J-IAMSTEM
Journal of Innovation, Advancement, and Methodology in STEM Education
Vol. 2, No. 6, pp. 504-525, November-December 2025
https://so13.tci-thaijo.org/index.php/j_iamstem

Reflecting on Feedback: How Formative Feedback Shapes Pre-Service Science Teachers' Pedagogical Content Knowledge of Inquiry from Context-Based STEM Lesson Designs

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Received: 23 Sep 2025 Revised: 30 Dec 2025 Accepted: 31 Dec 2025

Abstract. This study addresses a persistent gap in teacher education, namely the limited empirical understanding of how structured formative feedback influences pre-service science teachers' design and revision of inquiry from context-based STEM lessons. The study utilized a feedback process combined with reflection to develop Pedagogical Content Knowledge (PCK) for STEM education. The participants consisted of 11 groups of science teacher students. Data collection instruments included inquiry from context-based STEM learning lesson plans, teacher reflection logs, and semi-structured interviews. Data collection was conducted 44 hours according to the feedback and revision process. They received targeted formative feedback informed by a validated rubric (knowledge of subject matter and curriculum relevance, instructional strategies, students' understanding and practice, student assessment, technology and engineering design process). Data analysis involved descriptive summarization and qualitative evidence interpretation. Qualitative data comprise reflective journals and semi-structured interviews analysed via thematic coding. The research findings revealed that a systematic feedback process effectively helped teacher students improve their design of STEM learning design, particularly in knowledge of subject matter and curriculum relevance and connecting scientific principles to real-life problem situations, such as PM2.5 dust problems, turbid tap water issues, or the use of solar energy for fruit drying. Furthermore, students showed an enhanced understanding of designing inquiry steps, creating prototypes, and incorporating community contexts as the basis for learning. However, knowledge concerning learner understanding and assessment for learning development still requires additional reinforcement. The study contributes novel empirical evidence and a pragmatic rubric for linking formative feedback to concrete design improvements, offering methodological advances for evaluation and practical guidance for integrating the iterative feedback cycle into teacher education to strengthen preservice science teachers' capacity to design inquiry-rich, contextually meaningful STEM learning experiences.

Keywords: Formative feedback, Inquiry from context-based STEM, Pedagogical Content Knowledge (PCK), Pre-service science teacher

1. Introduction

STEM education has been promoted as a national strategy in Thailand to develop 21st-century skills in learners. It is believed that STEM education, in addition to developing 21st-century skills, can also stimulate learners' innovative knowledge because STEM education connects and applies theoretical knowledge to real-life situations. STEM education is not merely about transmitting knowledge in science, technology, engineering, and mathematics; instead, it is a learning management approach that aims to stimulate innovative knowledge, focusing on concretely connecting and applying theoretical knowledge to real-life situations and problems (NESDC, 2019; Yuenyong, 2019). STEM education is recognized as the most effective method to promote quality 21st-century citizenship skills, enabling learners to possess the necessary skills to apply knowledge appropriately. The heart of STEM education not only teaches problem-solving methods but also teaches learners skills such as critical and analytical thinking, creative thinking, communication, time management, collaboration, decision-making, and complex problem-solving. These skills collectively are known as "soft skills," which are crucial for success in the modern world (McDonald, 2016; Moore & Smith, 2014).

STEM education is a multidisciplinary approach that emphasizes practical design processes to enhance content and practice by integrating everyday contexts of science and mathematics through technological and engineering processes (Chesky & Wolfmeyer, 2015). A fundamental perspective of STEM education emphasizes learner-centered learning, focusing on practical knowledge and skills rather than just factual knowledge (Williams, 2019). STEM education activities involve problem-solving processes within the social context of real-world situations. Learning in this manner does not aim for learners to simply memorize facts but to experience knowledge through hands-on activities, critical thinking, and problem-solving in authentic social contexts, while also promoting innovation and entrepreneurship (Roehrig et al., 2021; Williams, 2019; Yuenyong, 2019).

In reality, despite the critical importance of STEM education, its implementation in Thailand still faces significant obstacles and challenges, particularly concerning teachers. The practical application of STEM learning management in Thai classrooms requires further development to ensure that teachers possess the knowledge and ability to manage and assess learning effectively (Shernoff, Sinha, Bressler, and Ginsburg, 2017). Firstly, teachers still have misconceptions about STEM learning management. Some teachers may view it merely as teaching separate STEM subjects or lack a true understanding of integration, leading to activity designs and learning management that deviate from the original objectives (Vichaidit & Faikhamta, 2017; Sohsomboon & Yuenyong, 2023).

Secondly, many teachers lack expertise in designing and evaluating STEM activities, especially those that emphasize problem-based learning, which is a core component of this educational approach. The problems used must be authentic real-life problems relevant to the students' daily lives (Sutaphan and Yuenyong, 2019). Pre-service teachers must urgently develop themselves to possess the vision, knowledge, and skills aligned with educational trends that promote 21st-century skills. The STEM education approach emphasizes problem-based learning, where problems introduced in the classroom encourage learners to apply knowledge to find answers or solutions. These problems are real-life societal issues related to the students' daily experiences. By practicing problem-solving, learners develop essential skills and competencies for life in the 21st century (Sutaphan and Yuenyong, 2019).

Thirdly, teachers still lack Pedagogical Content Knowledge for STEM education (PCK-STEM). Teachers must not only know STEM subject content but also thoroughly understand "how to teach" that content within the STEM context. This ensures that learners can truly construct understanding and develop themselves. Without strong PCK-STEM, learning management becomes soulless "STEM." Therefore, it is crucial for teachers to possess knowledge and understanding of Pedagogical Content Knowledge for STEM education (PCK-STEM) to ensure effective learning management and achieve the objective of developing learners' skills to become quality 21st-century citizens

Amidst these challenges, in the context of developing teachers to effectively design and manage STEM learning, providing feedback is considered one of the most important and effective strategies for learning development (Duijnhouwer et al., 2012; Omilani & Ogbonna, 2023). Feedback is a form of formative assessment during instruction to measure progress and promote learning development (Sohsomboon & Yuenyong, 2021). It is a non-judgmental, developmental assessment that allows teachers to reflect on themselves, learn from experience, and continuously improve. It aims to reinforce and develop learners' knowledge and skills, a process in teaching and learning that involves presenting information after learners respond to initial instruction. When feedback is provided to facilitate improvement and development, it maximizes the effectiveness of learning management. Understanding and providing feedback to help learners improve and develop by facilitating reflective discourse in designing STEM learning management is crucially important because the reflective process serves as a guide for evaluating ideas, helping to recognize areas needing improvement and leading to the development of suitable STEM lesson plans for the learning context, ultimately maximizing effectiveness for learners in STEM education (Duijnhouwer et al., 2012; Omilani & Ogbonna, 2023). If students recognize and strive to improve based on the feedback received, it can lead to maximum effectiveness for learners in those specific contexts. The reflective process that arises from receiving feedback is a guideline that helps evaluate one's own ideas, leading to awareness of areas needing development and the creation of highly effective STEM lesson plans for learners. When pre-service teachers receive guidance and opportunities to revise based on feedback, it becomes a crucial factor in helping them develop the necessary skills and knowledge to truly design learning management that meets the demands of STEM education. Ultimately, this will have a positive impact on the development of students' skills in the classroom

Therefore, this research is of great importance, focusing on reflecting the results of feedback on the design of inquiry-based STEM learning management by science pre-service teachers who have been trained and have actively designed these activities. This research is more than just collecting data to merely "know what happened"; it aims to deeply understand:

1) Pre-service teachers' concepts and understanding: How they understand the principles and concepts of inquiry-based STEM learning management design, and how their understanding changes after receiving feedback.

2) Obstacles and opportunities for development: What challenges do pre-service teachers encounter in their design, as revealed by feedback, and how does that feedback promote or create opportunities for development?

3) Approaches to aid development: The research findings will lead to the development of more appropriate training guidelines or curricula to optimally enhance pre-service teachers' potential in designing inquiry-based STEM learning management in the future.

Thus, this study is not merely an academic study but a part of a systemic problem-solving effort to create teachers with the greatest potential to lead Thai education towards fostering 21st-century citizens. It aims to reflect on the results of feedback on the design of inquiry-based STEM learning management by science pre-service teachers who have undergone training in designing such activities, to understand their concepts and comprehension of learning management design, and to guide the further and more effective development of pre-service teachers' ability to design inquiry-based STEM learning management.

2. Materials and Methods

A qualitative research design was employed in this study, utilising an interpretative case study approach with an ethnographic document analysis (Cohen et al, 2011) orientation to examine how formative feedback influences pre-service science teachers' Pedagogical Content Knowledge for STEM education (PCK-STEM) through inquiry from a context-based design perspective. The interpretative paradigm is suitable for this research, as it aims to investigate participants' meaning-making and design reasoning across iterative feedback and vision cycles (Taylor et al., 2012). To provide systematic measures of change, qualitative analysis was complemented by rubric-based scoring Gardner & Gess-Newsome (2011) of PCK-STEM dimensions.

2.1 Participants and study context

The Participants consisted of 33 third-year science education students from the Faculty of Education, Nakhon Phanom University, who were enrolled in the course "Design of Learning Management for Science Learning Area at Secondary Level," module in 2024. The general context of the sample group is that these students are general science teacher students in a 4-year program, with practice teaching opportunities in their third and fourth years.

The curriculum requires students to take courses related to science learning management at both primary and secondary levels in their third year. This prepares them for professional teaching experience and practical teaching in schools. The course syllabus of the "Design of Learning Management for Science Learning Area at Primary Level," "Design of Learning Management for Science Learning Area at Secondary Level," are fairly similar, but different in the context of students in primary and secondary level. However, in the course of "Design of Learning Management for Science Learning Area at Primary Level," the participants studied with another instructor in Science Education divion, facuty of Education, Nakhon Phanom University. This indicates that it was the students' first time learning about inquiry from context-based STEM education, and also their first time learning from the researcher as an instructor.

2.2 Materials for data collection

The data was collected from the STEM lesson design (initial, revised and final versions), regarding Inquiry from context-based STEM education from Sutaphan and Yuenyong (2019) which consist of seven stages 1) Identification of social issue stage 2) (Identification of potential solution stage) 3) Need for knowledge stage 4) Decision - making stage 5) Development of prototype or product stage) 6) Test and evaluate the solution 7) Socialization and completion decision stage. Instructor formative feedback (written annotations, structured feedback template), reflection form completed after each cycle, semi-structured interviews, and PCK for STEM scoring rubric. A PCK for STEM scoring rubric comprise five components adapted from Gess-Newsome (2025): 1) Knowledge of subject matter and curriculum relevance, 2) Knowledge of instructional strategies, 3) Knowledge of students' understanding and practice, 4) Knowledge of student assessment, and 5) Knowledge of technology and engineering design process (Sohsomboon & Yuenyong, 2006), which shown in . Each component employed a three-level performance scale with explicit descriptors. All research data collection instruments (PCK for STEM scoring rubric, reflection form, interview guide) were iteratively refined through expert review.

2.3 Learning activities of the module

The learning management for the course "Designing Learning Management for the Science Learning Area at the Secondary Level," spans 16 weeks for a total of 64 hours. The structure of the learning management is as in Table1.

Table 1: Learning activities of the module

Week	Learning Activities
1-4	**Objective:** Develop a strong understanding of designing STEM education learning management using an inquiry-based contextual approach, drawing upon the framework by Sutaphan and Yuenyong (2019). **Activities:** -Study and analyze learning standards, indicators, and core science curriculum content relevant to societal issues. -Research and analyze contemporary social issues suitable for developing inquiry-based contextual learning experiences. -Present and discuss potential social issues for learning design, incorporating feedback for refinement.
5-6	**Initial Design & Conceptualization** **Objective:** Design the initial framework for inquiry-based contextual STEM education learning management. **Activities:** -Design the foundational steps of inquiry-based contextual STEM education, focusing on identifying social issues (Step 1), aligning with learning standards and indicators (Step 3), and prototyping problem-solving solutions (Step 5). -Present design concepts, engage in discussions, and integrate peer feedback for improvements.
7-10	**Developing Learning Management Plans** **Objective:** Create comprehensive inquiry-based contextual STEM education learning management plans. **Activities:** -Develop detailed inquiry-based contextual STEM education learning management plans. -Present the developed plans, discuss their components, and revise based on constructive feedback.
11-12	**Considering and designing for Scaffolding for problem-solving** **Objective:** Shape the ideas of approaches or methods for using media and innovations in learning management for scaffolding students in learning science and problem-solving. **Activities:** -Explore and conceptualize media and innovative tools for effective scaffolding in science learning and problem-solving. -Practice to design approaches or methods for using media and innovations in learning management for scaffolding students in learning science and problem-solving. -Present and discuss these scaffolding approaches, refining them based on group discussion and feedback.
13-14	**Designing Authentic Assessments** **Objective:** Design effective assessment strategies that promote and measure 21st-century skills development in science learning. **Activities:** -Explore and conceptualize ideas for designing science learning assessments that foster 21st-century skills. -Practice developing detailed Scoring Rubrics specifically designed to assess these skills within science learning management. -Present the designed Scoring Rubrics, engage in discussions, and revise them based on critical feedback.
15-16	Micro-teaching **Objective:** Apply and refine developed learning management plans through practical micro-teaching sessions. **Activity:** Deliver micro-teaching sessions, integrating all learned principles and designs.

2.4 Pedagogical Content Knowledge for STEM Education

The conceptual framework for developing Pedagogical Content Knowledge for STEM Education (PCK for STEM Education) (Sohsomboon & Yuenyong, 2026), which was developed from Gess-Newsome's (2015) conceptual framework for developing science pedagogical content knowledge, has 5 components as shown in Table 2.

Table 2: Scoring rubrics of PCK for STEM Education

Excellent	Good	Fair
1) **Knowledge of subject matter and curriculum relevance** refers to the teacher's good understanding of the content, goals, and objectives of each subject, and the related emotional skills to be applied in problem-solving practice in the specific context of daily life.		
The teacher has a very good understanding of the content, goals, and objectives of the subject matter and emotional skills. They can design and present the connections between goals and objectives, content knowledge, and emotional skills with their application or practice to situations or issues in daily life.	The teacher has a good understanding of the content, goals, and objectives of the subject matter. They can find connections between the goals and objective knowledge and their application or practice to situations or issues in daily life.	The teacher has a good understanding of the content, goals, and objectives of the course in terms of crystallized knowledge and is ready to apply curriculum knowledge. They have problems applying this knowledge in the problem-solving process related to daily life issues.
2) Knowledge of instructional strategies -Basic knowledge of designing appropriate and suitable activities that engage students in problem-solving in real-life contexts or situations. -Ability to use appropriate teaching strategies related to constructivist teaching to help students overcome obstacles at each step of the problem-solving process, and to use appropriate teaching materials to connect learners to the subject matter and its application in problem-solving situations. -Basic knowledge and skills in designing and selecting teaching strategies to support students' soft skills.		
The teacher can design and use appropriate teaching strategies and instructional materials to engage students in the problem-solving process, considering the design and use of teaching strategies to support students' soft skills, and can design appropriate teaching strategies to support students' problem-solving practice at each step.	The teacher can design and use appropriate strategies and instructional materials to engage students in the problem-solving process. They consider designing and using teaching strategies to support students' soft skills but cannot design appropriate teaching strategies to support students' problem-solving practice at each step.	The teacher can design and use appropriate teaching strategies and instructional materials to engage students in the problem-solving process. They cannot design and use teaching strategies to support students' soft skills. They cannot design appropriate teaching strategies to support students' practice in the problem-solving process.
3) **Knowledge of students' understanding and practice** The teacher has knowledge, understanding, and practical experience with students. The teacher has knowledge of the needs and difficulties of each student in developing knowledge and abilities to practice through the problem-solving process.		
The teacher considers and can stimulate and understand students' needs and the difficulties of the skills required for the problem-solving process. They can identify the necessary skills to help each student strive for success at each step of the problem-solving process.	The teacher considers the understanding and practice of students but has difficulty (misconceptions) in identifying the needs and complexities of each student in developing the ability to practice through the problem-solving process.	The teacher considers the importance of student understanding but does not practice skills or practical skills. It appears that the teacher focuses student understanding only on crystallized knowledge (misconceptions).

Excellent	Good	Fair
4) **Knowledge of student assessment** -Knowledge of selecting appropriate assessment methods to evaluate students' learning about the nature of STEM education, emphasizing the learning process and knowledge practice. -Knowledge of designing appropriate learning materials to assess students' learning regarding the goals and objectives of STEM learning. -Knowledge to decide where and when to assess student learning.		
The teacher considers formative assessment to evaluate students' learning processes and practice. They can design appropriate instructional materials to assess students' learning regarding the goals and objectives of practicing through the problem-solving process. Assessment materials are appropriately designed to stimulate students' abilities to do things at each step of problem-solving related to the goals and objectives of that practice activity.	The teacher considers formative assessment to evaluate students' learning processes and practice. They intend to design instructional materials to assess students' learning regarding the goals and objectives of practicing through the problem-solving process but have difficulty designing and using appropriate assessment tools and materials for practice. For example, at some steps, assessment tools and documents may not align with the goals and objectives of the practice process.	The teacher intends to design instructional materials to assess students' learning regarding the goals and objectives of practicing through the problem-solving process but has a misunderstanding about formative assessment. For example, they intend to assess students' understanding and ability summative rather than intending to improve students' practice.
5) **Knowledge of technology and engineering design process** refers to the nature of technology and engineering design processes as a norm for optimizing problem-solving processes related to human needs. The ability to conceptualize human needs can lead to knowledge and entrepreneurial skills.		
The teacher understands the nature of technology and engineering design processes for entrepreneurship. The teacher considers the norm of optimization for problem-solving processes related to human needs and connects it with entrepreneurship.	The teacher understands the nature of technology and engineering design processes for human-needed problem-solving. The teacher considers the norm of optimization for problem-solving processes related to human needs.	The teacher understands and considers the importance of the nature of technology and engineering design processes but focuses only on problem-solving processes unrelated to human needs.

2.5 Data collection

There were a total of 33 students, and the instructor assigned them to groups of 3 students each, making 11 groups in total. The students formed their groups voluntarily.

The data was collecting from the design of STEM education learning activities according to the inquiry-based approach in the context of Sutaphan and Yeunyong (2019) from lesson plans, reflections, and improvements to lesson plans from week 4-14, spanning 44 hours. This involves analyzing feedback given by instructors to students and considering issues that led to improvements and corrections by students, as well as conducting follow-up (in-depth) interviews on interesting topics. Students work reflections basesd on scoring rubrics of PCK for STEM Education in Table 2. Additionally, micro-teaching in weeks 15-16, during which the instructor assessed their overall competence in STEM education learning management based on their teaching practice.

Knowledge of subject matter and curricular relevance mainly interpreted from the relevence of indicator from science core curriculum with knowledge practting in lesson plan and the implication and content knowlwdge for practicing in problem solving process. The data was collected from the coherence of activity and curriculum in lesson plan and the science pre-service teacher understanding from reflecting, lesson plan, and interview.

Knowledge of instructional strategies was interpredted from the process of teaching throughout lesson plan and interview.

Knowlwdge of students' understanding and practice was mainly interpreted from considering and designing for scaffolding for problem-solving activities in week 11-12.

Knowledge of student assessment was generally interpreted from designing authentic assessments activities in week 13-14.

Knowledge of technology and engineering design process was interpreted from the science pre-service teachers' consideration of the process of knowlwdge implication for problem-solving the real world sitauation and the ideas of entrepreneurship.

2.5 Data analysis

The data analysis employed qualitative analysis; coding, thematic and descriptive analysis (Cohen et al., 2011; Creswell, 2002). A deductive coding frame based on the five PCK for STEM scoring rubrics (Table 2). Thematic analysis identified patterns linking feedback to specific revisions and conceptual changes.

Trustworthiness was maintained via peer debriefing, triangulation across data sources (lesson plan, feedback, interview), member checking of the interview transcripts and emergent interpretations, and a documented audit trail of coding decisions and instruments. The data analysis continued until thematic saturation was reached (Lincoln & Guba (1985).

2.6 Ethical considerations

The ethics issue for humane research was considered in this study. The ethics approval was obtained, and informed consent was secured from The Research Ethics Committee of Nakhon Phanom University Ethics Committee in Human Research, Thailand authority ethics review processes number HE4968 on the Declaration of Helsinki and the ICH Good Clinical Practice Guideline. Participants were fully informed about the study's objectives, procedures, and their rights, including the right to withdraw at any point, and provided their consent for data collection. All collected materials were then anonymized, stored in a secure location, and systematically destroyed after the analysis was concluded

3. Finding

This research is a study to promote the design of STEM education learning management based on the inquiry-based approach in the context of Sutaphan and Yuenyong (2019) for science teacher students at the Faculty of Education, Nakhon Phanom University. The method used was providing feedback for students to reflect on in developing their STEM education learning management design. The data collected included the STEM education learning management plans developed by students following the inquiry-based approach using context as a base, feedback from the instructors, and revisions made based on the instructors' feedback, as well as semi-structured interviews. The researchers analyzed the data and presented the results of the analysis as following sequential

3.1 Summary of the lesson plan design

The conclusion in this section is the final result where students designed STEM education learning activities using an inquiry-based approach according to the context of the problem, relevant theoretical principles, and prototypes or systems for problem-solving. All 11 student groups completed the design of their STEM education learning activities up to the final stage. There were revisions or changes to the topics or issues in the activity design along the way, due to suggestions and discussions between students and the instructor, who was also the researcher, the problem statements, relevant theoretical principles, and prototypes or systems for problem-solving for all 11 student groups are shown in **Table 3**.

Table 3: Summary of STEM education learning activity design result using an inquiry from context-based STEM approach

Group	Problem Statement	Theoretical Principles in Curriculum	Prototype or System for Problem Solving
SPT1	News from Thai-PBS about the flood situation from the overflowing Mekong River in Ban Phaeng District, Nakhon Phanom Province, in September 2024.	Impacts of floods. Coastal erosion.	Develop a prototype of a flood barrier to prevent overflow from the Mekong River into residential and agricultural areas.
SPT2	Boat sinking incident at Huai Kok Khoon Reservoir, Nakhon Phanom Province.	Buoyancy and sinking. Floating of objects in liquid.	Develop a boat prototype, specifying its shape, construction materials, and passenger seating plan.
SPT3	Nakhon Phanom Province is primarily an agricultural area, leading to situations of fruit oversupply.	Chemical reactions.	Production of fruit jam with pectin.
SPT4	Low pineapple prices in several districts of Nakhon Phanom Province.	- Heat transfer by conduction, convection, and radiation. - Design, select, and build equipment to solve daily life problems using knowledge of heat transfer.	Electric oven or solar dryer for drying fruit and making processed fruit products.
SPT5	Persistent issues with the quality of tap water in Ban Noen Sa-ard, Mueang District, Nakhon Phanom Province, which is turbid, reddish, and has an unpleasant odor, with no resolution.	Apply separation methods in daily life by integrating science, mathematics, technology, and engineering.	Design a water filter to resolve issues of turbidity, redness, and unpleasant odor for household consumption.
SPT6	Nakhon Phanom is a province that promotes indigo-dyed fabric. Situation regarding faded fabrics and the desire for fabric dyeing.	State the functions of different parts of human, animal, and plant bodies (Grade 1)	Design fabric dyeing using natural colors.
SPT7	Flood situation from the overflowing Mekong River in Mueang District, Nakhon Phanom Province, in September 2024.	Impacts of floods. Coastal erosion.	Find solutions such as building a drainage system or water barriers.
SPT8	Students at sports schools in Nakhon Phanom Province require appropriate nutrient intake to meet their daily energy needs.	Nutrients. Appropriate energy and nutrient proportions for gender and age.	Design a one-week meal plan suitable for the energy expenditure of sports school students.

Group	Problem Statement	Theoretical Principles in Curriculum	Prototype or System for Problem Solving
SPT9	News reports warning from the FDA about exaggerated advertising claims for soap, which may illegally contain prohibited or harmful substances.	Design solutions for daily life problems using knowledge of chemical reactions, integrating science, mathematics, technology, and engineering.	Design a herbal soap formula.
SPT10	Problems faced by gardeners with high prices of chemical fertilizers and negative long-term effects of continuous use, such as soil degradation.	Nutrients that affect plant growth, and selecting appropriate nutrients for plants in a given situation.	Design a formula and develop natural fertilizers suitable for the growth of specific plant species.
SPT11	Fuel energy shortage, with natural gas imports leading to significantly increased electricity production costs.	Explain energy changes and transfer related to solar cells.	Design materials, equipment, and tools for farm use, along with an explanation of their functions.

SPT stands for Science Pre-service Teacher, referring to science teacher students. The numbers after SPT indicate the sequence or order.

Eleven groups of students designed STEM activities based on real-world problems in Nakhon Phanom province. They connected these contexts with principles and theories from the science core curriculum and developed prototypes/problem-solving systems.

Examples of contexts included flood situations and water safety, quality of potable water, agricultural product oversupply and value addition, athlete nutrition, chemical product safety, natural textiles/dyeing, and solar energy.

The principles applied covered the effects of floods and erosion, buoyancy, heat transfer, substance separation, chemical reactions, plant nutrients, and energy conversion/transfer.

Proposed solutions included water barriers or drainage systems, boats and seating arrangements, electric or solar-powered fruit dryers, water filters, fruit jams, herbal soap formulas, natural fertilizer formulas, weekly nutrition menus, and solar-powered farm equipment. This reflects the integration of science, mathematics, technology, and engineering to create solutions aligned with community contexts.

3.2 Summary of pedagogical content knowledge for STEM education

The PCK for STEM education of SPT2, 3, 6, 7, 8, 9, and 11 will not be reported as their competencies could not be effectively assessed due to insufficient information. For example, SPT2, 7, and 11 did not submit complete reflections on their learning management, so their development paths will not be analyzed, as they are considered not to have fully followed the research. SPT9 failed to submit work related to student promotion. Group 8's design lacked continuity. For SPT3 and 6, the knowledge required to solve problems from the problem situation and the knowledge presented by the students according to the indicators in the core curriculum were inconsistent. Specifically, SPT3 wanted students to make jam, which should involve knowledge of jam-making methods and pectin, but the students connected it to the topic of chemical reactions. For SPT6, the situation involved faded fabric requiring dyeing, but the identified indicator was "Grade Grade1 tells the functions of different parts of the human body, animals, and plants." Additionally, the scope of the subject's learning management was at the secondary level, but the students presented primary level indicators, which showed an inconsistency.

Summary of pedagogical content knowledge for STEM education from completed worked science pre-service teacher was shown in **Figure 1**.

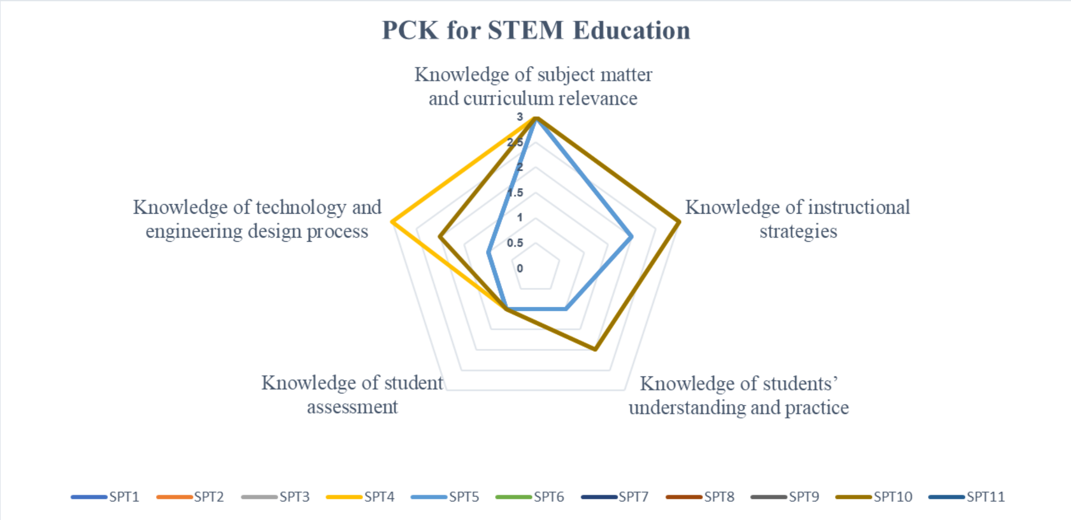
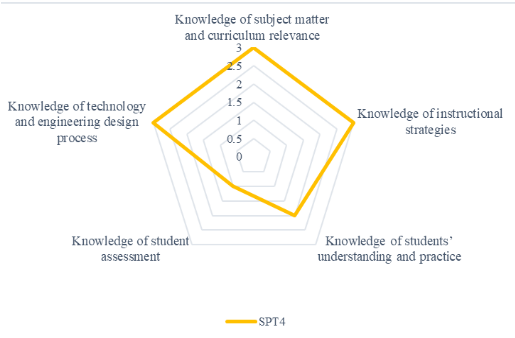
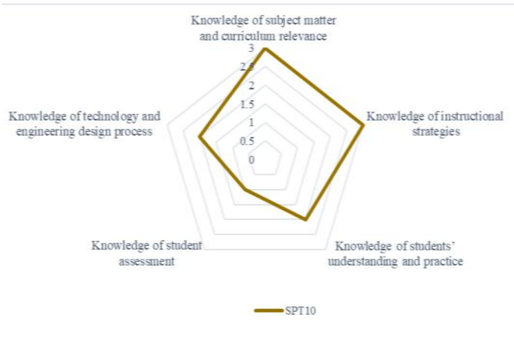


Figure 1: Summary of Pedagogical Content Knowledge for STEM Education

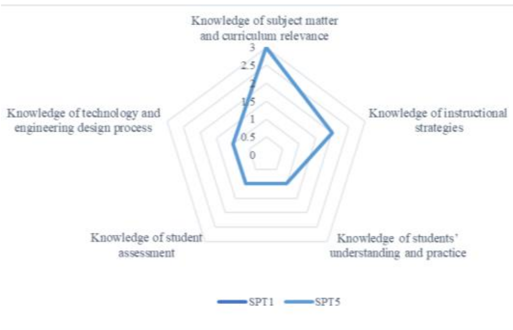
From Figure 1, the summary of Pedagogical Content Knowledge for STEM education can be found in three patterns as follows:



Pattern A



Pattern B



Pattern C

Figure 2: Three patterns of science pre-service teacher PCK for STEM

3.3 Pedagogical content knowledge (PCK) for STEM education

This section will explain the guidelines for assessing science pre-service teachers' PCK for STEM education which will exemplify one example from pattern A.

3.3.1 Pedagogical Content Knowledge for STEM from pattern A

Pedagogical Content Knowledge for STEM from pattern A (Figure 2: Pattern A) received Excellent knowledge of subject matter and curriculum relevance, Excellent Knowledge of instructional strategies, Good Knowledge of students' understanding and practice, Fair knowledge of student assessment, and Excellent knowledge of technology and engineering design process. The students who developed PCK for STEM education in this pattern was SPT4.

Initially, the students presented their concept for creating a fruit dryer machine implementing the knowledge of heat transfer from science core curriculum. At first, the SPT4 presented a general intention of making the fruit dryer machine without explaining the specific situation or issue related to the prototype. The situation they brought in was the overall situation about fruit in the country.

To develop the inquiry from context-based STEM learning activity, the researcher asked the students the following questions:

Instructor: Why did you decide to design an activity on this topic?

SPT4-1: We looked for topics from the curriculum and were familiar with this topic (heat transfer). Also, we saw that many districts in Nakhon Phanom grow a lot of pineapples, so we decided to design this activity.

Instructor: Oh, that's interesting. But why do farmers need this (fruit dryer)? What is the problem?

SPT4-2: I think the problem is that there are a lot of pineapples in the market, which makes the price of pineapples very low, about 5-10 baht per kilogram.

Instructor: OK, but how will the prototype help farmers in this situation?

SPT4-1: So, I thought that processing (drying) the pineapples would add value, and they could probably be sold at a higher price.

Instructor: Very good! So, what does the prototype (fruit dryer) look like?

SPT4-3: We will assign the students to design what kind of fruit dryer they want.

Instructor: Yes, the students will design it, but what about the prototype in your imagination? There are many kinds of fruit dryer machine like electronic one or solar one. The shapes are also different. What kind of fruit dryer machine you would like students to make? We should have a picture of the prototype in mind so we can guide the students' practical work for them to design.

SPT4-3: Yes, teacher, I understand. We will design a draft of the fruit dryer prototype first.

Instructor: Excellent, dear! Now, let's try to adjust it.

From the discussion, the researcher probe SPT4 to specify the social situation and require to elaborate the situation related closer to the local or students' context asking about the problem of the situation. Another important point was that the guideline for students' practice of making fruit dryer machine, they need to have ideas and understand the process of making it in order to be able to assist students to design and assemble the machine. The SPT4 students wrote reflections as in **Table 4**.

Table 4: SPT4 reflection of developing social issue and prototype

Inquiry from context-based STEM	Activity	Reflection
1.Identification of Social Issues	Write an explanation of a social issue that can serve as a problem prompt for students, so they can use curriculum content to design ways to solve that problem. Teacher presents the social issue. Students and teacher discuss the guiding questions.	**Instructor:** Provide a clear conceptual framework for the social issue so students understand what problem they must solve. **SPT4:** Add question prompts that help students become aware of the problem.
2.Identification of potential solution		
3.Need for Knowledge	Prepare science, mathematics, or other curriculum-based learning activities; prepare tools, frameworks, or skills needed to design solution approaches. Students conduct experiments on heat transfer and jointly discuss the results. The set includes three activities: Activity 1: Conduction Activity 2: Convection Activity 3: Radiation	**Instructor:** Provide additional knowledge about engineering design. Provide additional knowledge about processing. **SPT4:** Add activities that allow students to apply their knowledge of heat transfer to solve the problem. Add knowledge about instrument/tool-use skills.
4.Decision-making		
5) Development of prototype or product	Develop prototypes, protocols, or systems according to the chosen design. During prototype development, students may seek additional help from partners, experts, or others. Students draft a model along with the equipment used to solve the problem.	**Instructor:** Provide sample drafts/models to make the ideas concrete. **SPT4:** Give illustrative examples, e.g., students might design a box for processed fruit to increase product value. Students can search for product information from online sources and adapt it.
6) Test and evaluate the Solution		
7) Socialization and completion decision stage		

From that conversation the SPT4 Revise their social issue expanding and emphasize the local problem of pineapple form farmer in Nakhon Phanom province.

The teacher presents the issue of low pineapple prices in Nakhon Phanom Province due to market oversupply and insufficient factory capacity, as reported by Post Today. The content is as follows:

ที่มา : https://www.posttoday.com/politics/551919

Figure 3: News about pineapple in Nakhon Phanom province

> "As of May 26, 2018, Maj. Gen. Somchai Khrappachai, Commander of the 210th Military Circle in Nakhon Phanom Province, ordered military personnel to assist farmers in Phon Sawan and Tha Uthen districts with transporting pineapples to market. Farmers were suffering from the lowest pineapple prices in a decade—down to 2–3 baht per kilogram from the usual 8–10 baht—resulting in losses because of high transport costs, with production costs at 3 baht per kilogram.
>
> Phon Sawan and Tha Uthen are well-known areas for growing sweet pineapples in Nakhon Phanom, with over 8,000 rai under cultivation. However, during the harvest period, the market is flooded with produce, causing prices to drop. Currently, Nakhon Phanom Province, together with relevant agencies, has set up seven pineapple sales points in Mueang Nakhon Phanom District and is campaigning for the public to help purchase to distribute the produce. Peeled pineapples are sold at 8–10 baht per kilogram.
>
> Kasem Raksujarit, the Nakhon Phanom provincial agriculture officer, said that during the harvest season this area can harvest 50 tons of pineapples per day, and it is expected to reach 70 tons in June. This is a key factor in the price decline because the market is oversupplied and there are no processing plants or sufficient capacity to absorb the produce. Therefore, the province, in cooperation with various agencies, is adding more sales points and publicizing to encourage the public and tourists to help buy, as well as planning long term for farmers to manage production so it does not come to market all at once during the season, in order to reduce the oversupply problem."

From that conversation the SPT4 had tried to design the prototype of fruit drying machine.

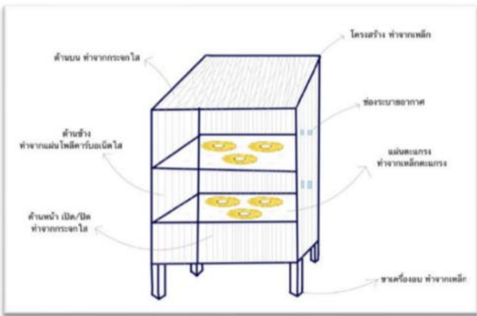


Figure 4: The prototype of solar fruit dryer machine

Regarding SPT4 writing reflection and the revise version of their work, it could be implied that the students understand very well of what they have to improve; expanding the social situation and specifying closer to the local, get an idea of the prototype to guide students' practice.

After that the students required to develop lesson plan regarding inquiry from context-based approach (Sutaphan and Yuenyong, 2019).

Students were shape the ideas about scaffolding students through problem-solving process. Then students design scaffolding through the problem-solving process as shown in **Table 5.**

Table 5: SPT4 ideas of the scaffolding

Inquiry from context-based STEM	Activities	Scaffolding (Promoting Self-Directed Learning) — ZPD
1. Identification of Social Issues	- The teacher introduces the real-world problem of low pineapple prices in Nakhon Phanom due to oversupply and limited processing, citing a relevant news report (e.g., PostToday). - Students individually complete Worksheet 1, outlining initial thoughts on approaches to solving the low pineapple price problem in the community.	-The teacher uses engaging visuals (images) and provides a concise summary of the news to contextualize the problem. -Through a guided discussion, the teacher prompts critical thinking with questions like: 1. "Why do you think pineapple oversupply is happening?" 2. "If we could help farmers reduce spoilage, what broader impact might that have?" (Encouraging students to move from problem identification to potential impact).
2. Identification of Potential Solutions	- Students, in groups, research existing methods of pineapple processing and value addition used by farmers in Tha Uthen district, Nakhon Phanom, using internet or other provided learning resources. - Groups brainstorm and conceptualize various ways to design pineapple processing methods that extend shelf life. - Groups then share and refine ideas, specifically discussing how principles of heat transfer could be applied for efficient processing and increased value.	-The teacher acts as a facilitator, guiding students towards relevant resources. -The teacher introduces the concept of a solar dryer as a suggestion, framing it as an energy- and cost-saving option, but allows students to explore other ideas first. This provides a "just-in-time" hint to nudge their thinking without giving them the answer.
3. Need for Knowledge (Experimental Inquiry)	Groups conduct experiments to explore heat transfer principles, discussing their findings: - **Activity 1: Conduction** (Objective: Explain heat transfer in a metal plate). - **Activity 2: Convection** (Objective: Explain heat transfer in water). - **Activity 3: Radiation** (Objective: Explain heat transfer by thermal radiation).	After students have engaged with the experiments to build their own understanding, the teacher provides targeted explanations of heat transfer principles, connecting them directly to the solar dryer context: - *Conduction:* "Where did you see direct contact transfer, like a metal plate?" - *Convection:* "How did the hot air move inside your setup?" - *Radiation:* "What generated heat without direct contact?" The teacher then shows a video of a working solar dryer, allowing students to visualize theoretical principles applied in practice, and guides a discussion on its pros and cons, subtly reinforcing the environmental and economic benefits for the specific context of Nakhon Phanom.

Inquiry from context-based STEM	Activities	Scaffolding (Promoting Self-Directed Learning) — ZPD
4. Decision-Making (Design Planning)	Students, in groups, collaboratively plan their solar dryer design in Worksheet 2, including the rationale for material selection and structural configuration.	The teacher acts as an consultant, reinforcing the specific context of Nakhon Phanom (cost reduction, to guide students towards the most appropriate solution. The teacher uses carefully crafted "decision-guiding questions" to prompt deeper thought and self-correction, enabling students to evaluate their own designs: - "How can **you** make the most efficient use of solar energy in **your** design?" - "What specific structural configurations would best suit drying pineapple, considering **its** shape and moisture content?"
5. Development of Prototype or Product	- During construction, students individually explain and document in Worksheet 3: - "Which material are we using for heat conduction, and why?" - "How do our ventilation openings create convection currents?" - "Which part of our design primarily receives sunlight for heat via radiation?" - Groups record their design choices and expected functions in Worksheet 3: "Design and Test the Solar Dryer."	The teacher provides concrete examples of successful prototypes they (or previous students) have built. This visual aid helps students to self-assess their own choices, refine their ideas, and address practical challenges during construction, moving them closer to independent problem-solving by providing a tangible benchmark.
6. Test and Evaluate the Solution	-Test their solar dryer prototype by: - Placing it outdoors and drying pineapple. - Recording the internal temperature hourly. - Observing and documenting changes in the pineapple flesh (e.g., texture, color, moisture level) over time. Students then evaluate their dryer based on: - Drying duration and outcome. - Internal temperature profile. - Time taken for pineapple to be fully dried with no remaining moisture.	The teacher co-observes the evaluation process, offering targeted questions and prompts ("What did you expect to see versus what actually happened?") rather than direct instructions. This collaborative observation provides "formative feedback" within the ZPD, allowing students to identify areas for improvement themselves before a formal presentation, fostering self-correction and refinement.
7. Socialization and Completion Decision Stage	- Groups design and deliver a creative and engaging presentation (e.g., a video for social media) showcasing their solar dryer. - Presentations must explain the heat transfer principles applied, demonstrate its operation, and present drying results. - Classmates and the teacher provide constructive feedback.	The teacher facilitates a higher-order discussion, shifting from the specific project to its broader implications. They guide students in evaluating the project's real-world applicability ("Do you think this solar dryer could genuinely help the community? Why or why not?"). Finally, the teacher helps summarize the project's advantages, limitations, and future improvement directions, empowering students to synthesize their learning and consider next steps for independent action or further inquiry.

The science pre-service students were shaped the ideas about authentic assessment and identify how to assess students' performance in STEM education. The students' ideas about assessment in STEM education shown as in the **Table 6.**

Table 6: SPT4 ideas of students' assessment

Inquiry from context-based STEM	Activity	Assessment
1. Identification of Social Issues	The teacher presents the issue of low pineapple prices in Nakhon Phanom Province, prompting them to implement knowledge to design solutions for the problem.	-Worksheet 1: Approaches to solving low pineapple prices in the community. -Using questions to test students' understanding.
2. Identification of Potential Solutions	Activity to inquire about existing knowledge of students related to the problem in step 1. Ask about appropriate and feasible answers based on knowledge and context.	- Students brainstorm how to design pineapple processing to preserve pineapples. - Teacher shapes to building a solar-powered dryer as an energy and cost-saving approach. - Students collaboratively discuss within their groups how to apply heat transfer principles efficiently for pineapple processing.
3. Need for Knowledge	Prepare science, mathematics, or other curriculum-related learning activities. Prepare necessary tools, mindsets, or skills for designing problem-solving approaches.	- Activity Sheet 1: Heat Conduction - Activity Sheet 2: Convection - Activity Sheet 3: Heat Radiation - Knowledge Sheet 1: Heat Conduction - Knowledge Sheet 2: Convection - Knowledge Sheet 3: Heat Radiation
4. Decision-making	- Develop various solution approaches and designs (Prototypes, Protocols, or Systems). - Select the best solution approach and design.	- Worksheet 2: Planning how to select equipment.
5. Development of Prototype or Product	- Develop prototypes, protocols, or systems according to the design. - For prototype development, students may seek additional assistance from partners, experts, or others.	- Worksheet 3: Design and testing of a solar-powered dryer.
6. Test and Evaluate the Solution	- Develop a conceptual framework or testing method for the product or prototype. - Test the product or prototype according to the testing framework. - Evaluate the product or prototype according to the testing framework.	- Worksheet 4: Testing the solar-powered dryer.
7. Socialization and Completion Decision Stage	- Students present the work process to find solutions and develop products or prototypes. - Students demonstrate how the product or prototype works. - Students listen to feedback from reviewers and receive comments to reflect and redesign based on what they learned. - Students present the final decision-approved product or prototype.	- Students present the developed solar-powered dryer, designing a unique and engaging presentation method for their group. Examples include creating a video presentation for various platforms and presenting according to topics such as: - Explaining the heat transfer principles used in the solar-powered dryer. - Demonstrating its operation and showcasing the results of drying pineapples.

Regarding all the data, SPT4 PCK for STEM education were interpreted as follow:

Knowledge of subject matter and curriculum relevance was initiated as Excellent. Based on the instructor's feedback, the student has a good understanding of explaining and elaborating on situations. Their thought process in product design, including their ability to apply scientific knowledge from the core curriculum to solve daily life problems, is very good. The introduced situations are clear and plausible, especially in the initial design phase. The students were able to improve in setting the scene, they show their understanding and can elaborate on problem situations clearly. They were able to elaborate how heat transfer could be able to implement in making fruit dryer machine.

Knowledge of instructional strategies was found as Excellent. This is due to the student's ability to appropriately design context-based STEM inquiry learning activities step-by-step. The student understands how to manage learning in the "need for knowledge" stage to equip learners with knowledge to solve problems presented by the teacher. They can design learning management using appropriate methods to support students' problem-solving at each step. The researcher suggests that the student add more detail to the problem situations to create a clearer conceptual framework for social issues. For example, regarding question formulation, the question "How will it be asked?" is posed, along with designing a prototype dryer. This is to provide the student with a anchor in learning management, guiding them on what knowledge teachers need to have for problem-solving. In the "need for knowledge" stage, there may still be other important principles needed to help students design an efficient fruit dryer.

Knowledge of students' understanding and practice in problem-solving was regarded as Good. This is because the student focused on activities to impart knowledge and build learners' understanding of scientific principles and theories, without considering the learners' difficulties or complexities in practical problem-solving to build a fruit dryer. Examples include: "How should the fruit dryer be assembled?" or "What should the fruit dryer look like?"

Knowledge of student assessment was appraised as Fair. This is because the student intended to design learning assessment guidelines for students based on formative assessment. They attempted to design worksheets, questions, or scoring rubrics to assess learners, but the student lacked understanding of formative assessment. They still focused more on assessing students' understanding and abilities rather than assessing for development and improvement to solve students' problems. The student still used the term "test students' understanding" in their feedback on assessment, and their questioning and assessment guidelines were inconsistent with the learning activity and learning objectives of that activity.

Knowledge of technology and engineering design process for STEM education was originated as Excellent. The science pre-service teachers considered to create the scene for students to solve the real-word problem based on human needs and connected situations and problem-solving approaches with entrepreneurship, drawing from the concept of processing pineapples and selling them at higher prices.

> **Researcher:** How will the prototype help farmers in this situation?
>
> **SPT4-1**: I thought that besides selling fresh pineapples, processing (drying) them would add value and likely fetch a higher price.

This demonstrates an entrepreneurial mindset in problem-solving to add value to pineapples for sale.

3.4 Discussion of research results.

This study reflects on the feedback given for designing STEM education learning activities using an inquiry-based approach tailored to the context of science student teachers. It was found that most students encountered problems and challenges in the process of designing inquiry-based STEM learning management from context, especially in the "Set the Scene" stage where students couldn't find a way to lead a problem situation towards a solution. This reflects that science pre-service teachers were accustomed to traditional teaching methods that emphasize principles and theories without connecting knowledge to application or practice. Students are unable to apply knowledge to solve everyday problems and should be guided towards learning management that focuses on enabling learners to solve problems by putting knowledge into practice.

This is evident in many groups that started from curriculum content and then tried to find a context to connect it with, rather than starting from real societal problems. This reflects an adherence to a content-based teaching paradigm rather than a problem-based one. This finding is consistent with the research of Sutaphan and Yuenyong (2019), which indicates that creating an interesting social context is the most crucial starting point for inquiry-based learning.

The "fragile points" are the "Set the Scene/Need for Knowledge" stage and the PCK dimension of assessment with engineering-entrepreneurship, which adds mechanistic details to Gess-Newsome's (2015) framework in the Thai context. Initial sentence: "Our findings align with Shernoff et al. (2017) and Roehrig et al. (2021) who point out that teachers need targeted development to drive STEM integration and ongoing assessment. Simultaneously, our work is more specific regarding the fragile points at the Set the Scene/Need for Knowledge stage and the engineering/entrepreneurship dimension of PCK."

Regarding knowledge of instructional strategies, the science pre-service teachers still lack concepts about creating environments to promote problem-solving for learners. They are not yet familiar with the idea of learners using knowledge to solve problems by creating prototypes or products as solutions. Instead, science pre-service teachers were familiar with terms like "model" or "experiment," indicating a lack of connection in applying knowledge to solve problems. The research results also highlight the confusion among student teachers between the concepts of 'model' and 'prototype,' as seen in several groups that focused on designing activities for students to create models to demonstrate scientific principles rather than developing prototypes to solve problems within a given context. This finding reflects that knowledge about the Engineering Design Process, a core component of STEM education, has not been fully integrated into the thinking of student teachers. Therefore, science pre-service teachers tend to design learning management where learners follow instructions rather than using their own ideas to design problem-solving approaches. Students misunderstand the terms hands-on practice, experimentation, and designing problem-solving approaches, which aligns with the misconception of STEM and the adherence to experiments/models rather than design for problem-solving (Vichaidit & Faikhamta, 2017).

Familiarity with teaching methods that emphasize factual knowledge makes the transformation of social problems into engineering design problems less fluid (Shernoff et al., 2017; Vichaidit & Faikhamta, 2017). This aligns with the challenges faced by teachers/student teachers in integrating design-based STEM and formative assessment (Shernoff et al., 2017; Roehrig et al., 2021).

Regarding knowledge of students' understanding and practice in problem-solving, students are still stuck in traditional teaching and learning that emphasizes knowledge and understanding rather than applying knowledge to solve problems. Students focus on understanding content without considering how to encourage learners to successfully engage in problem-solving at each step.

Adherence to knowledge transmission-based teaching models is another significant obstacle identified in this research. However, this research process has shown that continuous feedback and opportunities for students to reflect on and improve their work are effective tools for breaking old mindsets. This is evident in the development of student groups with higher PCK-STEM competency, consistent with Duijnhouwer et al. (2012) and Omilani & Ogbonna (2023) concept that formative feedback is a crucial mechanism for reinforcing student teachers' Pedagogical Content Knowledge (PCK).

Regarding knowledge of student assessment, the familiarity with teaching and learning that emphasizes knowledge and knowledge assessment leads to students lacking ideas and being unable to design assessment approaches that promote learners' problem-solving abilities, even though instructors try to guide students to design assessments following a formative assessment approach.

Knowledge of technology and engineering design process, emphasizing human needs, is a new concept for the sampled students. This makes students unfamiliar with connecting human needs in designing learning management. In particular, the concept of entrepreneurship is even more distant from typical science classroom learning. It is observed that only two groups were able to connect problem-solving approaches with the concept of entrepreneurship.

5. Conclusion

This research aims to promote the design of STEM education learning management based on the inquiry approach in the context of Sutaphan & Yuenyong (2019), through systematic feedback processes and reflections from science teacher students. The research findings are summarized as follows:

The study identified three patterns of developing Pedagogical Content Knowledge (PCK) for STEM. Overall, participants demonstrated strength in content and curriculum but faced challenges in designing activities for students to solve design problems, formative assessment, and connecting to human needs and entrepreneurial contexts.

Science pre-service teachers showed significant development in PCK-STEM through their reflection (Kulgemeyer et al., 2021). They were better able to connect real-life problem situations with the science curriculum, selecting relevant and deeper content and principles such as heat transfer, substance separation, buoyancy, and chemical reactions.

Knowledge of students' understanding and practice remains an area for development. The students still focused on designing activities to build "content knowledge" rather than encouraging students to engage in step-by-step problem-solving, such as assembling a fruit dryer or creating other problem-solving prototypes.

However, the feedback and reflection cycles helped clarify problems and link content to solutions (e.g., Groups 4, 10), consistent with the positive role of feedback in PCK development (Duijnhouwer et al., 2012; Omilani & Ogbonna, 2023). The findings reflect the influence of a content-focused teaching background, which is not yet conducive to designing engineering problems in real-world contexts. Simultaneously, the feedback-reflection cycle in the course helped students gradually link 'content-context-solution' more clearly, supporting the suggestion that feedback is a crucial mechanism for PCK growth (Omilani & Ogbonna, 2023; Gess-Newsome, 2015).

PCK for STEM must cover five dimensions, and "assessment methods to guide design and prototype testing" are key to driving inquiry from context-based STEM beyond experiments/models.

Knowledge of student assessment remained at a satisfactory level. Students still focused on assessment for understanding rather than formative assessment, leading to confusion in objectives and designing scoring rubrics for improving student work Sohsomboon & Yuenyong, 2021).

It can be seen that out of the five components of PCK for STEM, only knowledge of subject matter and curriculum relevance were at an excellent level for science pre-service teachers. The remaining components show that science pre-service teachers still need development to improve their competence, such as knowledge of instructional strategies, knowledge of students' understanding and practice, knowledge of student assessment, and knowledge of technology and engineering design process. This research indicates that producing science teachers who can effectively teach STEM education is not just about providing STEM knowledge but requires a paradigm shift in teaching and a strong, continuous feedback process (Hattie & Timperley, 2007). This research shows that teaching STEM is new for science pre-service teachers, and it is very difficult for instructors to develop students comprehensively in all aspects simultaneously. The research indicates that teacher development must be gradual and continuous, and to be effective, it should be developed one aspect at a time.

Continuous feedback had a positive effect on the development of students' mindsets (Hattie & Timperley, 2007). The feedback-reflection process helped students "relax their knowledge-transfer-centric mindset" and shifted them to design activities according to context-based STEM education concepts more effectively, which showed that reflection truly enhanced PCK-STEM.

In summary, systematic feedback made the STEM education learning plans developed by student's completer and more suitable for practical application, both in terms of content, teaching methods, and connection to problems in the community context.

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