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PROMOTING PROBLEM-SOLVING SKILLS IN STEAM: A NEED ANALYSIS FOR LEARNING MANAGEMENT AMONG PRE-SERVICE MATHEMATICS TEACHERS

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ABSTRACT

The objectives of this research were to study the needs and approaches for developing a STEAM-based learning model to enhance problem-solving skills of pre-service mathematics teachers. A mixed-method research approach was used, combining quantitative and qualitative research methods. Quantitative data were collected using questionnaires administered to Bachelor of Education students majoring in Mathematics at a university in the Northeast of Thailand. Qualitative data were collected through structured interviews with three sample groups: (1) Bachelor of Education students majoring in Mathematics, (2) experts in STEAM-based learning, and (3) instructors. The research findings indicate that learning management should emphasize the use of real-life scenarios, organizing group learning activities where learners can exchange ideas and engage in step-by-step practice to systematically develop problem-solving skills. Learning management approaches should promote knowledge sharing and integration through creative design, exploration, investigation, and connecting information to learners' real-life contexts, with an emphasis on collaboration to enable learners to view problems from multiple dimensions and gain a deep understanding. The results of this study can be used as a guideline for developing a STEAM-based learning management model that effectively promotes problem-solving skills. This is because STEAM-based learning management is a crucial foundation for integrating knowledge from science, technology, engineering, arts, and mathematics, with the teacher facilitating Active Learning to encourage learners to see the value and apply knowledge to solve real-life problems.

KEYWORDS: STEAM-based Learning, Problem-solving Skills, Mathematics Education, Pre-service Teachers, Teacher professional development, Active Learning, Collaborative Learning, Instructional model.

1. INTRODUCTION

With the transition to Industry 4.0, Thailand must reform its education system, so that the education system is the main mechanism for driving the country, having a vision as follows: "All Thai people receive education and learn throughout life with quality, live happily, in accordance with the philosophy of sufficiency economy and the changes of the 21st century world" (Office of the Education Council, 2017). To achieve the vision in educational management, there has been a setting of goals for learners, aiming to develop all learners to have characteristics and learning skills in the 21st century, which emphasizes that instructors must be learning designers and facilitators, be co-learners, give advice in a friendly way to learners, by letting learners take action, having to rely on various methods so that learners develop according to their potential, focusing on practicing thinking process skills, facing problems, practicing to be able to do, able to think, able to create the body of knowledge of the learners themselves (Chongdengt and Lenanan, 2023; Sookrang et al., 2025). 21st century learning skills (3Rs8Cs) consist of the following skills and characteristics: 3Rs namely reading (Reading), writing (Writing), and arithmetic (Arithmetics); 8Cs namely critical thinking and problem solving skills (Critical Thinking and Problem Solving), creativity and innovation skills (Creativity and Innovation), cross-cultural understanding skills (Cross cultural Understanding), collaboration, teamwork, and leadership skills (Collaboration, Teamwork and Leadership), communications, information, and media literacy skills (Communications, Information and Media Literacy), computing and ICT literacy skills and communications (Computing and ICT Literacy), career and learning skills (Career and Learning Skills), and compassion, discipline, morality, ethics (Compassion) (Office of the Education Council, 2017; Cofino et al., 2026; Senkbeil, 2026). From the vision in educational management, which has set a goal for all learners to have characteristics and learning skills in the 21st century, which includes problem-solving skills, it is seen that there is a necessity to promote learners to occur problem-solving skills. Therefore, STEAM EDUCATION, which is a concept in learning management that integrates 5 disciplines namely Science (Science), Technology (Technology), Engineering (Engineering), Arts (Arts), and Mathematics (Mathematics), is therefore suitable to be brought to use in learning management to promote the occurrence of such skills (Klriengthaisong and Saksuparb, 2023; Tientongdee

et al., 2023; Aqilah Fauziyah and Palennari, 2024; Wang, 2024). Organizing learning activities according to the STEAM concept is a model that emphasizes creating bodies of knowledge to use in solving problems, including the development of new processes or products that are beneficial to real-life (Pornkiadtikhun et al., 2022). And also promotes learners to have various knowledge and skills, especially problem-solving skills, because learning to solve problems is thinking that requires reasoning combined with knowledge and experience in finding guidelines and taking action to solve problems, which problem-solving thinking is very important in real-life (Puttikul et al., 2020). Therefore, it is seen that problem-solving skills are an important matter that must be developed, where teachers must be able to manage learning to increase efficiency for learners, and student teachers who will be teachers in the future must also have problem-solving skills, in order to apply in learning management for learners efficiently, and be able to develop learners to occur problem-solving skills further. Therefore, organizing STEAM education learning activities can help develop problem-solving skills for learners (Chuaytanee et al., 2019; Detphiphatworakul et al., 2023). For the role of mathematics teachers, having good problem-solving skills will help be able to create a learning environment that promotes learners to practice analytical thinking and problem-solving skills systematically (Nanda and Rani, 2025). By which teachers should design activities that link mathematics content with real life contexts and promote learners to participate in learning by themselves and in groups, which aligns with the learning management guidelines according to the STEAM concept that emphasizes collaboration and the use of technology in solving problems. The development of these skills in teachers will help increase the efficiency of teaching and make learners truly occur the skills necessary in the 21st century.

From the information mentioned above, it makes it seen that the learning management model according to the STEAM concept is a model that will help push learners to occur problem-solving skills. By which current mathematics learning management needs to emphasize learners to develop skills in solving problems, because solving problems is related to the real-life of humans, because to be successful in any one matter, one must face problems and must find ways to solve problems in order to achieve that goal always (Chalatloed, 2017). Therefore, those who can solve problems efficiently must know how to think to find answers or new forms of methods, search for various alternatives,

different from the original ones, and be able to make decisions to choose the best problem-solving method according to the principles of reason and result, appropriate to the occurring situation. But from the educational management condition of Thailand, it does not facilitate learners to occur problem-solving skills. From the evaluation results of the Programme for International Student Assessment (PISA), it has the objective to evaluate the educational quality of various countries in preparing youth to have potential or basic abilities necessary for living in a changing world. The evaluation of PISA emphasizes evaluating the ability of students in using knowledge and skills to solve problems in life, which from the evaluation results of PISA 2022 found that Thai students have average scores in mathematics, science, and reading, decreasing in all three areas. And from considering the evaluation results of Thailand from PISA 2000 to PISA 2022, it is found that the average scores in mathematics and reading have a decreasing trend (OECD, 2023). Which the role of teaching teachers is highly important to the learning achievement of learners, including PISA test scores. Teachers who have the knowledge and ability in learning management that emphasizes analytical thinking, problem solving, and application of knowledge in real situations, will help learners be able to develop skills as PISA evaluates better. Furthermore, teachers should have skills in creating motivation and supporting learners to participate in learning, including the use of technology and various learning media to respond to the different needs of learners (OECD, 2025). And from the research study of Pengsook (2022), who taught pre-service mathematics teachers, it was found that students still lack problem-solving skills and still solve problems inappropriately for real-life situations. Which in the future, professional teacher students have a necessity to bring the ability in problem-solving to use in practicing the teaching profession in order to be professional teachers proudly. Therefore, making it seen that problem-solving skills are an important matter that must be developed. Therefore, teachers have a necessity to manage learning to develop learners to occur problem-solving skills, and teachers must be able to manage learning to increase efficiency for learners, to apply in learning management for learners efficiently, and be able to develop learners to occur problem-solving skills. And from the teaching of the researcher, it was found that the problem of professional teacher students mostly cannot use problem-solving skills in learning major subjects to their full potential, therefore resulting in quite a large number of professional

teacher students failing exams in major subjects (Nakhonratchasima Rajabhat University, 2022). From what has been mentioned above, the researcher sees the necessity to study the needs regarding learning management according to the STEAM concept to be used as a guideline for developing a learning management model according to the STEAM concept to promote problem-solving skills.

1.2. Objectives

To study the needs and guidelines in developing a learning management model according to the STEAM concept to promote problem-solving skills for Bachelor of Education students majoring in Mathematics.

1.3. Research Questions

1. How do Bachelor of Education students majoring in Mathematics have the needs for having learning management to promote problem-solving skills?
2. How do Bachelor of Education students majoring in Mathematics have the necessary needs in developing problem-solving skills?
3. How should the guidelines for developing a learning management model according to the STEAM concept to promote problem-solving skills be?

2. METHOD

2.1. Guidelines for learning management

According to the STEAM concept to promote problem-solving skills for Bachelor of Education students majoring in Mathematics is a research operation using a mixed method (Mixed method) consisting of quantitative research (Quantitative research) and qualitative research (Qualitative research) to obtain research results that are accurate and receive complete data, which has details as follows:

2.1. Population and Sample

The population consisted of 60 pre-service mathematics teachers at Nakhon Ratchasima Rajabhat University, Thailand, 10 Experts in STEAM-based learning, and 14 Instructors teaching Calculus 1. The sample included 30 pre-service mathematics teachers for the questionnaire (selected via cluster random sampling) and 15 pre-service mathematics teachers for structured interviews (selected via simple random sampling). This cluster random sampling method was chosen because the population was naturally organized into two separate classrooms (clusters) of 30 pre-service mathematics

teachers each. One intact classroom was randomly selected to participate. A sample size of 30 is considered statistically sufficient for this study as it represents 50% of the total population and meets the minimum requirement for parametric statistical analysis. Additionally, 3 experts in STEAM-based learning and 2 instructors were selected via purposive sampling, based on their experience in implementing STEAM-based learning and teaching Calculus 1.

3.2. Research Instruments

Data were collected using a questionnaire (IOC = 1.00) assessing learners' needs and guidelines for the STEAM-based model, and three structured interview forms (IOC ranging from 0.94 to 1.00) tailored for pre-service mathematics teachers, experts in STEAM-based learning, and the instructors.

3.3. Research Implementation Methods

Following ethical approval from Mahasarakham University, quantitative data were collected via questionnaires from 30 pre-service mathematics teachers. Qualitative data was obtained through individual structured interviews with 15 pre-service mathematics teachers, 3 experts in STEAM-based learning, and 2 the instructors to explore the needs and guidelines for developing the learning model.

3.4. Data Analysis

The researcher has analyzed quantitative data obtained from the questionnaire with statistical values, which are arithmetic mean and standard

deviation, necessary needs by using the improved Priority Needs Index (PNI) method, and analyzed qualitative data obtained from the interview by analyzing content, and bringing it to prioritize, and analyzed the characteristics of data thoroughly. After that, comparing data with related documents such as concepts, theories, or related research works, to analyze to find characteristics that are similar and different systematically, and link relationships between various data to see the overall picture of problems and needs clearly, which will be able to conclude results and propose guidelines for developing suitable learning management efficiently.

4. RESULTS AND DISCUSSION

In the study of needs, to be brought as a guideline for developing learning management according to the STEAM concept to promote problem-solving skills.

The results of the general data analysis of the questionnaire respondents have details as follows: The questionnaire respondents were male numbering 8 people (26.67%) and female numbering 22 people (73.33%). The age range of the questionnaire respondents was as follows: age 18 - 19 years numbering 23 people (76.67%), age 20 - 21 years numbering 7 people (23.33%), by which all questionnaire respondents were 2nd-year pre-service mathematics teachers. The results of data analysis in the need aspect and the guideline aspect in developing a learning management model from the questionnaire have details as follows:

Table 1: Shows the analysis results of the means and PNI modified from the questionnaire regarding the actual condition and expected condition aspect.

No	Item	Actual situation	Expected conditions	PNI _{modified}	Priority
1. Needs					
1.1 Learning Management					
1	Learners participate in designing learning activities.	3.73	4.33	0.16	2
2	Learners participate in expressing opinions about measurement and evaluation criteria.	4.13	4.40	0.06	7
3	The instructor organizes learning activities that promote learners' success or appropriate understanding of the content.	4.47	4.70	0.05	9
4	The instructor organizes learning activities that promote problem-solving skills in learners.	4.33	4.57	0.05	9
5	The instructor organizes learning activities that connect the content to real-life.	3.83	4.47	0.17	1
1.2 Teaching methods of instructors teaching Calculus 1					
6	The instructor uses learning materials to promote appropriate learning for the learners.	4.57	4.67	0.02	16
7	The instructor uses various technologies appropriately to align with the content.	4.70	4.67	- 0.01	23
8	The instructor appropriately introduces additional learning materials to the learners.	4.63	4.70	0.01	20
9	The instructor creates a classroom atmosphere by showing mutual respect for opinions and encouraging learners to have self-confidence.	4.63	4.73	0.02	16
2. Guidelines for Developing Learning Management Models					

2.1 Learning Management					
10	The instructor manages teaching time appropriately.	4.27	4.63	0.09	6
11	The instructor has prepared the teaching materials appropriately.	4.77	4.70	- 0.01	23
12	The instructor is well-prepared with appropriate learning management guidelines.	4.63	4.73	0.02	16
2.2 Learning management					
13	The instructor provides opportunities for learners to participate in expressing opinions about learning management activities.	4.73	4.50	- 0.05	25
14	The instructor provides opportunities for learners to participate in expressing opinions about measurement and evaluation criteria.	4.4	4.63	0.05	9
15	The instructor appropriately processes or steps for managing learning.	4.60	4.67	0.01	20
16	Learners have reviewed prior knowledge necessary to link in learning new content.	4.33	4.53	0.05	9
17	Learners have practiced problems-solving by themselves and with other learners in a group.	3.93	4.50	0.14	3
18	Learning management makes learners have the ability in actions that are step-by-step in nature.	4.47	4.67	0.04	13
19	Learning management makes learners use technology in studying and researching.	4.20	4.37	0.04	13
20	Learning management makes learners have opportunities to check their own works and have corrected flaws.	4.13	4.57	0.10	5
21	Learners can choose to use methods to study and find knowledge by themselves in various ways freely.	4.33	4.60	0.06	7
The teaching of the instructors teaching Calculus 1					
22	The instructor prepares learners for learning by informing them of the learning objectives and encouraging them to answer questions.	4.53	4.67	0.03	15
23	The instructor interacts with the learners appropriately.	4.87	4.63	- 0.05	25
24	The instructor provides opportunities for learners to participate in knowledge exchanges with the instructor and with other learners.	4.57	4.63	0.01	20
25	The instructor has the use of questions to stimulate thinking and reinforce learners to have determination in learning.	4.4	4.50	0.02	16
26	The instructor uses learning materials to capture the learners' attention.	3.97	4.50	0.14	3

Table 1 illustrates the actual and expected conditions of STEAM-based learning management. While instructors currently utilize technology effectively (mean = 4.70), learner participation in activity design remains low (mean = 3.73). Conversely, learners highly desire an atmosphere of mutual respect and confidence (mean = 4.73). Prioritizing activities that link content to real-life situations is essential to stimulate motivation and enable students to construct knowledge independently (Sanguanrat and Waree, 2024; Hezron, 2024). Encouraging student participation in instructional design further aligns learning with their interests and fosters collaborative skills (Swangiang, 2022; Suwanrak, 2023). Additionally, the use of creative and relatable learning media is crucial for making complex content accessible and engaging (Tonawanik and Donavanik, 2019; Chaluthong and

Plangsorn, 2024; Lama, 2024). Creating a positive psychological and physical environment that responds to basic needs like self-esteem and group cooperation is fundamental to facilitating full potential in the 21st-century classroom (Li et al., 2005; Sottipolanun, 2018; Phrakrusuwattanadhammaporn, 2023; Mariano and Chiappe, 2021; Promsurin, 2023).

4.1. Qualitative Data

The results of interviewing the interview participants, which is qualitative data, which consists of needs and guidelines in developing a learning management model according to the STEAM concept to promote problem-solving skills for Bachelor of Education students majoring in mathematics, have details as follows:

Table 2: Summary of interview results of learners, experts in STEAM-based learning, and instructors teaching Calculus 1.

Interview Issues	Learners	Experts in STEAM-based learning	Instructors teaching Calculus 1
Suitability of learning management in the subject	Learners view that the content is quite difficult, and the examples brought to use in teaching are	-	-

	not enough to understand, and the learners themselves have little participation in the classroom.		
The aim of the STEAM-based learning model is to promote problem-solving skills.	-	The components of the model have comprehensive-ness, and have processes that affect the promotion of problem-solving skills. In organizing learning activities, the instructors should arrange to align with the curriculum and learners so that learners occur connected competencies and it is a skill enhancement to be able to use in real-life.	The instructor should design situations relevant to real-life, and promote learners to learn through taking action, by which learners can see the overall picture of the situation, and analyze the situation to find guidelines in solving problems.
Content of STEAM-based learning management to promote problem-solving skills	-	The model should have modernity and align with 21st century skills, having clear integration and linkage of content in each discipline. And in learning management, learners should be allowed to use inquiry processes to find guidelines in solving problems, together with the use of technology to help in solving problems, along with bringing help in designing problem solving, able to create clear visible pictures, and checking the results obtained from solving problems.	Content suitable for learning management includes functions and graphs, limits and continuity, and applications of derivatives.
Learning management process is based on the STEAM concept to promote problem-solving skills.	-	The instructor must create situations that are interesting to the learners or that they have experienced themselves, so that learners can understand the situation. This will make learners have the feeling of wanting to participate in solving problems. For learning activities, the instructor uses active learning, collaborative learning, and mastery learning by solving problems.	Learning management processes that encourages learners to develop to their full potential, taking into account individual differences, with the following steps: 1) Creating situations for learners to analyze problems; 2) learners writing initial models to be used in problem-solving; 3) learners demonstrating problem-solving methods until they achieve results; 4) learners collaboratively summarizing the results; and 5) providing feedback from the instructor and other learners in the classroom.
Learning management activities based on the STEAM concept to promote problem-solving skills.	The instructor presents problem scenarios in the learning process that can promote problem-solving skills, which learners can apply in real-life. However, there may be some situations where learners need time to review and understand before attempting to solve the problem, and learners should practice a variety of situational problems.	Activities should be engaging for learners and connected to real-life. They should allow learners to practice higher-order thinking skills and reasoning, enabling them to explain problem-solving methods. Technology can be used to aid problem-solving, visualizing the process and steps involved, ultimately resulting in a final product. The instructor's role is to facilitate learning throughout the process and recommend learning resources for learners to study and research independently, fostering learning and extending their thinking.	The integrated learning method (Integration Instruction) involves connecting different subjects or content areas to generate knowledge that can be applied in real-life, leading to problem-solving skills. The learning method should allow learners to learn in groups so that group members can share knowledge and gain insights from others' perspectives on the problem.
Learning Management Guidelines	The instructor should provide examples of real-life situations so that learners can choose different methods to solve	-	-

	problems, with the instructor acting as a guide.		
The role of the instructor in learning management to develop problem-solving skills in learners.	-	-	The instructor should arrange environments that facilitate learning, to create an atmosphere for learners to learn, and the instructor should use problem situations suitable for learning of learners. The instructor should provide opportunities for learners to participate in organizing learning activities and allow them to practice independently. The instructor's role is to facilitate learning for learners.
The role of learner in learning management to make learners occur problem-solving skills.	-	-	Learners participate in group activities and must share responsibility. Group members need to help each other express opinions, analyze, and solve problems together, drawing on learning from experience or what they observe in real-life to construct their own knowledge.
Measurement and evaluation	The test administered to the learners was subjective, which resulted in the learners not being able to show their work correctly in its entirety.	The instructor should measure according to authentic condition (Authentic Assessment) by evaluating formatively (Formative Assessment) to develop the learning of learners by observing learning behaviors of learners through various activities, and evaluating summatively (Summative Assessment) to judge quality after ending learning management.	The instructor should assess learners authentically by using formative assessment to provide feedback for further development and summative assessment to evaluate quality after the learning process is complete.

From Table 2, the issues from interviewing pre-service mathematics teachers, experts in STEAM-based learning, and the instructors can be summarized as follows: 1) Objectives of the learning management model according to the STEAM concept to promote problem-solving skills should align with the curriculum and learners, by which the instructors should design situations related to real-life, and promote learners to learn through taking action, so that learners see the importance of the content, and relate to real-life, occur motivation in learning and develop problem-solving skills (Bunyatsathian, 2024; Ketusiri and Rianru, 2025). The student interview results found that the instructors should determine situations occurring in real-life, so that all learners jointly participate in choosing to use various methods, by relying on linking with prior knowledge or experiences of learners in solving problems. Learners should have to plan before solving problems, to be able to operate problem-solving step-by-step, able to be checked, which will be promoting problem-solving skills to learners. It may be because using situations linked to the real-life of learners will make learners able to understand occurring

situations well, affecting critical thinking skills and problem-solving skills. Because learners can analyze problems correctly, by emphasizing the importance of organizing activities to develop diverse thinking, relying on coordinated working of various types of thinking skills, applying original experiences linked to various processes or tools, to find guidelines in making decisions with more efficiency (Treffinger and Isaksen, 2005; Wood, 2006; Hansena and Jumrusprasert, 2024). 2) Content of learning management according to the STEAM concept to promote problem-solving skills should be content that can be integrated with various disciplines, and has linkage with real situations, which has content as follows: 1. Functions and graphs, learners create mathematical models of function graphs related to real problems, such as planning travel routes. 2. Limits and continuity, learners explore the limit concept through experiments and the use of technology, such as motion simulation software, to understand the continuity concept in scientific processes. 3. Application of derivatives, learners solve problems related to changes, such as calculating speed and rate of change in various

systems. By which learning management of this nature will help learners practice holistic problem-solving skills and see the importance of mathematics in real-life (Pantaranontaka et al., 2020; Kanjan and Poonpaiboonpipat, 2023). Learning management should allow learners to use inquiry processes, helping learners have more motivation in learning. Learners get to practice asking questions, researching information, experimenting, and evaluating by themselves (Resmol and Leasa, 2022; Sansompron, 2026). Moreover, the use of technology to help learners make problem-solving skills has diversity and more modern. Learners can therefore apply knowledge and tools available in solving problems efficiently (Fitriani et al., 2024; Kaewkoon et al., 2025). By which the instructors interview results found that the instructors should design integrated learning management (Integration Instruction) that has linkage of disciplines or content of various subjects together, by considering individual differences. The suitable content in learning management in the Calculus 1 course is functions and graphs, limits and continuity, and application of derivatives. Learning management is bringing situations related to real-life for learners to study, and analyze to find guidelines in solving problems, and using group learning management methods, so that members in the group have exchanging learning with each other. Learners get to practice analyzing to find problem-solving guidelines, and taking action to solve problems by themselves, by having linkage with situations in real-life, which will make learners able to develop until occurring problem-solving skills. In the part of the instructors, they have the duty to arrange an environment that facilitates learning, to create an atmosphere for learners to want to learn, and to be facilitators in learning management for learners. By opening opportunities for learners to have participation in organizing learning activities, allowing learners to take action by themselves. 3) Learning management processes according to the STEAM concept to promote problem-solving skills should be processes that promote learners to develop themselves to full potential, by considering individual differences. The instructors must determine situations that stimulate learners' interest or situations that learners experience by themselves, so that learners can understand that situation, which will make learners have the feeling of wanting to participate in solving problems. By learning activities, the instructors use active learning activities and collaborative learning activities and real learning by solving problems (Mastery Learning) to open opportunities for learners to exchange opinions and

develop problem-solving skills in real contexts (Vale and Barbosa, 2023; Olawale, 2024). Furthermore, the interview results of experts in STEAM-based learning found that the learning management model should be arranged to align with the curriculum and learners, by having clear integration and linkage of content in each discipline. By collaborative working activities, the instructors must determine situations that stimulate learners' interest or situations that learners experience by themselves, so that learners can understand that situation, which will make learners have the feeling of wanting to participate in solving problems. And learners can use technology to help in solving problems, to be able to see the picture more clearly. In the part of the instructors, they have the duty in facilitating learners throughout the learning period, and recommending learning sources that learners can study and research by themselves to occur learning and extend ideas to lead to problem-solving 4) Learning management activities according to the STEAM-based learning to promote problem-solving skills should be activities that learners pay attention to and link with real-life by being able to practice learners to use higher-order thinking skills and give reasons able to explain problem-solving methods. And learners should learn as a group so that members in the group can share knowledge and receive deep information from the perspectives of others about the problem (Sookrang et al., 2025; Harefa and Hulu, 2024). It is the development of problem-solving skills and social skills simultaneously. Moreover, learners can use technology to help in solving problems by seeing the picture and the problem-solving process, until finally coming out as a piece of work. The instructors have the duty in facilitating learners throughout the learning period and recommending learning sources that learners can study and research by themselves to occur learning and extend ideas further. And from interviewing the instructors, it was found that the learning management model by integration in the Thailand 4.0 era according to the STEAM-based learning is therefore suitable for learners because it is linking disciplines and content in many subjects together and can be integrated in education of all levels (Jaradrawiwat, 2017). Learning management activities should emphasize group processes to make learners get to learn together. From exchanging opinions between members in the group, it causes learning to find algorithmic steps in solving problems, until occurring as problem-solving skills (Nurdyansyah et al., 2017; Suratno and Waliyanti, 2023). 5) For measurement and evaluation, the instructors should measure results according to

authentic condition (Authentic Assessment) by evaluating formatively (Formative Assessment) to give feedback to learners, making learners able to develop themselves further, and evaluating summatively (Summative Assessment) to judge quality after ending learning management. This will make learners find strengths and points needing development, resulting in continuous self-improvement, and it is also promoting systematic problem-solving skills (Chandeewanta, 2023; Akib et al., 2024; Deenok and Kaewmee, 2025). The interview results of experts in STEAM-based learning found that in the part of measurement and evaluation, it should measure according to authentic condition by evaluating formatively to develop the learning of learners by observing learning behaviors of learners through various activities, and summatively to judge quality after ending learning management. Therefore, learning management according to the STEAM concept that should be brought to use to promote problem-solving skills should manage learning in group formats and emphasize learners to take action by themselves. Furthermore, it also makes learners create bodies of knowledge by themselves, able to apply, and design pieces of work creatively according to learners' thoughts. Consequently, it will let learners have durable knowledge by occurring learning during practice step-by-step until occurring as problem-solving skills. Similarly to prepare people to have readiness in the digital era, bringing the STEAM learning management model to use seriously will be able to make each learner develop skills and competencies necessary for being a person in the digital era (Hadinugrahaningsih et al., 2017; Shatunova et al., 2019; Muangram and Dathong, 2023). And the instructors interview results found that in the part of measurement and evaluation, the instructors should measure results according to authentic condition by evaluating formatively to give feedback to learners, which makes learners able to develop themselves further, and evaluating summatively to judge quality after ending learning management.

From analyzing and synthesizing qualitative data obtained from in-depth interviews and surveying the opinions of pre-service mathematics teachers, experts in STEAM-based learning, and the instructors, it was found that there are important issues that are consistent, which can be summarized to be guidelines in developing a learning management model according to the STEAM concept to promote problem-solving skills as follows: 1) Objectives of the learning management model emphasizes creating problem-solving competencies

by linking with real-life, to stimulate interest and make learners see the overall picture of the problem more clearly, and occur problem-solving skills that can be used actually, not just in textbooks. 2) Learning management content should be modern, be clearly integrated, use technology to help in designing, creating pictures, and checking the correctness of results, especially in the content regarding functions and graphs, limits and continuity, and application of derivatives, to promote learners to create pieces of work or innovations from problem-solving. 3) For learning management processes according to the STEAM concept, the instructors create problem situations that are close to oneself or stimulate interest, so that learners want to participate. Learners can show problem-solving methods until getting results, by using inquiry processes, together with jointly summarizing results between learners in the group to find guidelines in solving problems. When ending activities, there is reflection of results from the instructors and classmates to improve the thinking process. 4) Learning management activities according to the STEAM concept emphasizes active learning as well as teamwork and uses collaborative learning. They lead to occur exchanging of diverse perspectives by using technological tools in searching, designing, and checking results, and lead to see clear problem-solving steps until occurring as a piece of work.

The instructors act as facilitators to allow learners to be able to learn fully to potential, and to stimulate learners to use higher-order thinking skills. 5) For measurement and evaluation, it is an evaluation to develop by measuring results from real practice and behaviors in the classroom, not just results on the answer sheet. It also focuses on evaluation during learning to give reflective results to learners promptly, and focuses on summative evaluation to measure quality of success by evaluating both individually and as a group by considering individual differences.

5. CONCLUSION AND RESEARCH FINDINGS

The study results of the needs and guidelines in developing a learning management model according to the STEAM concept to promote problem-solving skills for Bachelor of Education students majoring in Mathematics emphasize the transition from learning complex theories to active learning that links with real situations in real-life. The key point is learners' participation in designing activities, and solving problems through collaborative learning. For content

suitable for learning management according to the STEAM concept, it should have concrete characteristics, have empirical results, and emphasize problem-solving processes, such as functions and graphs, limits and continuity, and application of derivatives. Learning management will be transmitted through inquiry together with the use of technology to create simulation pictures and check results until occurring as creative pieces of work. The instructors must have the role as facilitators and use of authentic measurement to reflect different potentials individually and problem-solving skills that can be applied actually in the teaching profession.

5.1. Limitations and Benefits of the Research

There are four limitations of the research. Firstly, the study results are limited only to Education students majoring in Mathematics, which may have contexts of needs and basic skills different from learners in other programs. Because they do not study to apply solely, but they must study to know how to teach others to apply. Secondly, this research emphasizes mainly on problem-solving skills, but may not yet cover other skills necessary in the 21st

century, such as communication skills, or critical thinking in detail. Thirdly, changing the role of learners to participate in designing activities may take time to adjust. Fourthly, the instructors must have high expertise in integrating STEAM disciplines. On the other hand, there are two aspects of benefits and values of the work. Firstly, in a practical sense, the instructors receive clear guidelines in managing calculus learning, to make content more interesting and reduce the difficulty of content with technology, so that learners receive training in problem-solving skills and working jointly with others. These are important competencies in practicing the teaching profession in the future. Secondly, in an academic sense, it expands the scope of the STEAM concept from previous often used at the basic education level to integration at the higher education level, especially in advanced mathematics subjects. Moreover, the work provides a learning management model that has already systematically analyzed necessary needs (Need Assessment), which can be used as a reference database for research to develop the mathematics instructors curriculums at the international level further.

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