhibit negligible alterations. A careful analysis of average scores reveals a significant improvement in CoP A, while CoP B shows a slight increase. CoP operations, particularly with Lesson Study, prioritize expert coaches with extensive instructional management experience. They facilitate knowledge exchange and provide valuable insights to enhance teaching and learning. This aligns with the importance of collaborative learning and working with more experienced individuals, as emphasized by Wenger [8].

Collaboration with knowledgeable peers fosters diverse perspectives and supports the growth of CoP members. In specific domains like technology, the newer generation of CoP members has the opportunity to acquire knowledge of emerging innovations and engage in knowledge exchange activities. Consequently, within CoP A, which consists of student teachers with varying levels of teaching management experience, the implementation of learning activities within the CoP-LS, proves to be a more effective approach. This combination contributes to a greater advancement of TPACK. This is evident from group discussions where student teachers reflect on the outcomes of knowledge exchange activities or the feedback received, which aims to improve instructional practices. The success of operational endeavors within the practitioner community relies significantly on its members, who are considered the key drivers of a strong CoP with diverse expertise. Their contributions lead to effective knowledge management, collaborative learning exchanges, and motivation among members to attain successful outcomes [45]–[48]. Furthermore, from the research study, it will be observed that driving the success of LS in a learning community depends on various factors such as a sense of unity, motivation, cooperation, commitment, support, sincerity, reciprocity, and organizational structure [49]. Therefore, in establishing a CoP and undertaking various activities, consideration must be given to these factors. An analysis of the group discussions and activities of CoP A, comprising members with diverse backgrounds and serving in mentor-mentee roles, engenders a sense of mutual trust and camaraderie among the members. The confidence in experienced senior members may contribute to the effectiveness of activities within the CoP, ultimately leading to favorable outcomes.

In analyzing both CoPs, it is evident that there has been limited progress in developing CK. This can be attributed to the study's focus on students enrolled in the General Science program at the Faculty of Education, Mahasarakham University. These students already possess expertise in the subjects they will teach, causing them to prioritize the challenges and novelty of instructional design over CK. Consequently, CK receives less attention during learning exchanges, discussions, and reflective thinking, resulting in its insufficient development among student-teachers. Moreover, the process of reflective thinking sheds light on the effectiveness of integrated CoP-LS activity. This particular approach has proven to be instrumental in facilitating a notable enhancement of the student-teachers' TPACK. Notably, it not only contributes to the improvement of their TPACK but also alleviates their workload, instills confidence in instructional design, and fosters the implementation of more effective teaching and learning activities.

5. CONCLUSION

Technological pedagogical content knowledge is essential for the professional development of teachers. This research has shown that integrated CoP-LS activities are notably more effective cultivating TPACK among pre-service teachers. In addition, establishing a well-structured significantly contributes to enhancing TPACK in aspiring teachers. Consequently, it is strongly recommended that teacher education programs incorporate CoP-LS activities into their curriculum to bolster TPACK for pre-service teachers. These activities should emphasize practical engagement, aiding aspiring teachers in understanding the core CoP-LS principles, fostering trust, openness, and the capacity for critical reflection on learning. This, in turn, encourages self-assessment and continuous learning. By immersing future teachers in hands-on experiences, they can cultivate a profound comprehension of these principles. This in-depth understanding empowers them to effectively apply these principles in their teaching practices, fostering their professional growth, benefiting their students' development, and ensuring the sustained progress of the teaching profession.

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