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Enhancing Competency in Designing Learning Activities Based on Stem Education of Pre-Service Science Teachers

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Pre-service science teachers have difficulty with designing learning activities and writing lesson plans using STEM education. This research aims to: (1) develop a learning package to enhance competency in designing learning activities using STEM Education approach for pre-service science teachers, (2) implement the learning package to develop undergraduate students' competency, and (3) study students' opinions toward the instruction. This research was classroom action research, which used ADDIE model (Analysis, Design, Development, Implement, and Evaluate) to develop and implement the learning package in enhancing student competency in designing learning activities. The participants of this study were 31 fourth-year undergraduate students enrolled in the course of Science Instruction, in the program of Bachelor of Education in the Department of General Science, Faculty of Science. The research tools consisted of: (1) the learning packages, (2) the students' competency assessment form by evaluating from tasks and performance of the students using scoring rubrics, (3) the competency self-assessment form, and (4) the students' opinions questionnaire towards the instruction. Both quantitative data and qualitative data were collected by using the competency assessment forms and the questionnaire. The statistics used to analyze the data were mean, standard deviation, and percentage. The results show that 67.74% of students were at excellent level from assessing students' competency, and 32.26% of students were at good level. The mean score of overall competencies of the students were 83.43%. The students' competency from self-assessment was at low level before learning, and it was at very high level after learning, and the students' opinions towards the instruction were highly satisfied. The qualitative data from open ended questions questionnaire were analysed using content analysis. The result showed students' feedback and satisfaction toward learning. The finding can benefit science teachers and curriculum developers in designing learning activities.

Keywords: ADDIE model, STEM Education, pre-service teachers, science instruction, active learning, teaching methods

INTRODUCTION

In Thailand, one of "Standards of Knowledge and Professional Experience of Teachers according to the Teachers Council of Thailand regulations On Professional Standards (No. 4) B.E. 2562 identify that pre-service teacher need to have competency in learning management (Ministry of Education, 2020). This poses expectations for teacher education. The program of curriculum and instruction in the university should develop student competency in teaching and learning innovation including enhancing various skills and abilities in teaching. One of the key elements in developing pre-service teachers is enhancing competency in designing learning activities. As the researcher worked as the instructor of the program of Bachelor of Education in the faculty of science in University in Thailand. This program was a five-year bachelor's degree in teacher education program that all students must do coursework for four years and spend one year in a school to gain field experience and conduct teaching practice to

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complete the licensure requirements. The pre-service teachers are required to be able to design and develop lesson plans, learning management, learning activities, learning materials, and assessment. Therefore, they need to be prepared for going teaching practice or internship in schools. The researcher taught the course of science instruction for the fourth- year undergraduate students for four years. The result of evaluating the course by the students, which collected data by using questionnaire and informal interviews showed that they had some problems in designing learning activities and creating lesson plans. In addition, collecting data from the questionnaires after teaching showed that the students' responses indicated that they have the most difficulty with designing learning activities based on STEM education. They need learning materials and examples of creating lesson plans and designing learning activities. In addition, pre-service science teachers need to develop 21st -century skills. Beer (2018) indicated that students need to develop the 21st-century skills because these skills are important for working in the future. Ismail, S. A. A., & Jarrah, A. M. (2019) investigated the impact of teaching practice on pre-service teachers' perceptions of their pedagogical preferences, teaching competence and motivation for choosing teaching as a future career. Pre-service teachers or student teachers need to be provided opportunities and support for developing their teaching, training program benefit toward teacher education program. Active learning is one of the approaches to student teaching, where they learn through reading, observing, listening, writing, discussing and reflecting. Active learning methods can improve the quality and depth of studying and increase motivation in learning. The use of active learning technologies was considered, such as problem-based learning technologies, project method technologies, team work technologies, role playing technologies, information and communication technologies. This fact indicates a great desire of students to know their personal capabilities in the process of educational and professional activities (Bochkareva et al., 2020). Active learning is an instruction approach for teaching and learning in a university. It is a way to promote student learning and develop student skills (Budoya, Kissake, & Mtebe, 2019). To improve the quality of pre-service science teachers, one goal of course of science instruction is to develop 4th year undergrad students for scaffolding them to practice about teaching strategy, creating learning materials, assessment, and evaluation. Promoting pre-service teachers to improve competency in learning and teaching including creative thinking skills to prepare students for the future. Developing undergrad students to practice learning and innovation skills is necessary in the 21st century (P21 Partnership for 21st century learning, 2017). Therefore, the researcher intends to develop instructional design using the ADDIE model.

Instructional design by using ADDIE model

The ADDIE model is an instructional design process consisting of five phases: (1) analysis, (2) design, (3) development, (4) implementation, and (5) evaluation. The ADDIE model can develop instructional design (Culatta, 2019; Quigley, 2018). ADDIE Model is the popular model used for designing instruction. It can develop student learning performance and promote teaching and learning process. Each phase is a flexible approach used to create a tool effectively. The principle of instructional design is a systematic process for planning the teaching system. The objective is to help the students learn in a systematic way. It supports developing instruction and creating teaching and learning materials (Ismail et al., 2018). Several works (Budoya, Kissake, & Mtebe, 2019) show that ADDIE model was effective for promoting teaching and learning for undergraduate students. The study revealed that the phase of analysis included needs analysis, analysis of learners, content analysis, technical analysis, structural analysis, and analysis of the learning environment. In design phase is a process which includes responding to the questions of how to carry out the objectives and strategies determined in the analysis phase. This phase includes defining the objectives, designing the course contents, the learning and teaching process, and the evaluation system. In development phase included the preparation of the platform to be used such as preparation of contents, developing learning materials, evaluation tools. In phase of implementation is a process of conducting with learners, using tools, and supporting the

learning environment. The final phase is evaluation, the learner was evaluated following the learning objectives or goals that set at the design phase. Therefore, this research used ADDIE model to develop a learning package and the instructional design for enhancing competency of pre-service science teachers in designing learning activity base on STEM education.

STEM education

The term "STEM education" is now widely used and has become an international topic for many years. STEM had its origins in the 1990s at the US National Science Foundation (NSF) for helping students learn across STEM fields, which integrated engineering and technology with science and mathematics in undergraduate and K-12 school education. Goals for STEM education are to increase advanced training and careers in STEM fields and to expand the STEM capable workforce, including increase scientific literacy for all students. STEM means "science, technology, engineering, and mathematics". Literature reviewing found that integration across different disciplines of STEM differently using various terms such as, multidisciplinary, interdisciplinary, and transdisciplinary (Margot & Kettler, 2019; Ring, et al., 2018). The term "STEM education" refers to teaching and learning in the fields of science, technology, engineering, and mathematics; typically including educational activities. While scientific inquiry involves the formulation of a question that can be answered through investigation, engineering design involves the formulation of a problem that can be solved through constructing and evaluating during the post design stage. STEM as an interdisciplinary discipline requires that pedagogical approaches must be altered from traditional approaches to support student learning. There are many publications on STEM education research. According to Li et al., (2020), with the rapid increase in the number of publications on STEM education in recent years, reviews of the status and trends in STEM education research internationally support the development of the field. They conducted a systematic analysis of 798 articles in STEM education published between 2000 and the end of 2018 in 36 journals to get an overview about developments in STEM education scholarship. The results show that research in STEM education is increasing in importance internationally. Their analysis suggests that the research community had a broad interest in both teaching and learning in K-12 STEM education. Instructors use strategies based on active learning in STEM education for improving learning outcomes of undergraduate students (Theobald et al., 2020). Tharayil et al., (2018: p.1) have described that "extensive research has shown that active learning strategies are generally more effective than traditional lecture for promoting a wide range of desirable educational outcomes, including increased student learning and better retention in STEM programs".

Pre-service teachers are expected to have 21st-century skills to be successful in their future working. For preparing pre-service science teachers to be effective teachers in the future, they should increase knowledge and understanding in STEM education for developing skills of students to be able apply knowledge of four disciplines (STEM) to solve problems in daily life and real world, and to prepare students for working related STEM issues, and to increase the interest in STEM careers. To integrate STEM applications into the course and to enhance pre-service teachers' competency, the researcher developed the instructional design of the course and focus on STEM education and implement active learning. As mentioned before, the research questions of this study are: (1) Does using learning packages that developed by instructional design based on ADDIE model enhance students' competency in designing learning activities based on STEM education? (2) What effects does the learning packages have on students' competency, and students' opinions toward instruction? This research aims to 1) develop a learning packages to enhance competency in designing learning activities using STEM Education approach for pre-service science teachers, using ADDIE model as an instructional system design to develop a learning packages, 2) implement the learning packages with 4th year undergraduate students and study the students' competencies, which divided into two sections;

(1) assessing students' competencies by the researcher as the lecturer, and (2) assessing competency by students using self-assessment, and 3) study students' opinions towards the instruction.

METHOD

Participants were 31 fourth-year undergraduate students (8 males and 23 females) enrolled in the course of Science Instruction in the second semester of the academic year 2020. They were taught by the researcher. They were pre-service teachers studying at the bachelor degree in education (5-year program), in the program of Bachelor of Education in the Department of General Science, Faculty of Science, Srinakharinwirot University in Bangkok, Thailand.

This research is classroom action research to solve problems about competency in designing learning activities of the fourth-year undergraduate students in the course of science instruction, and to develop the learning packages or training packages, and to build student competency in creating learning activities using a STEM education approach. The research process used ADDIE model of five steps; (1) Analysis, (2) Design, (3) Development, (4) Implement, and (5) Evaluate. The research tools were developed by the researchers to collect data consisting of: (1) the learning packages, (2) the students' competency assessment form by evaluating from tasks and performance of the students using scoring rubrics, (3) the competency self-assessment form, and (4) the students' opinions questionnaire towards the instruction. Both quantitative data and qualitative data were collected by using the competency assessment forms and the questionnaire. Data collection and data analysis consisted of (1) the students' competency in designing learning activities, (2) the competency self-assessment of the students, and (3) the students' opinions towards the instruction.

The theoretical framework of this study is shown in Figure 1.

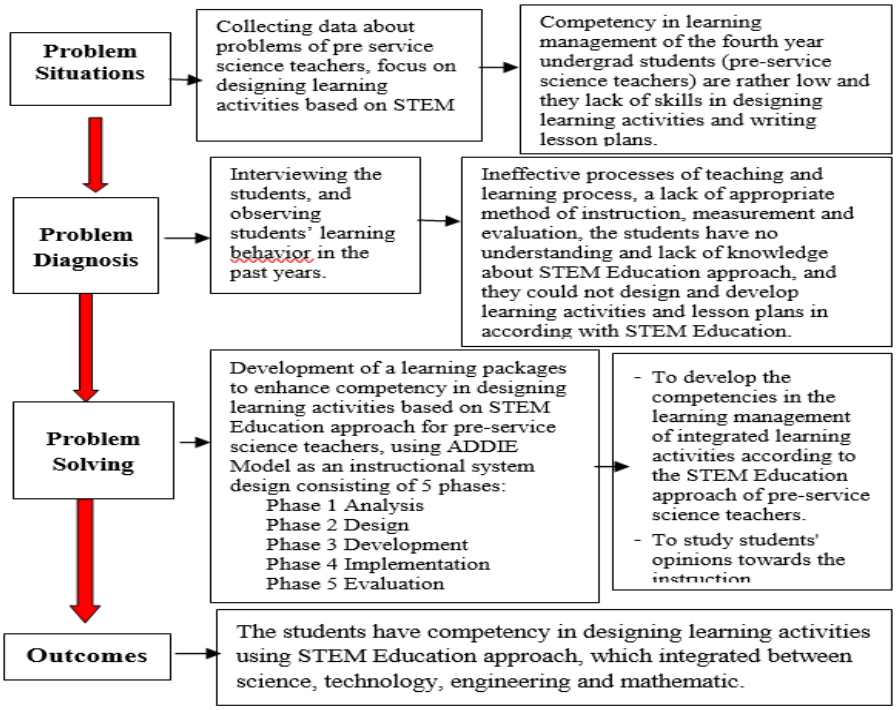

Figure 1
The theoretical framework

The ADDIE model was used in the research process, which has five phases (Analysis, Design, Development, Implement, and Evaluate) as Figure 2.

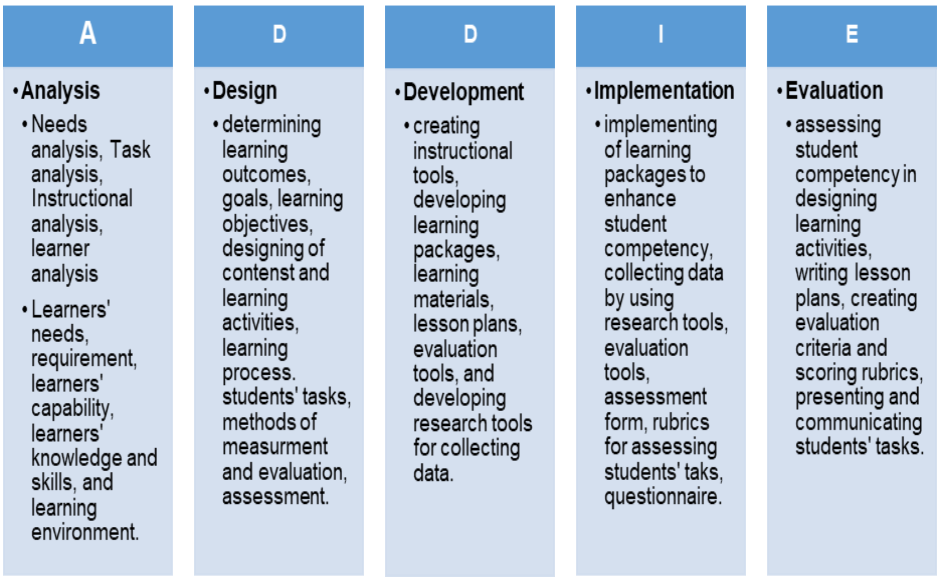

Figure 2
ADDIE model for this study

Phase 1: Analysis

In this stage, the qualities of the intended students are analyzed, including their background knowledge, prior experience, interests, and attitudes. In analysis phase involve identify problems and determining processes including the learning environment. Clarifying instructional problems in course of Science Instruction. The response from the students, which the researcher reviewed, indicated that they needed learning resources and learning materials to assist them in creating learning activities and lesson plans. The researcher identified the learning objectives and analyzed related content. The participants in this study were 31 fourth-year students who enroll in science instruction courses. The students' prior knowledge and skills were examined. The learning packages' objectives and content were determined.

Phase 2: Design

The instruction's outline was created. The researcher designed learning activities, learning materials, and assessment. Enhancing student competency while incorporating the STEM education principle into the teaching and learning process is a key objective. Students have the chance to engage in independent study through the learning activities. To promote 21st-century abilities, various teaching methods were used to engage students in learning such as learning centers, group investigations, small-group discussions, group process learning, group presentations, and questioning. This study boosted students' usage of digital technology while focusing on activity-based learning. The learning packages based on STEM education that used in this research were developed by the researcher. The elements of the learning packages consisted of the principles, objectives, topic concepts, instruction, assessment and evaluation, assessment tools, scoring rubrics for assessing students' tasks and learning performance, learning materials, and learning resources. The learning packages' contents are separated into four units; Unit 1: learning management using STEM education, Unit 2: designing

learning activities and assessment based on STEM education approach, Unit 3: writing lesson plans, and Unit 4: presenting students' tasks and communicating students' feedback toward STEM education approach. Each unit's component includes learning objectives, activity time, activity flow, measurement, evaluation, learning resources, exercises, and worksheets. Each unit take time for 4 hours, total time for instruction use 16 hours. Learning activity using STEM education focus on engineering processes consisting of 6 steps (Figure 3).

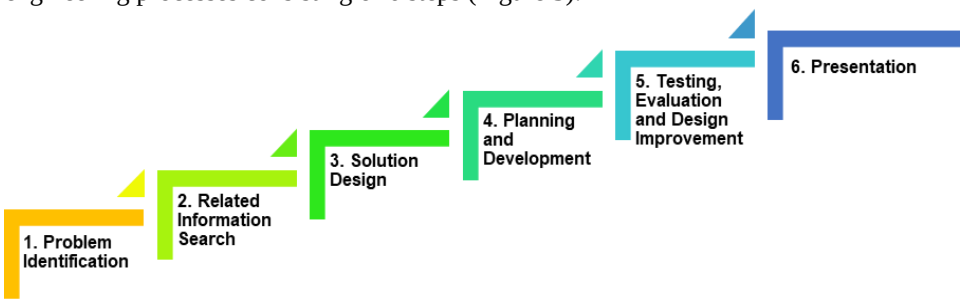

Figure 3
Engineering process of STEM education approach

Phase 3: Development

The learning packages, instructional materials, assessment and evaluation tools, and questionnaires were produced. The following research tools were used to gather data: (1) the learning packages; (2) the competency evaluation form for students; (3) the competency self-assessment form; and (4) the students' opinion survey regarding the teaching. Three experts evaluated the quality of the learning packages. The results revealed that the learning packages' quality had a mean score of very good quality (mean=4.63, S.D.=0.20). After that, the learning packages were revised by the researchers in response to the experts' feedback. For the competency assessment forms for the students, rubrics were established. Scoring rubrics were utilized to assess students' performance on both the processes and the products. Descriptions of student performance at various quality levels are included in the rubric. A rubric has three parts: 1) performance criteria; 2) rating scale; and 3) indicators. The criteria describe the key elements of a student work or product. The rating scale identifies levels of performance. The indicators provide concrete descriptors for each level of performance. The evaluation criteria were designed, documented, and included requirements that students must meet for the assignment. The following four-point rating scale was used: (excellent = 4, good = 3, acceptable = 2, poor = 1). The assessment's performance quality was identified. The student competency were divided into five competencies(total score: 170) as follows; Competency 1: Knowledge and understanding of learning management according to STEM Education approach(Score = 30), Competency 2: Ability to design learning activities(Score = 40), Competency 3: Ability to write a lesson plan (Score = 60), Competency 4: Ability to create evaluation criteria and scoring rubrics(Score = 20), Competency 5: Ability to present their work, and communication skills(Score = 20). Students were assessed for competence 1 using the worksheets that they will get in the Unit 1 assignment (Week 1). Students were assessed using assessment forms that included assessment criteria and rubrics for competencies 1-4. For competency 2, the tasks the students completed from Unit 2's activities (Week 2), Competency 3's and Competency 4's tasks (making lesson plans and rubrics) from Unit 3's activities (Week 3), and Competency 5's tasks (student presentations from Unit 4's activities, Week 4), in which the students presented their lesson plans and rubrics to the class, were used to evaluate the students. Four assessment forms were created using assessment criteria of four quality levels as follows.

1. Assessing competency in designing learning activities (LA).

1) LA are aligned with the established learning objectives.
2) LA are in line with the principles of STEM Education.
3) LA are innovative, modern, and interesting.
4) LA promote learners to do the activities by themselves.
5) LA encourage learners to integrate knowledge of science, technology, mathematics, and engineering design processes.
6) LA develop learners in group working and working with others.
7) LA encourage learners to develop analytical thinking skills and critical thinking skill.
8) LA encourage learners to develop problem solving skills.
9) LA encourage learners to develop creativity and innovation skills.
10) LA encourage learners to develop their skills in using information technology and communication skills.

2. Assessing competency in writing a lesson plan.

1) Define learning objectives that encompasses three areas: knowledge, skills, processes, and desirable attributes.
2) Write learning objectives that is academic correct.
3) Write and summarize the concept of contents clearly and appropriately.
4) Write the contents correctly and having sufficient and appropriate details.
5) The content and activities can be set in accordance with the learning objectives.
6) Design learning activities in accordance with STEM education principles and guidelines.
7) Write procedures for the activities clearly, and able to perform.
8) The activities are suitable for the level or age of the learners.
9) The time allotted for the learning activity is reasonable.
10) All learning materials used in the lesson are list in the lesson plan and materials are appropriate for doing activities.
11) The measurements are consistent with the learning objectives.
12) Using a variety of measurement methods, both knowledge and skills.
13) Designs and utilizes a variety of assessment tools.
14) The topics of lesson plans are appropriate.
15) The use of language is correct and appropriate.

3. Assessing competency in creating evaluation criteria and scoring rubrics.

1) Create assessment criteria that are consistent with learning objectives.
2) Identify the qualities to be assessed of the list of assessments or indicators appropriately.
3) Compose information to create evaluation criteria appropriately.
4) Write a clear description for the quality level.
5) Use the language in writing a quality level correctly and appropriately.

4. Assessing competency in presenting students' work, and communication skills.

1) Describe and present the work performed.
2) Use techniques and methods in presenting their works.
3) Use technology in developing their works.
4) Use strategies to get the audience engaged and interested in presentation.
5) Communicate effectively and have good personality in presentations.

The questionnaire and the self-assessment form were developed by the researcher to collect the required data. The competency self-assessment form of the students is a 10-item Likert-scale. (5-point Likert scale; 1 = very low, 2 = low, 3 = moderate, 4 = high, and 5 = very high). The questionnaire was created in order to learn the students' perspectives on instruction. The goal of the student opinion survey is to gather comments and student satisfaction toward instruction. The data were collected after implementing the learning package. The questionnaire has two main sections. The first section

included a 25-item Likert scale of five-point scale (1 = highly dissatisfied; 2 = dissatisfied; 3 = neutral; 4 = satisfied; 5 = highly satisfied). It was divided into three parts: part 1: students' opinions toward STEM education, part 2: students' opinions on the advantages and value gained after learning, and part 3: students' opinions on learning management. The second section consisted of four open-ended questions.

Phase 4: Implementation

Data collection of this study was in this phase. The process of training the students was conducted for four weeks (4 hours per week). The participants were taught by the researcher using learning packages consisting of 4 units. The students will be provided some learning medias such as files of handouts, worksheets, VDO clips about STEM. The researcher used six video clips to increase students' comprehension of STEM principles and best practices. In Unit 1, students worked in group of five members to learn about designing learning activities based on STEM education through studying six case studies of learning activities. These case studies consisted of six learning packages that developed by the researcher. The four learning units are organized as follows: Unit 1: the Think Pair Share teaching method was used to examine students' prior understanding of STEM education. Small groups of 4-5 students are formed in the classrooms to work on the assignments. The students engaged in group discussions and idea sharing. They were asked with several questions to express their prior knowledge and opinions regarding the principles for developing learning activities based on STEM education, such as What is STEM education? Then, the students watched video clips regarding the fundamentals and application of the STEM (Science, Technology, Engineering, and Mathematics). Three VDO clips are provided (from www.ipst.ac.th), each of which shows an example of a learning activity for elementary or secondary students. The students used six learning packages to investigate designing learning activities based on STEM education guidelines. Figure 4 depicts the learning activity employing learning centers and six case studies. There are six learning centers that have six learning packages (LP). After that, they were given worksheets to complete in order to test their knowledge and comprehension of the STEM Education approach (Task 1). In addition, the students were assigned task from worksheets to practice self-directed learning abilities.

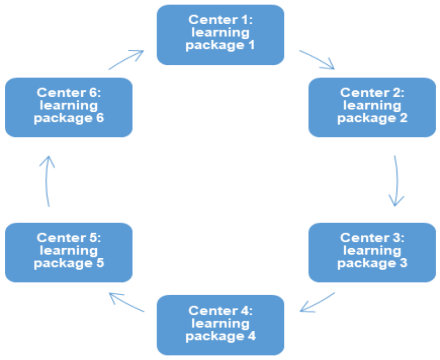

Figure 4
Using learning centers to learn 6 learning packages in Unit 1

Center 1, Learning package 1: Invention from waste materials for 5th grade students.
Center 2, Learning package 2: Water treatment for lower secondary students.
Center 3, Learning package 3: Light and visibility for lower secondary students.
Center 4, Learning package 4: Making mucilage and creating paper mache for lower secondary students.
Center 5, Learning package 5: Friction for 9th grade students.
Center 6, Learning package 6: The natural rubber latex process for 9th grade students.

Unit 2, the students learned designing learning activities by watching three VDO clips, and the researcher used questioning strategies to assess the students' comprehension. Students then carried out their tasks in groups. There are two tasks: (1) designing learning activities based on STEM education(Task 2), and (2) creating rubrics for evaluating student work (Task 3). The students used laptops, tablets and iPads to complete their assignments. At the conclusion of the unit, the students

presented their work to the class (practicing presenting and communication skills). Unit 3, The students worked on developing lesson plans using STEM-based learning activities (Task 4). They gained knowledge about how to specify learning objectives (cognitive domain, psychomotor domain, affective domain). They studied the components of a lesson plan and had group discussions. In this unit, the learning center method was applied. There are six learning centers (6 lesson plans). After that, they discussed and share ideas about creating lesson plans. Each group used laptops and iPads to develop lesson plans, and they used smartphones in searching information from learning resources such as www. Stemedthailand.org. Unit 4, the students presented their works (Task 5). The researcher encouraged students' discussion by using questions. After that, the students worked in group to reflect their opinions toward STEM education. Methods of small group discussion, brainstorming, and group presentation were used in this unit. At the end, the students were required to complete a self-assessment and a questionnaire. Learning strategies were used to encourage the students to participate in learning, organizing learning activities, and practicing various learning skills, including using learning technologies such as learning center, using case studies, group investigation, group presentation, small group discussion, brainstorming, think pair share, questioning, using learning media, video clip, slide power point, and other multimedia. Students were taught to set group goals, share roles, divide task, and communicate face to face. Using the rubric score and the assessment forms, the learning outcomes and competency of the students were assessed from group projects, student assignments, and group presentations.

Phase 5: Evaluation

Data analysis was conducted in this phase. Both descriptive and analytical statistics were used to analyze the data obtained from the questionnaire and the assessment forms. The effectiveness of implementing the learning package to enhance the student competency was evaluated from (1) students' competencies using assessment forms, (2) students self-assessment using self-assessment form, and (3) students' opinion toward instruction using a questionnaire. Data on the students' competencies was gathered from evaluations of their performance using the scoring criteria on the assessment forms. The frequency, mean, standard deviation, and percentage were used to assess the quantitative data. In order to assess the qualitative data, content analysis was used. The qualitative data were organized and categorized into themes.

FINDINGS

The students' competency in designing learning activities.

Quantitative analysis of the students' competencies was analyzed using the frequencies, and percentages. Mean scores of students were compare with criteria as follows; 80-100% = Excellent, 70-79% = good, 60-69% = fair, 0-59% = Poor. The total number of the students in each competency are summarized in Table 1.

Table 1
Data analysis of the students' competency (*n*=31)

Competency	Number of students in each competency (Number(%))			
	Excellent	Good	Fair	Poor
1. Knowledge and understanding of learning management according to STEM Education approach.	26 (83.87)	5 (16.13)	0 (0)	0 (0)
2. Ability to design learning activities.	26 (83.87)	5 (16.13)	0 (0)	0 (0)
3. Ability to write a lesson plan.	21 (67.74)	10 (32.26)	0 (0)	0 (0)
4. Ability to create evaluation criteria and scoring rubrics.	16 (51.62)	15 (48.38)	0 (0)	0 (0)
5. Ability to present their work, and communication skills.	11 (35.48)	10 (32.26)	10(32.26)	0 (0)
Overall competencies	21 (67.74)	10 (32.26)	0 (0)	0 (0)

Table 1 shows the number of students that were assessed each competency. The results shows that overall competencies of 21 students(67.74 %) were at excellent level, and 10 students(32.26%) were at good level. Considering each competency, Competency 1, 83.87% of students were at excellent level, and 16.13% were good level. Competency 2, 83.87% of students were at excellent level, and 16.13% were good level. Competency 3, 67.74% of students were at excellent level, and 32.26% were good level. Competency 4, 51.62% of students were at excellent level, and 48.38% were good level, and Competency 5, 35.48% of students were at excellent level, 32.26% of students were at good level, and 32.26% of students were at fair level. After that, the mean scores for each competency of 31 students were analyzed by using percentage. The results are summarized in Figure 5.

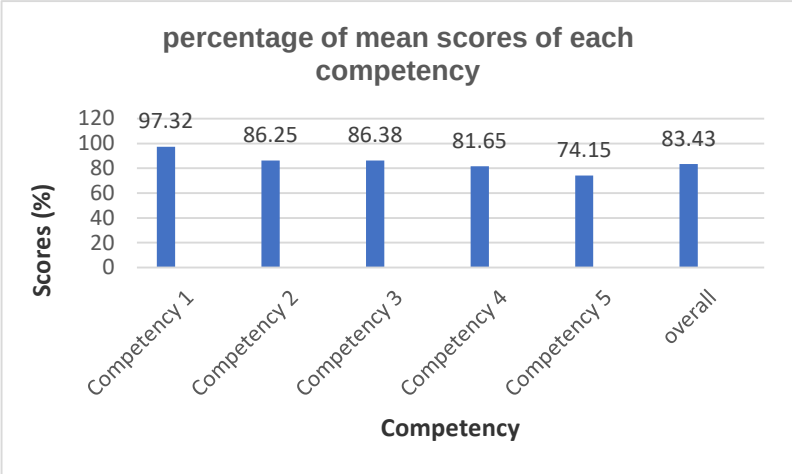

Figure 5
The mean scores of each competency

Figure 5 shows that overall competencies of the student were 83.43%. Competency 1-5 shows scores at 97.32%, 86.25%, 86.38%, 81.65%, and 74.15% respectively.

The competency self-assessment of the students.

The results of student self-assessment before and after learning were analyzed with mean(M), standard deviation(SD) as Table 2.

Table 2
Data analysis of student self-assessment

	Item	Level of students' competency					
		Before learning			After learning		
		M	SD	level	M	SD	level
1	I understand the principles STEM Education approach.	2.30	0.74	low	4.30	0.46	very high
2	I can define the behavioral learning objectives used in the organization of learning activities.	2.33	0.79	low	4.27	0.44	very high
3	I can design learning activities using STEM Education approach.	1.90	0.83	low	4.07	0.51	high
4	I can write a lesson plan.	1.90	0.87	low	4.27	0.44	very high
5	I can create learning materials.	2.27	0.77	low	4.23	0.56	very high
6	I can determine the measurement and assessment method.	1.83	0.73	low	4.20	0.40	high
7	I can organize learning activities integrating STEM Education.	1.93	0.89	low	4.33	0.54	very high
8	I use digital technology to organize learning activities.	2.67	0.75	moderate	4.30	0.46	very high
9	I have learning and innovation skills (4Cs) to create activities.	2.33	0.83	low	4.17	0.52	high
10	I see the value and benefits of organizing learning activities using STEM Education.	3.07	1.06	moderate	4.93	0.25	very high
	Total mean score (M)	2.25	0.83	low	4.31	0.46	very high

Table 2 shows level of students' competency before and after learning. The results shows that before learning, most items(80%) was at low level, total mean score was 2.25(SD = 0.83), and after learning, most items(70%) was at very high level, total mean score was 4.31(SD = 0.46).

The students' opinions towards the instruction.

The quantitative data from the first section of questionnaire (25 items of five-point rating scale) was analyzed using item analysis, mean and standard deviation (SD), and compared with criteria as follows: 4.21-5.00 (highly satisfied; HS), 3.41-4.20 (satisfied; S), 2.61-3.40 (neutral; N), 1.81-2.60 (dissatisfied; D), 1.00- 1.80 (highly dissatisfied; HD). The results are presented in Table 3.

Table 3
Data analysis of students' opinions toward the instruction

No	Item	Mean	SD	Level
Part **1** Students' opinions toward STEM education				
1	I see the importance of learning activities using STEM Education.	4.83	0.38	HS
2	I think learning activities based on STEM Education can improve learners' 21st century skills.	4.87	0.41	HS
3	I understand the principles and guidelines for organizing learning activities according to the STEM Education.	4.27	0.44	HS
4	I can design learning activities according to STEM Education guidelines.	4.13	0.68	S
5	I can develop lesson plans using the learning process based on STEM Education.	4.27	0.44	HS
6	I can create the performance evaluation criteria.	3.97	0.46	S
7	I can design learning activities according to STEM Education.	4.33	0.54	HS
8	I can apply the knowledge to develop learning skills and innovation for students.	4.40	0.51	HS
	Total Mean part 1	4.38	0.57	HS
Part 2 Students' opinions on benefits and value gained after learning				
9	I have developed problem solving skills.	4.50	0.57	HS
10	I have developed creative thinking skills.	4.50	0.57	HS
11	I have developed information technology skills.	4.30	0.68	HS
12	I have developed collaboration skills.	4.50	0.57	HS
13	I have developed communication skills.	3.03	0.61	N
14	I have developed critical thinking and analytical thinking skills.	4.43	0.57	HS
15	I have developed competency in using STEM Education.	4.67	0.48	HS
	Total Mean part **2**	4.28	0.58	HS
Part **3** Students' Opinions on learning management				
16	The content is suitable for the learner level.	4.57	0.51	HS
17	The content is up to date.	4.43	0.57	HS
18	Content is appropriate and has sufficient details to enhance knowledge and understanding.	4.43	0.50	HS
19	Learning activities are aligned with learning objectives.	4.73	0.45	HS
20	The learning activities are appropriate.	4.63	0.49	HS
21	The time for the learning activities is reasonable.	4.10	0.75	S
22	The learning materials used are appropriate.	4.10	0.65	S
23	Digital technology is used to promote learning.	4.33	0.76	HS
24	Measurement and evaluation methods are appropriate.	4.60	0.50	HS
25	Overall satisfaction toward learning management	4.57	0.57	HS
	Total Mean part **3**	4.45	0.62	HS
Total mean		4.38	0.59	HS

Table 3 shows that the students' satisfactions toward the instruction were at highly satisfied (mean = 4.38, SD = 0.59). The results of Part 1 to Part 3 were at highly satisfied. The qualitative analysis of four open-ended questions from the questionnaire shows that the students have positive opinions toward the instruction. The learning package help motivate students and promote them have more participation in learning and they had developing various learning skills such as problem-solving skills, collaborative skills, and communication skills. Students claimed that learning materials, especially those that offer examples of designing learning activities, motivate them to learn, think, and enhance their knowledge and comprehension of STEM Education. Some students struggle with

searching for information in learning resources and engaging in self-directed learning. Examples of responses from students to each question are provided below.

Table 4
Examples of some statements from students' opinions

Question	Examples of some statements
1) What did you think about instruction?	"Using group process learning and learning materials make more students' interest", "Using learning centers was helpful", Watching VDO clips is useful to encourage learning", "There are several teaching and learning strategies to boost student competency".
2) What advantages did you receive learning based on STEM education?,	"I was able to create lesson plans using the learning process based on STEM Education", "I practiced creating rubric scoring for assessing student learning", "I worked in group and exchanged idea with friends, working in groups, learning with collaboratively made me understand more in writhing lesson plans".
3) What problems did you meet from doing activities using STEM education approach?	"I have difficulty in creating rubrics for assessing product and process of student performance", "I have trouble determining learning objectives", "I am unsure about creating criteria of evaluation tools", "I need to improve my communication skills", "I have trouble searching for information using the internet and technology tools"
4) Do you have any opinions or other comments?	"I need to learn more examples of designing learning activity based on STEM Education", "I need examples of various lesson plans", "Should increase time for doing activities", "time for organizing activities are not appropriate, there are not enough time for completing tasks, therefore, should increase time for doing activities such as five hour per unit".

Utilizing learning modules can help students become more proficient at creating STEM-based learning activities.

DISCUSSION

From the research questions of this study, the finding show that using learning packages that developed by instructional design based on ADDIE model enhance students' competency in designing learning activities based on STEM education. And the effects of the learning packages have on students' competency, and students' opinions toward instruction. The following reasons explain the results of this research. Using ADDIE model can develop instructional strategies, and improve the students' competency. Students can improve their ability to design STEM-based learning activities by using learning packages. The results shows that a number of 21 students (67.74%) show competency at excellent level, and 10 students (32.26 %) have competency at good level. The total competency mean scores for the students were 83.43%. Competencies 1, 2, 3, 4, and 5 had mean scores of 97.32%, 86.25%, 86.38%, 81.65%, and 74.15%, respectively. The student self-assessment indicated that before learning, the competency was at low level, and after learning it was at very high level. Using learning packages that include various instruction strategies can enhance competency in designing learning of pre-service science teachers. Using multimedia help promote student learning such as using VDO clips, application, and social network. Most of these students have abilities and competency following the learning objectives that determined. They can design leaning activities based on STEM education including creating lesson plans, worksheets, and evaluation tools. In addition, they have developed competency in using technology devices for creating leaning materials. The students improved problem solving skill and creative thinking skill in designing learning activities based on STEM education approach. The STEM education approach uses problem-based and project-based learning with a set of particular learning outcomes to promote student learning while challenging students to explore and invent. The students improved competency in presenting their works by using electronic multimedia such as program PowerPoint, Microsoft word, Adobe Photoshop, Canva, GoodNote, and Procreate. Using various teaching strategies can encourage students' learning. The analysis found that

the students have positive opinions toward teaching and learning process. The students' competency can be improved by using the ADDIE Model.

Budoya, Kissake, & Mtebe (2019), in their study found that using ADDIE model was effective for developing leaning materials and effective research tools including media and technology elements. The students increased motivation to learn. They developed several skills such as critical thinking, problem solving skills, collaboration skills, and communication skills. Learning center is a teaching method of active leaning. The students have developed their competency in learning. The research of Stolk, Gross, & Zastavker, (2021) shows that active learning is more effective than lecture-based learning in enabling undergraduate students to connect their personal interests and passions with a strong sense of meaning, importance, and relevance. According to Nguyen et al., (2021) their study shows positive benefits of using active learning in undergraduate STEM courses and positive affective and behavioral outcomes in terms of students' self-reports of learning, enjoyment, self-efficacy, attendance, participation, and course satisfaction. The use of active learning in STEM fields has been linked to improvements in student retention and learning. Active learning can improve 21st century skills of learners. Valtonen et al., (2021) investigate the development of pre-service teachers perceived 21st-century skills and dispositions. 21st-century skills refer to skills that students are expected to possess for successful future careers. The ways students perceive these skills are significant. According to Buitrago-Flórez et al., (2021), the social, technological, and economic changes that have occurred in the 21st century have made critical thinking, creativity, communication, and collaboration, key competences to face the challenges of a rapidly changing world. Therefore, the instruction should enhance students' four 21st century competences (critical thinking, communication, collaboration and creativity), and increasing student ability to solve problem situations. Active leaning methods of teaching help the students build meaningful knowledge.

Students have abilities to develop lesson plans. They could design instructional strategies that align with stated learning objectives. They designed learning activities integrating Science, Technology, Engineering and Mathematics, which these activities solve the problems in daily life, and develop learners' innovation and learning skills. The lesson plans provide opportunities for students in doing activities by themselves. Using learning packages as learning materials and using learning center as teaching method help the students received knowledge and understanding about STEM approach. Putra et al., (2021) reported that the development of science and technology in 21st-century education has led to a paradigm shift in learning. The success of technology integration in learning can be seen from the teacher's competence to design learning material. The application of project-based learning and STEM approach could develop learning skills as 21st-century learning objectives. The results of Sudarsono et al., (2022) found that the geometric problem-solving abilities of students who learn with STEM learning are better than students who learn with ordinary learning. STEM learning can activate students in the learning process. The questions presented must encourage students to seek and use an approach from the perspective of solving. Giving questions can develop the ability to produce various answers or solutions in solving problems.

Using formative assessment and authentic assessment can enhance the student competency including self-assessment encourage learning achievement. The students' competency were evaluated using scoring rubrics. Scoring rubrics have been used to evaluate group activities, students' tasks and oral presentation. The rubrics were presented to the students before they carried out their assignments. The criteria and levels of quality were explained to the students before they performed their tasks. From observing, it was found that the students studied and discussed about scoring rubrics before creating their tasks. The students gave feedback that they studied rubrics before designing learning activities and creating lesson plans in order to make good lesson plans. Students' responses indicate that rubrics aided them in both planning and when performing the assignment. The study of Wafubwa, & Csíkos (2022) revealed that formative assessment strategies can improve the performance of low achieving

students and also improve their metacognitive awareness.Self-assessment as a formative assessment strategy can enhance students' metacognitive awareness because students who participate in self-assessment monitor their thinking processes and are able to assess their learning process.The impact of formative assessment conceptualized as an instructional approach on students' achievement and their metacognitive awareness.

Another finding is the students' opinions towards implementation of learning packages and the instruction, which the students have satisfaction were at highly satisfied, and they have positive feedback toward the instruction. They give feedback that they have more competency in designing learning activities and creating rubrics for assessing performance and products of students. Collecting data from open-ended question show that the students like the learning packages and they could study and worked more effectively. They stated that "learning materials such as case studies of learning packages and lesson plans were good examples to promote them in learning". The examples of six learning packages were good case studies that enhance students' learning. The findings of the study of Almuqayteeyb, T. A. (2021) indicated that preservice teachers have positive attitudes towards using case study as a teaching method. The case study method is beneficial for improving preservice teachers' interest and engagement, which has the potential to improve student learning.

In addition, the students practiced communication skills when they worked in group and discussed with their friends, and when they presented their tasks in front of the class. In addition, students' feedback showed that they need to improve learning performance. Some students need to develop self-directed learning skill. Self-directed learning (SDL) can encourage student responsibility for learning, increases student retention and builds self-esteem. SDL is a learning process that promote personality characteristics in learning of students. Students have to take responsibility and initiative to determine their learning needs, and formulate learning goals. The research results of Rini et al., (2022) found that there is a significant influence of students' digital literacy skills on self-directed learning. The influence of the two variables has a positive direction, which means that the higher the student's self-directed learning is, the better his digital literacy skills will be. It also explains that the level of student self-directed learning can be viewed from their digital literacy competencies. Self-directed learning will make students plan, implement, and evaluate learning with full responsibility for themselves and are expected to work independently to achieve learning goals. The results of the study of Salleh et al., (2019) illustrate that self-directed learning is a factor that has a good impact to lifelong learning. The study follows a relational survey to investigate and measure the degree of relationship amongst self-directed learning, social networking sites and lifelong learning. The findings of the research corroborate that self-directed learning positively affects lifelong learning.

CONCLUSION AND SUGGESSTION

In order to improve the competency of fourth-year undergraduate students in designing learning activities using STEM Education, writing lesson plans, establishing assessment tools, and creating scoring rubrics, this research used the ADDIE paradigm as instructional design. The findings show that most students were able to design lesson plans consistent with the goals of STEM Education, improving problem solving skills and creative thinking skills from doing activities, doing assignments, presenting students' tasks. The students had good opinions toward instruction. The result showed that the implementation of learning packages developed by ADDIE model could enhance students' competency in learning management, and designing learning activities based on STEM education. Evaluating of the competency in designing learning activities using STEM education approach of pre-service science teachers showed that 67.74% of students were at excellent level, and 32.26% of students were at good level. Overall competencies of students were 83.43% mean scores, which mean scores of each competency are as follows; competency 1: Knowledge and understanding of learning management according to STEM Education approach(97.32%), competency 2: Ability to design

learning activities(86.25%), competency 3: ability to write a lesson plans(86.38%), competency 4: ability to create evaluation criteria and scoring rubrics(81.65%), and competency 5: ability to present their works, and communication skills(74.15%). The results of competency self-assessment showed that before learning the students' competency were at low level, and after learning the students' competency were at very high level, and the students' opinions toward the instruction were at highly satisfied level. The qualitative data from observing the students' behavior, students' tasks and four open-ended questions from the questionnaire indicated that the students have positive opinions toward the instruction. They have developed many several skills. Therefore, the students' competencies were improved by using learning activities based on STEM education, and the use of ADDIE model help developing the instruction. Using learning packages and various teaching techniques based on active learning can enhance self-directed learning and learning skills of students. The results demonstrated that active learning and formative assessment can improve student ability. The results of this study will help future educators construct successful teacher education program, course of instruction and prepare undergraduate students to teach science in the classroom. The results of this study can benefit science teachers and curriculum developers in designing learning activities based on STEM approach to enhance students' competency. The use of STEM education approach is to prepare students for working and developing their future lives. It is recommended that future studies should study students' competency by using others learning materials and active learning methods including developing research tools for formative assessment and using scoring rubrics as assessment tools to improve student performance.

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