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Bridging knowledge and community: Innovative community-based learning to strengthen mathematic pre-service teachers' problem-solving competency

Sukanda Dankunprasert [1], Kanyarat Cojorn [2*], Kanyarat Sonsupap [2], Bovornpot Choompunuch [3], Sawitree Ranmechai [1], Areerat Nonsuwan [2], Yanapat Tongron [4]

[1] Department of Educational Research and Development, Faculty of Education, Mahasarakham University, Mahasarakham, THAILAND
[2] Department of Curriculum and Instruction, Faculty of Education, Mahasarakham University, Mahasarakham, THAILAND
[3] Department of Educational Psychology and Guidance, Faculty of Education, Mahasarakham University, Mahasarakham, THAILAND
[4] Department of Mathematics, Faculty of Science and Technology, Nakhon Ratchasima Rajabhat University, Nakhon Ratchasima, THAILAND

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Abstract
This study aims to develop a learning activity grounded in the community-based learning (CBL) approach to enhance the problem-solving competency of mathematics pre-service teachers. Designed using the ADDIE instructional design model, the process spanned from needs assessment to post-implementation evaluation. The prototype was tested with 24 mathematics pre-service teachers through open-ended assessments. The study introduces a structured framework for CBL activities in five stages: preparation, problem identification, creation, implementation, and reflection. Findings show that CBL activities significantly enhance problem-solving competency by bridging theoretical knowledge with real-world contexts. This approach not only strengthens problem-solving abilities but also supports deeper integration of knowledge into teaching practice. By incorporating CBL principles into the ADDIE model, the study offers a collaborative, practical strategy for instructional design. Peer interaction was facilitated through group projects, while community engagement involved working with local stakeholders to address authentic problems–both integral to developing the problem-solving capacity of future mathematics teachers.

Keywords: ADDIE model, mathematics pre-service teachers, professional development, professional growth, teacher education

INTRODUCTION

The VUCA world–marked by volatility, uncertainty, complexity, and ambiguity-demands an education system that prepares learners for rapid, unpredictable change. Teacher education must equip pre-service teachers with the knowledge, skills, and competencies to thrive in such contexts, with problem-solving as a core ability for guiding students through uncertainty and complexity (Bennett & Lemoine, 2014; Gleason, 2018). As the foundation of the education system, they must be trained to design and implement instructional activities that cultivate key competencies, especially problem-solving, in their students.

In Thailand, problem-solving is a key higher-order skill in the competency-based curriculum. It involves creative and adaptive thinking to develop solutions, innovations, and methodologies as well as the ability to analyze information, assess impacts, and apply systemic thinking for comprehensive resolution (Office of the Basic Education Commission, 2021a). Effective problem-solving also entails reflective practices to assess the

✉ sukanda.d@msu.ac.th ✉ kanyarat.c@msu.ac.th **(*Correspondence)** ✉ kanyarat.s@msu.ac.th ✉ bovornpot.c@msu.ac.th ✉ sawitree.r@msu.ac.th ✉ areerat.n@msu.ac.th ✉ yanapat.t@nrru.ac.th

Contribution to the literature

- This paper introduces a structured framework for integrating community-based learning (CBL) into mathematics teacher education, developed through the ADDIE model.
- It provides empirical evidence that CBL activities can significantly enhance pre-service teachers' problem-solving competency by bridging theoretical knowledge with authentic, real-world contexts.
- The study expands instructional design research by demonstrating how community engagement and peer collaboration can be systematically embedded to support the professional growth of future mathematics teachers.

processes and outcomes of addressing challenges. It includes identifying and defining problems, gathering relevant data, designing and selecting solutions, and implementing them effectively (OECD, 2019). Beyond producing solutions, it involves assessing their impact and integrating interdisciplinary perspectives to address future challenges.

With the growing importance of real-world problem-solving, community-based learning (CBL) has become a game-changing strategy that bridges the gap between theoretical knowledge and practical community engagement, fostering hands-on learning and social impact. Through CBL, pre-service teachers develop essential problem-solving skills by being immersed in authentic, real-world contexts, where they engage actively, think critically, and interact meaningfully with community members. CBL strengthens pre-service teachers' capacity to tackle complex issues by integrating theoretical foundations with practical, real-world experiences, ultimately cultivating civic-minded professionals who are committed to creating positive change (Melaville et al., 2006). CBL also encourages collaboration between schools and local organizations, providing student teachers with meaningful opportunities to apply their learning in real-life contexts. One of its fundamental goals is to make education relevant by incorporating personal experiences and social dynamics into the learning process, ensuring that pre-service teachers actively engage in solving community-based challenges which also contributes to the application of knowledge in social service.

Additionally, community-based mentoring–offered through both face-to-face and online modalities–plays a crucial role in developing pre-service teachers' higher-order thinking skills (Gamage et al., 2021). This method improves the learning process because it supports the relationship between teachers and pre-service teachers and bolsters the links between learning and community (Crump, 2002; Tinoco-Giraldo et al., 2020). Nevertheless, even though the importance of CBL has been identified in previous studies in fostering engagement and critical thinking, there is a gap in studies on how CBL can be implemented systematically to enhance problem-solving competency among mathematics pre-service teachers. In order to fill this gap, the current study is aimed at designing and delivering learning activities that will be based on the principles of CBL in order to improve problem-solving competence of mathematics pre-service teachers. This is to prepare teacher students who are key stakeholders within the education sector with the readiness and abilities needed to succeed in the VUCA world of the 21st century. The outcomes will present a pragmatically relevant, contextually authentic framework that will incorporate the principles of CBL in teachers education so that the graduates will be prepared to create quality learning experiences that will enable their own students to overcome complicated situations in the real world.

LITERATURE REVIEW

Community-Based Learning

CBL plays a pivotal role in lifelong learning, by bridging formal and informal learning environments. It is recognized as an effective pedagogical strategy to promote public good through civic engagement and social responsibility (Kendall, 2004). This approach is particularly significant for pre-service teachers, as it enhances their understanding of societal dynamics and community, especially for pre-service teachers preparing their professional responsibilities. Furthermore, CBL can be a central goal in university education, as it supports the development of innovations at both the community and regional levels. This integration of academic theory with real-world practice not only enriches the educational experience but also contributes to meaningful societal impact (Fischer et al., 2009). CBL involves problem-solving in the context of real-world societal issues. Rooted in the foundational principles of experiential learning, it is designed to promote learning and develop learners by involving learners in activities related to individuals and the needs of the community. It achieves this by engaging them in activities directly related to the needs and dynamics of their community. CBL management is a learning management strategy or model that integrates content according to the curriculum to be linked to the community using operations as a base. CBL is guided by structured principles, as outlined by Melaville et al. (2006), to ensure a meaningful and impactful integration of education and community engagement. These guidelines emphasize collaboration among educators, learners, and community members, enabling a synergistic approach to both education and social development.

The four pillars of education–learning to know, learning to do, learning to live together, and learning to be–provide a comprehensive framework for developing effective and holistic pre-service mathematics teachers. "learning to know" refers to an approach focused on developing the cognitive processes, learning strategies, and knowledge acquisition methods of learners, with the aim of fostering lifelong learning and personal growth. In the context of mathematics pre-service teacher development emphasizes building strong cognitive foundations in mathematical concepts, reasoning, and problem-solving strategies. It involves training concentration, memory, and critical thinking, while integrating real-life contexts into mathematical learning to promote lifelong learning habits and the ability to apply mathematics meaningfully in diverse situations. *"Learning to do"* is the process of developing skills and competences, particularly in professional areas, that enable people to collaborate, adapt theoretical information to practical settings, and use it effectively in their jobs. This learning method focuses on equipping mathematics pre-service teachers with pedagogical skills, technological competencies, and practical classroom strategies needed to translate mathematical theory into effective teaching practice. This includes designing lessons, managing classroom interactions, and engaging in collaborative problem-solving that bridges academic mathematics with authentic, hands-on teaching experiences. *"Learning to live together"* emphasizes the ability to coexist peacefully in a multicultural society. This prepares mathematics pre-service teachers to work effectively in diverse educational settings. It fosters the ability to communicate mathematical ideas clearly, collaborate with colleagues, respect cultural and learning differences among students, and create inclusive classroom environments that promote mutual respect and equitable participation in mathematics learning. *"Learning to be"* supports the holistic development of mathematics pre-service teachers by cultivating creativity in lesson design, self-awareness in professional growth, and personal responsibility in fostering positive student learning outcomes. It also encourages the development of ethical awareness and a sense of social responsibility, enabling teachers to inspire students to appreciate the role of mathematics in addressing societal and environmental challenges.

These pillars shaped the CBL activities by aligning each phase with a specific development goal: *Learning to know* informed the choice of authentic mathematical problems; *learning to do* guided the inclusion of applied, project-based tasks; *learning to live together* was embedded through group work and community engagement; and *learning to be* inspired reflective practices. This integration ensured that the CBL activities strengthened not only mathematical competence but also the practical, social, and personal capacities needed for effective and socially responsive mathematics teaching. Thus, the learning process rooted in the community-based principle should be designed to promote broad and holistic learning. This approach offers opportunities for pre-service teachers to engage with real-world issues, linking the content to the context of their daily lives. The management of this learning process should integrate critical thinking skills, problem-solving, and the use of technology and multimedia, with assessments grounded in real-life situations that focus on understanding rather than content alone. Furthermore, learners should actively participate in self-assessment. When community-based teaching and learning methods are applied, the design of learning activities should emphasize the development of critical thinking and creative problem-solving abilities. This approach leads to meaningful changes in learners, improving their learning, skills, and behavior (Jensantikul, 2021). Therefore, employing community-centered teaching strategies is an effective means of promoting pre-service teachers' development and fostering a deeper understanding.

Problem-Solving Competency

According to Thailand's competency-based curriculum, problem-solving is classified as a higher-order thinking competency. It involves addressing challenges, developing products, methods, or innovations through creative thinking, or enhancing existing ideas to make them more practical. This includes comparing data sources, assessing the impact of problems using appropriate methods, considering systemic structures for comprehensive solutions, and reflecting on problem-solving processes (Office of the Basic Education Commission, 2021b). Higher-order thinking competencies are closely linked to cognitive processes that integrate to resolve complex problems. Educators define problem-solving as the cognitive ability to manage imbalances by harmonizing oneself and the environment to restore equilibrium or achieve a desired state (Polya, 1957). This process requires systematic thinking, critical reflection, and the ability to design and implement practical solutions (Greiff et al., 2013; Jonassen, 1997). Such competencies align with the program for international student assessment (PISA) framework, which positions problem-solving as the application of mathematical processes to authentic, real-world contexts (OECD, 2019).

The OECD (2019) highlights mathematical modeling as a critical aspect of the PISA framework, integrating it into mathematical literacy, which focuses on applying mathematics to real-world situations. Stacey and Turner (2015) describe modeling as a three-stage process–formulating, solving, and interpreting–that guides learners from identifying a real-world problem to deriving and validating mathematical solutions. This connection between problem-solving and modeling is central to mathematics education, as it transforms abstract knowledge into applicable skills for addressing complex challenges. Teachers play a crucial role in facilitating this process by helping students navigate between contextual realities and relevant mathematical tools, thereby fostering deeper mathematical literacy.

The PISA 2021 framework emphasizes that mathematically literate pre-service teachers can distill real-world problems to mathematical representations (OECD, 2019). The framework is linked to the problem-solving competence with mathematical reasoning for real-world application. This framework consists of 3 key components (OECD, 2019): *formulate* (translate real-world problems into mathematical form), *employ* (apply concepts, procedures, and reasoning to solve problems), and *interpret and evaluate* (assess and contextualize solutions for validity and practical significance) (OECD, 2019). For mathematics pre-service teachers, these skills represent the most important tool for equipping their future students to learn the right way to use math in a variety of context.

In this study, these competencies directly shaped the design of CBL activities. The *formulate* component informed tasks requiring participants to identify authentic community issues and express them mathematically. The *employ* component guided the inclusion of project-based activities for applying mathematical reasoning to generate solutions. The *interpret and evaluate* component was embedded through reflective discussions and community feedback to ensure solutions were both mathematically sound and socially relevant. Beyond guiding the design, this same framework was applied as an evaluative lens to assess the effectiveness of the developed CBL activities, examining how well they fostered each competency in mathematics pre-service teachers. In this way, the framework served a dual role–structuring the learning experience and providing a basis for evaluating its impact–ensuring alignment between the intended outcomes and the measured results.

ADDIE Framework

The ADDIE model is a widely adopted instructional design framework known for its systematic approach to creating effective educational experiences. It consists of five key phases: analysis, design, development, implementation, and evaluation, ensuring optimal learning outcomes.

1. Analysis–Assessing learners' needs, understanding the context, and defining learning objectives. This phase identifies gaps between the current state and desired outcomes (Gustafson & Branch, 2002). In this study, this phase identified the needs of mathematics pre-service teachers, examined the community-based context, and set objectives to strengthen problem-solving and modeling skills.
2. Design–Planning content, learning activities, and assessments. Instructional strategies are selected, and media choices are made to best support learning goals (Morrison et al., 2014). These phares outlined CBL activities, assessments, and instructional strategies, selecting tools and media to support mathematical engagement.
3. Development–Creating learning materials, producing interactive elements, and designing assessments based on the blueprint. Prototypes are tested to ensure effectiveness (Allen, 2006). This phase produced and tested materials, ensuring activities could effectively connect mathematical theory with real-world applications.
4. Implementation–Deploying materials and rolling out the learning experience. This phase includes teacher training and preparation to ensure smooth instructional delivery (Dick et al., 2009). The activity is delivered these activities in the target educational setting, with teacher preparation to facilitate CBL effectively.
5. Evaluation–In the evaluation phase, the assessment was done according to the CBL context by pointing out not only the quality of collaborative engagement but also the accomplishment of the intended competencies. Effectiveness was evaluated throughout primarily concentrating on the fulfillment of the learning objectives and detecting the places where modifications are needed (Morrison et al. 2014). In particular, this study used a problem-solving and modeling framework to assess the process and the outcomes of the CBL activities which, in turn, helped mathematics pre-service teachers achieve the problem-solving competence and achieving the study's objectives.

The ADDIE model consists of additive phases that are built from the previous ones and is, therefore, an iterative process. Designers go through early steps for review based upon the feedback and assessment results thus they ensure that the learning goals are properly addressed and achieved. The alignment, flexibility, and CE by this iterative process are the objectives to be met across a range of educative settings (Branch, 2010; Peterson, 2003). The ADDIE model is a well-known and powerful system in instructional design; it is the base that is used to create efficient teaching-learning experiences. The straightforwardness and flexibility of the model give the designers instructional content that is primarily targeted towards specific learning outcomes a great deal of advantage (Branch, 2010).

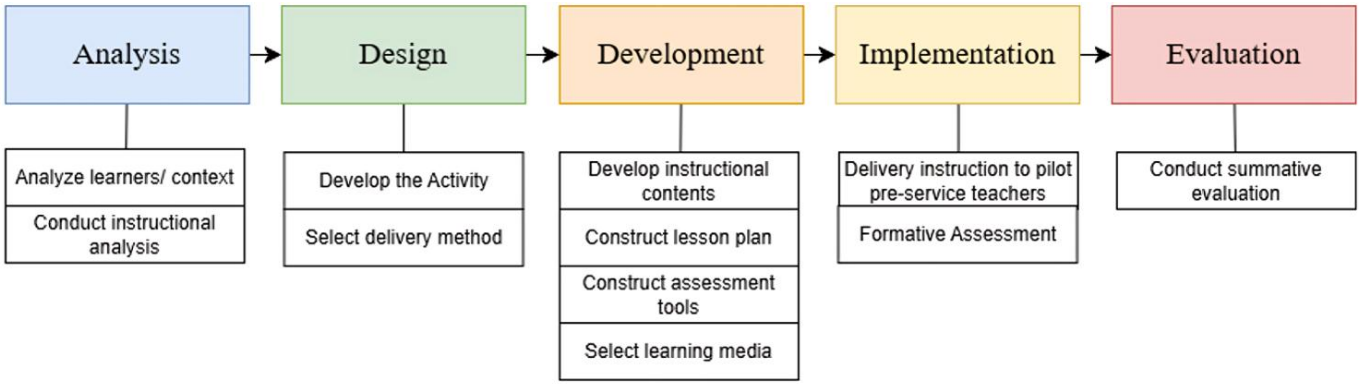

Figure 1. Research design through the ADDIE model (Source: Authors' own elaboration)

METHODOLOGY

This study aimed to develop a CBL activity to strengthen problem-solving competency of mathematical pre-service teachers. The activity was designed and developed using the ADDIE instructional design model. This model, which consists of five phases–analysis, design, development, implementation, and evaluation–is widely recognized for its structured approach to creating effective instructional materials and courses. By offering clear, defined stages, ADDIE ensures the systematic implementation of instruction, while its cyclical nature allows for ongoing refinement and improvement. **Figure 1** illustrates the conceptual framework for the development of the CBL activity.

As **Figure 1**, the process began with analysis, where learners' needs and instructional context were examined. In the design phase, the CBL activities were outlined, and delivery methods were selected. The development phase involved creating instructional content, lesson plans, assessment tools, and learning media. The implementation phase focused on piloting the activities with pre-service teachers and conducting formative assessments. Finally, the evaluation phase consisted of a summative evaluation to determine the effectiveness of the activities in meeting the targeted problem-solving and mathematical modeling competencies.

This study aimed to develop a CBL activity to enhance the problem-solving competency of mathematics pre-service teachers using the ADDIE instructional design model. Each phase of the ADDIE model was applied to guide the development of the learning activity are as follows.

Phase 1. Analyze Phase

This phase establishes the basis of instructional design through discovery of gaps between the present levels of competence and anticipated results of mathematics pre-service teachers. A needs analysis is conducted to determine challenges and root causes in instructional management. The participants included three CBL experts and three mathematics teachers, selected through purposive sampling to ensure relevant expertise and contextual knowledge. Two semi structured interviews are utilized, and the quality of research tools is assessed by experts (mean scores: 4.58 and 4.17) which states that the research tools and competencies are highly aligned. Such assessments were necessary to make sure that the teaching material and tests were factual and relevant to the target population. The methods of data collection are transcribed interviews, content analysis, and interpretation. The phase will make sure that teaching material is relevant, and it is oriented towards the requirements of the target audience.

Phase 2. Design Phase

This phase employs documentation and literature review to examine CBL and problem-solving competency. Data is gathered from documents, research, and interviews, then synthesized. Feedback from preservice teachers, instructors, and experts informs the analysis of teaching activities. Based on findings, CBL activities are designed to enhance mathematics pre-service teachers' problem-solving skills. The framework aligns with CBL principles, as confirmed through expert evaluation. Their ratings led to an item-objective congruence (IOC) of 1.00 meaning ideal congruence on the applicability of each item and an average suitability score of 4.65, which implies high overall appropriateness. These findings guaranteed content validity, which meant that the tools were not only theoretically sound but also practical in the education system they were supposed to be used.

Phase 3. Development Phase

In this phase, instructional strategies are developed based on analysis data, defining objectives, teaching methods, lesson plans, media, and assessments. The instructional approach is tailored to the target group, ensuring alignment with learning outcomes. Three experts, selected through purposive sampling, evaluated the materials. Moreover, the research instruments were developed including.

1. Ten lesson plans were created based on CBL activities. Expert evaluations rated their

effectiveness highly, with an average score of 4.65 (range: 4.33-5.00). The evaluations confirmed clarity, relevance, and alignment with objectives, reinforcing the lesson plans' content validity and suitability for developing mathematics pre-service teachers' skills.

2. Problem-solving competency test: This test consists of open-ended questions on five situational problems, aligning with the PISA 2021 framework. Open-ended items were chosen to allow participants to demonstrate their reasoning processes, creativity, and ability to justify solutions, which closed-ended formats cannot fully capture. It assesses three key mathematical literacy components:
   a. *Formulate*–translating real-world problems into mathematical terms. Indicators include 3 sub-aspect (SA):
      SA 1.1. Identifying the mathematical aspects of real-life problems.
      SA 1.2. Simplifying situations or problems to facilitate mathematical analysis.
      SA 1.3. Converting problems into mathematical language and identifying relationships in the problem's context.
   b. *Employ*–applying mathematical knowledge, skills, and tools to solve formulated problems. Indicators include 3 SA:
      SA 2.1. Developing and applying problem-solving strategies.
      SA 2.2. Utilizing mathematical tools to derive appropriate solutions.
      SA 2.3. Applying mathematical rules, algorithms, and structures to solve problems effectively.
   c. *Interpret and evaluate*–interpreting mathematical results in real-world contexts. Indicators include 3 SA:
      SA 3.1. Translating mathematical outcomes back into real-world applications.
      SA 3.2. Assessing the logical coherence of mathematical solutions in contextual scenarios.
      SA 3.3. Justifying the reasonableness and validity of mathematical conclusions within the problem's context.

The test underwent expert review to ensure validity and reliability, achieving an index of IOC of 1.00 and an average evaluation score of 4.44, indicating high effectiveness. Scoring was standardized using an analytic rubric with clearly defined criteria for each indicator to ensure consistency and inter-rater reliability. Each SA was rated on a 0-4 scale based on the level of competency demonstrated in the pre-service teacher assessment responses, with each aspect totaling 45 points and an overall maximum of 135 points.

Phase 4. Implementation Phase

The CBL activities were implemented to assess their effectiveness. Lesson plans were implemented using cluster sampling, selecting one group of 24 third-year mathematics pre-service teachers from Mahasarakham University. In this study, the researcher–who had an in-depth understanding of the CBL activities as the developer–personally conducted the implementation to ensure fidelity and alignment with the intended pedagogical approach. A meeting introduced the activities, followed by implementation. After completion, a problem-solving competency test was conducted, with data analyzed for mean, standard deviation, and percentage.

Phase 5. Evaluation Phase

In this phase, evaluation was integrated into each activity of the learning process. Two types of assessments were employed: formative and summative. The formative evaluation aimed to enhance the effectiveness of the instructional materials within each sub-activity. It followed assessment as learning, using structured worksheets aligned with the three problem-solving competency components (*formulate*, *employ*, and *interpret and evaluate*). Worksheets were scored via consistent rubric, and timely feedback was provided to help trainees reflect, adjust strategies, and autonomously develop their skills. Evaluation was carried out at each stage, beginning with the implementation phase, to determine the effectiveness of the CBL activity. Data were analyzed to calculate the mean, percentage, and effect size using Cohen's d, with interpretations following Sawilowsky (2009) benchmarks: d (.01) = very small, d (.2) = small, d (.5) = medium, d (.8) = large, d (1.2) = very large, and d (2.0) = huge. In addition, a problem-solving competency test was administered at the end of the activity to assess its overall impact.

FINDINGS

A comprehensive analysis of the needs of pre-service teachers, supplemented by interviews with stakeholders–including pre-service teachers, instructors, and CBL experts–yielded several key insights.

Pre-service teachers highlighted the importance of mathematics education that is practical and connects fundamental concepts to real-world scenarios. They appreciated experiential learning through interactive activities, active involvement in lesson planning, and varied assessment approaches. Rather than conventional exams, they favored authentic, performance-based evaluations that mirror real-life contexts.

Table 1. Overview of the activity based on the blueprinted of CBL approach

Activity	SA	Purpose	Activity description
Preparing	Reviewing	To make mathematics pre-service teachers aware of their prior knowledge and the environment that affects their learning.	To engage in a collaborative discussion and critique, brainstorming ideas about the prior knowledge on the topic.
	Knowing	To enhance mathematical knowledge and problem-solving competency.	Divide mathematics pre-service teachers into groups with specific responsibilities to collaboratively discuss, critique, and brainstorm ideas about the problem-solving competency ink to problem, in order to develop a deeper understanding and the ability to apply it effectively.
Problem finding	Planning	To enable mathematics pre-service teachers to plan and establish guidelines for data exploration.	Have each pre-service teacher discuss the issues together as a guide to explore community interested problems.
	Community surveying	To collect data from the community and analyze local issues.	Each mathematics pre-service teacher is required to design and develop a tool as part of the community survey problem.
	Conceptualizing	To gather and synthesize data obtained from the survey.	Each mathematics pre-service teacher shares their experience from the community to form their group.
Creative	Brainstorming	To develop approaches and methods for problem-solving	Engage in a brainstorming session to generate ideas pertinent to the interested problem.
	Sharing	To exchange ideas and refine problem-solving approaches.	Share their proposed solutions and engage in discussion to reach a group consensus.
Implementing	Implementing and collecting	To test problem-solving in real communities and collect data for further improvement.	Each group has presented and received approval for their innovation to solve the problem.
Reflecting	Reflecting	To summarize the results obtained from the implementation.	Each group has presented and reflected local comments from the community trials.
	Improving	To improve activities and establish best practices for the future.	Each group of mathematics pre-service teachers should use the feedback and suggestions from the trial use of their innovation to improve the prototype. They will collaborate to discuss, critique, and brainstorm ideas about the knowledge on the topic, with the aim of submitting the final innovation report in a written format.

Table 2. The problem-solving competency score of mathematical pre-service teacher

Item	N	Total	Pre-test		Post-test		Percentage (%)	Cohen's d
			M	SD	M	SD		
Problem-solving competency	24	135	58.07	16.01	85.75	15.94	63.52	1.73
1. Formulate	24	45	30.20	5.26	34.71	5.97	77.13	
2. Employ	24	45	21.40	2.70	25.33	6.18	56.29	
3. Interpret and evaluate	24	45	26.80	2.68	25.71	6.72	57.13	

Instructors and experts collaborated to design instruction that blended mathematical concepts with real-world applications. They suggested outcomes such as community-based research projects and problem-solving exercises that addressed local issues. They also stressed the importance of leveraging the community as a learning resource, incorporating real-world problems into instruction.

The research process involved reviewing literature on CBL and analyzing interviews and questionnaires. This led to the development of five learning activities, outlined in **Table 1**, designed to foster creative thinking, problem-solving skills, and experiential learning. These activities align with real-world contexts, ensuring pre-service teachers gain practical, applicable mathematical knowledge.

The outcomes of implementation phase, the evaluation of the CBL activity focused on assessing its impact on problem-solving competency. The data from this evaluation are summarized in **Table 2**, highlighting the effect of the application on mathematics pre-service teachers' competency to address and solve problems effectively within a real-world context.

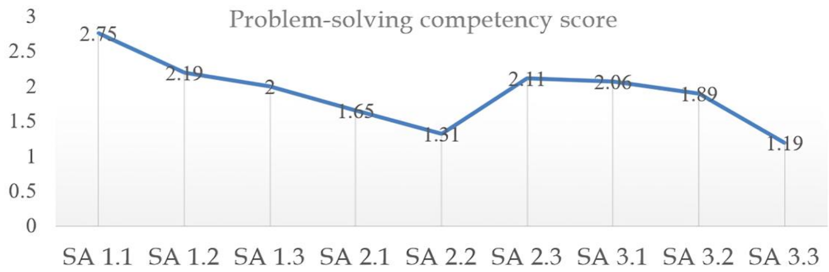

Figure 2. The mathematics pre-service teachers' mean score on each aspect of problem-solving competency (Source: Authors' own elaboration)

The scored highest in formulating and translating problem situations mathematically, averaging 34.71 (77.13%) which was the highest score among the three areas assessed. In employing mathematical concepts, facts, methods, and reasoning to solve problems, they achieved 25.33 (56.29%), while their score for interpreting, applying, and evaluating results was 25.71 (57.13%). Their overall performance averaged 85.75 (63.52%), demonstrating proficiency in problem-solving skills, particularly in problem formulation. Moreover, the calculated effect size (Cohen's d = 1.73) suggests a very large practical significance, indicating that participation in CBL activities had a meaningful impact on pre-service teachers' Problem-solving competency.

An analysis of each SA was conducted to examine the detailed development of problem-solving competency. Each SA had a total raw score of 45 points, which was scaled down to a maximum of 3.00 to align with the analytic rubric's full-score benchmark of 3 points per indicator. Scaling was calculated as *(raw score / 45)* × *3* and was criterion-referenced, based on predefined performance criteria. The data is presented in the form of a line graph in **Figure 2**.

Figure 2 presents the mean scores of pre-service mathematics teachers across different SAs of problem-solving competency. The results reveal stronger performance in formulating problems, while employing strategies received comparatively lowest scores. It was found that mathematics the highest sub-competency in SA 1.1, with an average score of 2.75, while the lowest sub-competency was in SA 3.3, with an average score of 1.19. These findings highlight the need for targeted instructional support to develop well-rounded problem-solving skills.

The insights gathered from interviews with mathematics pre-service teachers who engaged with the developed activities can be distilled into the following key themes.

Time Allocation

The time spent on instructional activities, especially on the knowledge development was inadequate. Moreover, scheduling problems appeared because of different course schedules of pre-service teachers and restrained collaboration. These issues demonstrate the necessity of longer working hours and more unified time schemes. For example, insufficient time for foundational learning impeded innovation and experimentation, crucial for deepening subject mastery. As pre-service teacher 1 noted, *"The time for building foundational knowledge, innovation, and experimentation is insufficient."* reflecting a gap in developing critical thinking and creativity.

Similarly, incomplete comprehension and application of key concepts resulted from rushed knowledge acquisition. Pre-service teacher 3 emphasized this by stating, *"I think the time allocated for learning the knowledge is too short, which leads to an incomplete understanding and application of the concepts. More time is needed."* highlighting the need for extended periods to strengthen cognitive competencies.

Moreover, scheduling conflicts across varied course timetables restricted effective collaboration, limiting the development of group communication and shared problem-solving skills. Pre-service teacher 4 explained, *"It's challenging to find matching free time for group work because our class schedules differ. As a result, decisions and knowledge application tend to rely heavily on the group leader. I wish I could be more involved,"* illustrating how logistical barriers diminished equitable participation and collaborative competency.

Knowledge Dimension

Pre-service teachers managed to use the knowledge of mathematics in real-life situations and make contributions to the solutions of the communities. Nevertheless, there are those who wanted to have a chance to revise and advance their knowledge. As pre-service teacher 1 stated, *"I was able to apply abstract mathematical knowledge and skills to address and solve various community issues."* highlighting growth in problem-solving and applied reasoning skills. Additionally, pre-service teacher 2 noted, *"I recognized and understood how mathematical skills are practically applicable and encountered in everyday life."* indicating increased awareness of mathematics' relevance beyond the classroom. Despite this progress, some participants expressed a need for more opportunities to review and refine their knowledge, suggesting a desire to strengthen conceptual mastery and confidence.

Experience

Pre-service teachers were able to get a first-hand experience in solving problems and putting mathematical knowledge into real-world situations. improving their practicality and ability to analyze. As pre-service teacher 2 shared, *"Through this process, I gained hands-on experience in using mathematics to address practical challenges."* illustrating growth in applied problem-solving abilities. Similarly, pre-service teacher 5 *"I had the opportunity to practice solving complex problems and apply mathematical knowledge to real-world situations."* reflecting strengthened skills in tackling authentic, complex tasks.

Group discussions with mathematics pre-service teachers who implemented the CBL Activity to enhance problem-solving competency highlighted key areas for improvement. The learning activity follows five steps: *preparing, problem finding, creating, implementing,* and *reflecting*. However, adjustments to sub-activities in the innovation phase were made based on feedback from practitioner communities in each area. These modifications aimed to refine the learning process and enhance its effectiveness.

Through these refinements, pre-service teachers developed essential competencies by engaging in collaborative discussions, problem identification, and real-world applications of mathematical concepts. The iterative process of adjusting activities based on practical insights allowed for a more tailored and meaningful learning experience. Additionally, participants worked together to reflect on their experiences and summarize best practices. These reflections contributed to a deeper understanding of how CBL can foster problem-solving skills. The key findings and recommendations are presented in **Table 3** and **Figure 3**, showcasing the successful implementation and impact of the adapted activities.

Table 3. Key highlights, modifications, and rationale for each activity step of CBL activity

Activity
1. Preparation
1.1 Reviewing: Given the background of the pre-service students and their prior knowledge, which is already quite familiar, the activities in this step shifted from merely highlighting brainstorming of prior knowledge to emphasizing the building of community knowledge aimed at fostering deeper understanding and effective problem-solving.
1.2 Knowing: Due to the mathematics pre-service teachers' lack of foundational knowledge and essential skills, this activity focused on strengthening their mathematical understanding and competencies for effective problem-solving. Peer-assisted group work was used, with responsibilities divided to facilitate collaborative discussion and critique, generate ideas, deepen understanding of relevant topics, and foster the ability to apply knowledge effectively.
2. Identification
2.1 Planning: The activity shifts the focus to collaborative group work, specifies problems based on the students' interests, and frames the discussion from a societal perspective. This change enhances the pedagogical clarity of the activity, moving from a simple discussion exercise to a purposeful, structured process designed to foster meaningful engagement, deeper understanding, and the development of problem-solving skills.
2.2 Community surveying: The activity emphasizes community-based, experiential learning through interaction, observation, and summarization. It explicitly links findings to mathematical problem-solving, enabling pre-service teachers to apply their knowledge in real-world contexts. This approach situates students in authentic settings, fostering not only technical skills but also collaborative learning, critical thinking, and the meaningful application of knowledge–essential competencies for preparing teachers to address complex problems in real communities.
2.3 Conceptualizing: This phase focuses on identifying community issues and explicitly connecting them to problem-solving skills. It involves active interaction, data collection, and analysis, enabling pre-service teachers to apply their mathematical knowledge effectively in real-world contexts.
3. Creation
3.1 Brainstorming: The activity involves collaborative group work, where pre-service teachers with similar interests share their experiences in creating and utilizing innovations in teaching and learning. This activity emphasizes the exchange of successful practices, fostering deeper reflection, collective learning, and the practical application of effective strategies, with the goal of systematically enhancing mathematical problem-solving competency.
3.2 Sharing: The activity involves collaboratively observing and analyzing classroom activities led by pre-service teacher, focusing on practical implementation, reflection, and addressing feedback. This approach enables pre-service teachers to develop a deep understanding of instructional design and planning before applying problem-solving strategies in real-world contexts.
4. Implementation
4.1 Implementing and collecting: The activity emphasizes evaluation, feedback, and refinement to ensure that pre-service teachers' innovations are effective, contextually relevant, and practically applicable. By assessing outcomes and incorporating community input, students can identify strengths and weaknesses in their solutions, make necessary adjustments, and strengthen their problem-solving skills in real-world situations.
5. Reflection
5.1 Reflecting: This activity emphasizes internal, collaborative reflection and peer learning to deepen pre-service teachers' understanding of effective practices, promote critical thinking, and improve the quality and impact of their innovations. By exchanging experiences and analyzing practices collectively, students can identify strengths and weaknesses, learn from peers, and refine their approaches to better address real-world problems.

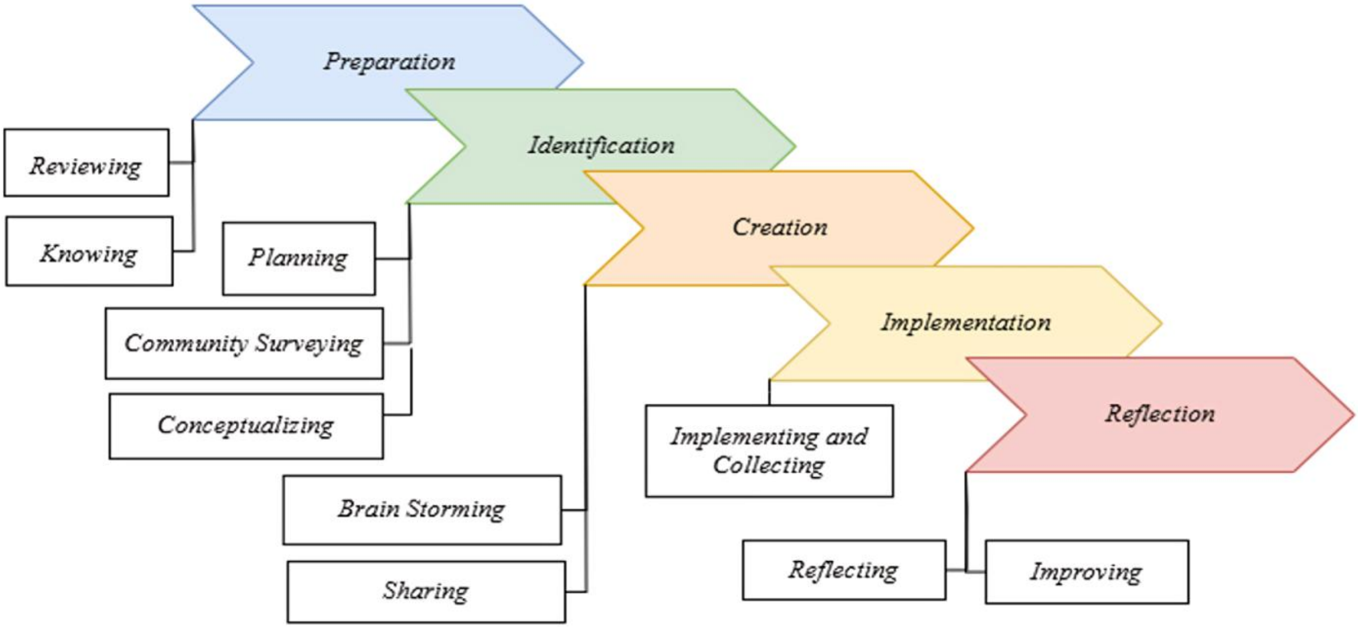

Figure 3. The CBL activity strengthens problem-solving competency of pre-service teacher (Source: Authors' own elaboration)

The findings of the research suggest that problem-solving skills among mathematics pre-service teachers can be improved practically by the learning activities constructed on the principle of a community-based approach. The study categorizes these activities into five core components, each comprising specific sub-activities, as outlined below:

- Preparation: Activities focusing on preparation of the mathematics pre-service teachers in terms of knowledge and experience prior to their taking the real community settings. Sub-activities include *reviewing* and *knowing*.
- Identification: Activities emphasizing community fieldwork to identify problems and analyze their causes in alignment with real-life contexts. Sub-activities include *planning, community surveying*, and *conceptualizing*.
- Creation: Engagement in community-based fieldwork aimed at identifying problems and analyzing the cause in an authentic context. Sub-activities include *brainstorming and sharing*.
- Implementation: Activities requiring mathematics pre-service teachers to engage with the community by applying their created innovations to solve problems in real-life contexts. Sub-activities include *implementing and collecting*.
- Reflection: Activities emphasizing reflective thinking about the procedures that have been performed, starting with the first steps to the final ones, inspiring self-reflection and assessment by the team to stimulate the constant learning and growth. Sub-activities include *reflecting* and *improving*.

DISCUSSION AND CONCLUSIONS

The activities were carefully designed to be implemented step by step according to the ADDIE model, in line with the needs of society, learners and all affected stakeholders. In addition, these activities are based on the basic principles of social learning: "learning to know", "learning to do", "learning to live together" and "learning to do" (Melaville et al., 2006). These activities are designed to bring the world of teachers and students closer to the real world of society enabling the teachers and students to relate, construct meaning, generate meaning of different opinions and determine the cause of different problems. This practice combines knowledge and concepts into a processual approach to developing new solutions. This leads to an increase in the problem-solving ability of the students because of these activities (Chung, 2019; Faozi et al., 2020; Kimonen & Nevalainen, 2020).

This study's originality lies in integrating the ADDIE model with CBL in mathematics education–a rarely documented approach for developing problem-solving competencies in community contexts. Combining structured instructional design with authentic, context-driven inquiry, the model moves beyond traditional classroom learning. As shown in **Table 2**, pre-service teachers' overall problem-solving scores improved from pre-test (mean [M]= 58.07, standard deviation [SD] = 16.01) to post-test (M = 85.75, SD = 15.94), with the most pronounced gain in the *formulate* aspect (77.13%). However, **Table 3** indicates that certain SAs–particularly *employ* (SA 2.1 = 55.00%, SA 2.2 = 43.61%)–remained relatively low, suggesting that while the approach strengthened some competencies, the ability to strategically apply these skills in varied contexts requires further development. Moreover, the most compelling evidence lies in the magnitude of the effect. Moreover, the calculated effect size (Cohen's d = 1.73) suggests a very large practical significance, indicating that participation in CBL activities had a meaningful impact on pre-service teachers' problem-solving competency. This large effect size provides strong evidence that CBL is a highly effective instructional strategy for enhancing problem-solving competency among pre-service teachers. It suggests that the experiential, real-world nature of CBL, which requires learners to identify, investigate, and solve complex challenges, is a potent catalyst for skill development. This is likely due to the active engagement and collaborative nature of CBL, which mimics the complexities of real-world problem-solving more effectively than traditional, passive learning methods (Savery, 2015).

In summary, integrating mathematical problem-solving competency with real-world problem-solving can be useful in enhancing the mathematical pre-service teacher understanding and motivating the pre-service teachers to learn mathematics. This would be an effective way to relate mathematics to community, social and cultural aspects, as abstract mathematical concepts would appear closer and easier to comprehend to mathematics pre-service teachers (Almarashdi & Jarrah, 2023; Stacey & Turner, 2015). In addition to this, it was also noted that in the teaching practice that involves contextual problems, the practice enables students to effectively fill the gap in their comprehension of the non-contextual mathematical activity (Manfreda & Hodnik, 2021). The study's findings indicate that teaching methods which incorporate cultural elements are well-received, enhancing motivation and engagement in the learning process (Jensantikul, 2021; Ritthikup, 2018). Also, CBL practices create a gap with learning mathematics by bringing about real-life challenges and cultural relevance. This creates a greater appreciation and appreciation of mathematics in the local culture and society (Gleason, 2018; Kendall, 2004). A learning approach that emphasizes applying knowledge to solve problems within the social and community setting does not only increase the knowledge base and problem problem-solving but also becomes a kind of social service-one that brings about a complete process of genuine learning, developing the life projects of students, and gaining an identity and meeting the practical needs related to an appropriate implementation (Conway et al., 2009; Torres et al.,2020). These findings have specific implications for education and suggest that integrating community, social, and cultural aspects into the curriculum can improve learning outcomes. It is related to learning and prior collaboration with the teacher (Melaville et al., 2006; Simswat, 2022).

The learning activities developed not only enhance the learning experience for pre-service teachers but also promote awareness and appreciation of the community, society, and culture. The implementation of these activities is highlighted in the possibility of relating the conceptual points to the practical applications that can cater to the needs of the community in a more comprehensive and relevant way. The results of this research are innovative as they combine the mathematical problem solving skills with the real world applications of the communities, thus, combining the academic knowledge with the real life applications (Fischer et al., 2009; Ritthikup, 2018; Turkkan & Karakus, 2018). This new method enables mathematics to be relevant and real life, it offers teachers with teaching resources that are responsive to the needs of society, and it yields data which will be used in the future designing of the courses and leads to positive results on pre-service mathematics teachers. It also gives significant evidence on the significance of exploring and resolving issues in society (OECD, 2013; Sholihah & Lastariwati, 2020). It was found that repeated hands-on practice, particularly within a practice-based model, and especially when the practice is guided by a clear viewpoint and objectives related to the community, can lead to meaningful development and foster professional growth (Hwang et al., 2018). The developed activities are innovative and build upon previous learning experiences by incorporating community contexts, societal influences, and cultural elements into the teaching of mathematical concepts. This approach enhances mathematical understanding while fostering social responsibility (Jalinus & Nabawi, 2018; Peterson, 2003). By bridging abstract and complex mathematical knowledge with tangible, real-world applications, students can better grasp its relevance and benefits. Additionally, it encourages a good attitude towards mathematics. This holistic educational methodology incorporates various learning dimensions in the community scenarios in terms of well planned activities. Finally, the work would add to the preparation of mathematics teachers by demonstrating how teachers can create learning activities that are both academically rigorous, culturally responsive, as well as socially impactful- closing the gap between theory and practice in a manner that would not only support educational, but also societal needs.

Recommendations

It is important to amend and adapt the particulars of the activities according to their aims and the setting using research findings and adapting them to the current needs. Particularly, the initial phases-particularly, those focusing on the *formulate* component- must consist of structured content in core fields of mathematical problem-solving such as gathering and analysis of data, contextual modeling, and choice of strategy. For activity 2 (*identification*) and activity 3 (*creation*), which operate within community-based contexts, careful consideration must be given to the cultural relevance, resource availability, and logistical constraints of the target community. Furthermore, this study was conducted within Thai teacher education programs and local Thai communities, and it might be difficult to apply the model to other cultural or institutional settings, such as variations in curriculum standards, patterns of teacher preparation, and systems of community engagement. In future studies, it is necessary to research its scalability, evaluate its implications on solving a problem in the long term, and compare its effectiveness to other instructional models to establish its wider applicability.

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