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Subject-specific pedagogy development training for Chemistry teachers in collaboration with ASEAN STEAM GROUP

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ABSTRACT

Many secondary school teachers are interested in implementing STEAM (Science, Technology, Engineering, Arts, and Mathematics) learning but still need assistance to plan their lessons through the development of SSP (Subject-Specific Pedagogy). STEAM is a learning approach aimed at helping students apply the primary content, practice it in everyday life, and have the skills required in the 21st century. Hence, the Chemistry Education Study Program Society Service Team of UNS, in collaboration with ASEAN STEAM researchers, aimed to improve the abilities of secondary school teachers in developing SSP for STEAM-based learning through this training. This training method was carried out hybridly. The activity began with a STEAM presentation and a workshop the next day. A pre-test and post-test were given before and after training. A supervision of making SSP was carried out the following day for two weeks. The participants who worked on five SSP pre-test and post-test questions showed a significant result increase in the average score of 0.6—based on a questionnaire filled out by 27 participants, 48.1% and 44.4%, respectively, stated that they had gained complete and very completely new knowledge and skills regarding the implementation of STEAM. As an evaluation, participants also provided suggestions for increasing training and mentoring time when training participants apply the training results at school.

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1. INTRODUCTION

STEAM (Science, Technology, Engineering, Arts, and Mathematics) education has emerged as a crucial approach to address the challenges of the 21st century. It integrates hard and soft skills, catering to the holistic development of students (Wahyuningsih et al., 2020). However, the successful implementation of STEAM education requires substantial support from the government, the reconstruction of a national curriculum, and significant changes in the national assessment system (Park et al., 2016). The integration of STEAM into education has been proposed as an engaging and realistic learning experience, allowing for better integration of disciplines and fostering creativity and problem-solving (Herro et al., 2017). Furthermore, the application of STEAM has shown to contribute to the development of students' skills

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in the 21st century, the alignment of technological advancements and the improvement of demands of modern times (Amiruddin et al., 2022).

STEAM education enhances students' skills and fosters curiosity and motivation, making learning becomes a fun and engaging experience (Siregar et al., 2023). Moreover, integrating science, technology, engineering, art, and mathematics offers an approach to educational design based on curricular integration and learning with analog and virtual technologies (Videla-Reyes & Aguayo, 2022). STEAM education's impact extends to acquiring 21st-century skills, such as critical thinking, problem-solving, creativity, communication, collaboration, innovation, and leadership, which are essential for the future workforce (Anagün, 2018). Additionally, STEAM learning provides a platform for students to use design thinking, promoting creativity and successful engagement in their learning (Cooke, 2022).

The development and implementation of STEAM education have also been explored in various contexts, such as the impact of STEAM-based e-modules on online learning and the improvement of students' creative thinking skills (Asih et al., 2021). Furthermore, the impact of project-based learning integrated with STEAM on students' communication skills and concept mastery in high school biology learning has been investigated, highlighting the positive outcomes of such an approach (Suciari et al., 2021). So, STEAM education is a multifaceted approach that enhances students' academic skills and nurtures their creativity, critical thinking, and problem-solving abilities, aligning with the demands of the 21st century. Integrating arts and humanities into STEM subjects offers a promising educational development avenue, preparing students to thrive in an increasingly complex and dynamic world.

Based on the description above, the essence of STEAM learning is to make students more creative in finding solutions to existing problems. However, in practice in the field, many students still need to be more active in the learning process due to the lack of implementation of innovative learning in the classroom. It will result in lower 21st-century students' skills, such as communication skills, critical thinking, collaboration, and creativity (Jufriadi et al., 2022). So, to foster the students' 21st-century skills, teachers must be able to design innovative learning tools. It aligns with the independent curriculum's vision, mission, and objectives.

An independent curriculum is a learning method that refers to a talent and interest approach (Azizah et al., 2023). Students can choose whatever lessons they want to study according to their interests. In general, the independent curriculum is a diverse intracurricular learning curriculum. Regarding implementing the independent curriculum in schools, many teachers still need to implement innovative learning such as STEAM-based learning. The limited knowledge of teachers in schools regarding STEAM-based learning has resulted in minimal implementation in classroom learning (Anugrahana, 2019). Apart from that, teachers' skills in designing STEAM-based contextual learning still need to be improved. So, it is necessary to organize a training to design SSP (subject-specific pedagogy) learning tools for teachers in collaboration with ASEAN STEAM Group Researchers.

Subject-specific pedagogy (SSP) is an essential educational approach that focuses on developing competency standards, materials, strategies, methods, media, and evaluation tools tailored to specific subjects. Competency standards in SSP refer to the specific skills and knowledge that educators are expected to possess to teach a particular subject effectively. These standards are often tailored to the unique requirements of each subject area, ensuring that educators have the expertise to deliver high-quality instruction (Wahyuni & Sumarni, 2018). Additionally, Johnston et al. (2014) identified core competencies for an undergraduate food safety curriculum, emphasizing the need for specific competencies within the subject area.

According to the materials, SSP emphasizes the development and utilization of appropriate teaching resources that align with the subject matter and the needs of the learners. It includes creating

engaging and informative materials that facilitate compelling learning experiences (Rahmawati et al., 2022). Furthermore, strategies and methods in SSP encompass a wide range of instructional approaches tailored to the subject being taught. These strategies and methods are often adapted based on contextual factors and the pedagogical needs of the learners at a given time (Fenyi et al., 2021)

Media also plays a significant role in SSP, with educators leveraging various forms of technology and multimedia to enhance the delivery of subject-specific content. It may include using interactive electronic modules, digital simulations, and other innovative tools to enrich the learning experience (Rahmawati et al., 2022). Additionally, evaluation in SSP involves using assessment instruments to measure and gauge students' learning outcomes. These instruments are designed to provide insights into the effectiveness of the teaching methods, the mastery of subject-specific competencies, and the overall academic progress of the learners. In terms of evaluation, a validity test of learning devices for economic learning outcomes using a contextual teaching and learning (CTL) approach demonstrates the importance of subject-specific assessment tools (Wahyuni & Sumarni, 2018).

Therefore, SSP encompasses a comprehensive framework that addresses competency standards, materials, strategies, methods, media, and evaluation instruments, all essential for delivering effective subject-specific instruction. The sequence of SSP development is presented in Figure 1.

Figure 1. The sequence of SSP development

2. METHODS

The implementation of the training activities was divided into three stages: preparation, implementation, and evaluation. Preparation activities included coordination with ASEAN STEAM Group researchers to conduct a training, data collection of secondary school teachers' needs regarding STEAM Learning, determination of training materials and schedules, and socialization and distribution of invitations.

The implementation activities were carried out hybridly, a collaboration among the Research Group (RG) Community Service Team at the Chemistry Education Study Program, FTTE UNS and ASEAN STEAM group researchers. An RG involved in this activity were the Natural Products, Molecular Engineering, and Chemistry Learning RGs, abbreviated as RG PARM-PK. This implementation activity began with the socialization and delivery of STEAM material by ASEAN researchers from Universiti Sains Malaysia. The activity was continued with the delivery of training materials for making SSPs along with examples of devices by speaker. from RG PARM-PK, ended with mentoring activities for making SSPs. Evaluation activities were carried out before, during, and after the training and mentoring process. Evaluation before the training process was in the form of a pre-test, during the training process through questions and answers, and after the training process, in the form of a post-test. Evaluation after the mentoring process was in the form of a questionnaire filled out by participants after the mentoring process was complete.

Activity Method

The implementation of this activity used five activities, namely: (1) Presentation and Q&A method; (2) Demonstration method; (3) Practice and mentoring method; (4) Module; (5) Evaluation design.

Presentation and Q&A method

The presentation method was used for socialization, STEAM materials delivery, and SSP-making training materials. Socialization was intended to explain the training process, rules during the training, obligations that participants must carry out, and how to obtain a training certificate. The delivery of STEAM materials covered STEAM and its development in ASEAN and the implementation of STEAM learning in schools. The SSP-making training material focuses on explaining the definition and understanding of SSP, STEAM Learning for Chemistry material, how to make SSP for chemistry material with STEAM learning, and examples of STEAM-SSP for chemistry material in high schools or vocational schools.

At the end of each presentation session, participants can ask questions guided by the moderator. The presenter will answer each participant's questions. This question-and-answer method was carried out as a form of interaction or communication between the implementing team and participants. The question-and-answer method was used during the presentation, demonstration, practice, and mentoring. Through this Q&A session, participants were expected to get sufficient information and understand the material about STEAM and its implementation in schools, especially in making SSP for chemistry materials using STEAM learning.

Demonstration method

The demonstration method facilitated the participants of training to directly see examples of SSP compilation, as demonstrated through PowerPoint slides. Training participants can learn how to reduce Learning Achievements into teaching modules for learning Chemistry materials based on the STEAM approach. This method is one way to help participants get a concrete picture in deepening their knowledge. After participants get a concrete picture of how to compile SSP for Chemistry materials with STEAM learning, they are directed to practice making SSP independently for the selected chemistry topic with direct guidance from the RG Community Service Team.

Practice and mentoring method

The practical method was carried out so that participants from the training can directly apply the knowledge gained from using the presentation, question and answer, and demonstration methods. The Community Service Team from RG PARM-PK facilitated assistance in helping participants practice the knowledge they have gained. Mentoring activities are carried out by assisting teachers when compiling SSP for STEAM-based Chemistry material. This mentoring was carried out periodically. Participants were divided into four groups to be assisted in a structured manner by the RG Community Service Team. Making SSP and mentoring were carried out for two weeks after the presentation of the training material. The implementation of mentoring was conducted online via Zoom meeting or WA. This mentoring was expected to produce output in the form of STEAM learning devices made by participants that were ready to be implemented. The participants sent devices compiled to the mentor via email or G-drive provided. Participants who have participated in all the training activities received a certificate of participation.

Module

The use of modules in this training aimed to provide participants with a reference to understand STEAM learning and how to create SSP for STEAM learning in Chemistry material. With the module, participants can also learn how to create SSP for STEAM learning. The module used in this training contained an introduction to SSP material, key points of SSP, STEM and STEAM education, the nature of

STEM, Characteristics of STEM, STEM learning patterns, characteristics of STEM learning, and examples of creating SSP for learning STEAM-based teaching materials.

Evaluation design

Evaluation was carried out to measure the success of the training activities. Three criteria were used as the basis for assessment to achieve the objectives of the training activities. First, the success of the implementation of the activity was measured based on the suitability between the plan and implementation. Participants' success was measured by their ability to apply their understanding individually in compiling SSP for STEAM-based chemistry material. Five pre-test and post-test questions measured the increase in participants' understanding during training of SSP. Meanwhile, the success of the training and mentoring was measured based on the results of the feedback questionnaire consisting of 18 questions.

3. RESULTS AND DISCUSSION

The results of implementing the training activities are presented in three stages: preparation, implementation, and evaluation.

Preparation Activities

The results of the preparation activities are the preparation of the implementation schedule, speakers, and participant invitations. Table 1 shows the activity schedule for participants.

Table 1. Activity schedule

Day, Date	Event	Venue
Friday, 13 -10 – 2023	- Implementation Socialization - Presentation of STEAM material	Buiding G FTTE-UNS
Friday, 20 -10 - 2023	- Pre-test - Presentation of training material for making SSP - Post-test	Buiding G FTTE-UNS
23 -10- 2023 to 03 -11-2023	- Participants independently prepare SSP-STEAM for learning chemistry material. - Guidance and assistance	Buiding G FTTE-UNS and participant house
Saturday 04 -11-2023	Filling in the participant evaluasi questionaire	Online

Implementation Activities

The results of the community service activities carried out by the RG PARM-PK Team were presented in three stages of implementation, namely the implementation of stage 1 on October 13, 2023, the implementation of stage 2 on October 20, 2023, and the implementation of stage 3 on October 23 to November 3, 2023. There were 67 participants spread across 14 provinces in Indonesia (Figure 2A). Other Provinces in Figure 2A show one participant from each of the other provinces: Bali, Banten, East Kalimantan, Central Kalimantan, Maluku, and Jakarta. Most of the participants came from Central Java (36 participants). This activity was carried out in a hybrid manner; some participants attended offline (Figure 2B), and the others attended online.

Figure 2. (A) Distribution table of participant data; and (B) Photo of participants who attended offline

Implementation of stage 1 on October 13, 2023

This implementation began with the socialization and delivery of STEAM - STrEaM material by ASEAN researchers from Universiti Sains Malaysia (USM). Figure 3 presents the evidence of implementation.

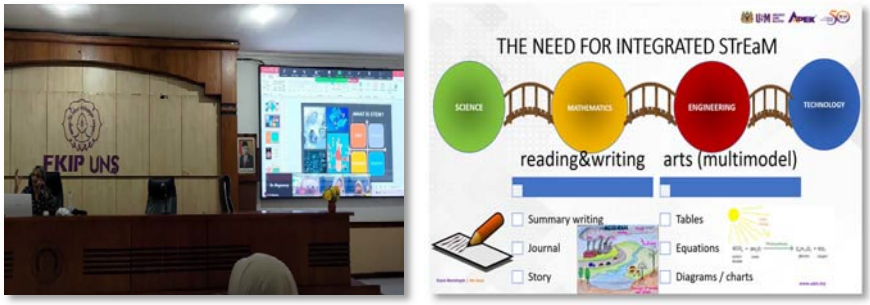


Figure 3. (A) Delivery of STEAM material by Speaker; and (B) Example slides

Implementation of stage 2 on October 20, 2023

The SSP preparation training activity was carried out on October 20, 2023. Speaker from RG PARM-PK delivered the training material containing information about making SSP and examples of its devices. This activity was also carried out hybrid (online and offline). The implementation image can be seen in Figure 4.

Figure 4. (A) Delivery of training materials for the Preparation of SSP by Speaker is accompanied by the RG PARM-PK Team; and (B) Examples of training material slides

Implementation of stage 3 from October 23 to November 3, 2023

The preparation of SSP activities for Chemistry material with STEAM learning was carried out by participants independently for 2 weeks, guided by the Team from RG PARM-PK. Guidance activities during the mentoring were carried out online. A snapshot of the implementation of the first day of mentoring is presented in Figure 5.

Figure 5. (A) Mentoring activities for the Preparation of SSP by the RG PARM-PK Team; and (B) A snapshot of online guidance by Speaker and Moderator

Evaluation Activities

Evaluation activities were carried out before, during, and at the end of the training and mentoring process. Evaluation was carried out to measure the success of the training activities that have been implemented. Evaluation before the training process was in the form of a pre-test, during the training process through questions and answers, and at the end of the process, in the form of a post-test. Three criteria were used to measure the achievement of the objectives of the training activities. The evaluation results of each criterion are described below.

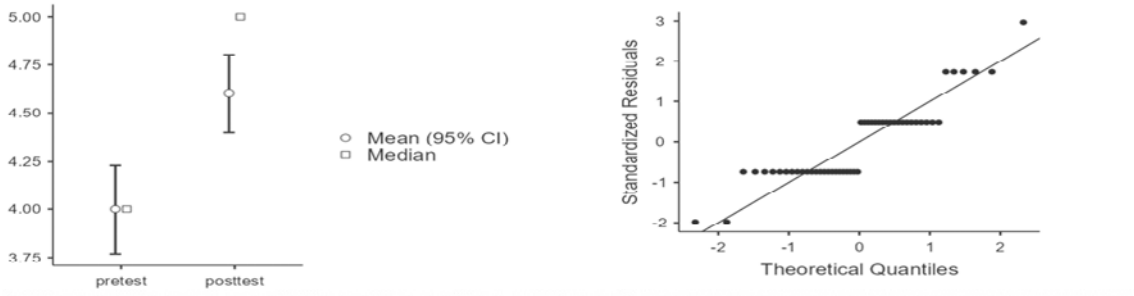
Evaluation of the success of the implementation of the activity

This evaluation was measured based on the suitability of the plan and implementation. The activity can be carried out according to the schedule and runs smoothly.

Evaluation of participant success

This evaluation measures the increase in participants' understanding during the SSP creation training. The evaluation is carried out by providing five pre-test and post-test questions in the form of multiple choices with five answer options related to SSP. The five questions are related to participants' understanding of SSP and its application in learning chemistry material, namely: (1) What is the main focus of Subject Specific Pedagogy (SSP)?; (2) Which of the following is a crucial aspect of effective Subject Specific Pedagogy (SSP)?; (3) In Subject Specific Pedagogy (SSP), why do teachers need to carry out differentiated learning?; (4) Which of the following is essential for science teachers in Subject Specific Pedagogy (SSP)?; (5) What is the role of implementing subject-specific pedagogy (SSP) in chemistry education?

The answers of 50 participants who worked on the pre-test and post-test questions were analyzed using non-parametric statistics using paired t-test because they were in one group and only looked at changes. The results of the statistical test of the distribution of participants' answers are presented in Figure 6, and the paired t-test in Figure 7. The pre-test and post-test results showed that after being given SSP material, the average understanding of participants about SSP increased.



Normality Test (Shapiro-Wilk)

		W	p
pretest - post-test		0.847	< .001

Note. A low p-value suggests a violation of the assumption of normality

Descriptives

	N	Mean	Median	SD	SE
pretest	50	4.00	4.00	0.833	0.118
posttest	50	4.60	5.00	0.728	0.103

Figure 6. Distribution of answers from 50 training participants who completed the pre-test and post-test and the results of the normality test

Paired Samples T-Test

			Statistic	±%	df	p	Mean difference	SE difference	95% Confidence Interval Lower	95% Confidence Interval Upper		Effect Size
pretest	posttest	Student's t	-5.25		49.0	< .001	-0.600	0.114	-0.830	-0.370	Cohen's d	-0.742
		Bayes factor$_{10}$	5422	1.92e-8								
		Wilcoxon W	22.0 *			< .001	-1.00	0.114	-1.50	-1.000	Rank biserial correlation	-0.884

Note. H_a $\mu_{Measure\ 1 - Measure\ 2} \neq 0$
* 23 pair(s) of values were tied

Figure 7. Results of the paired samples T-test

Evaluation of the success of the training and mentoring process

The success of the training and mentoring process was measured based on the results of the feedback questionnaire consisting of 18 questions. Evaluation through this questionnaire was carried out after the mentoring process was completed. From this evaluation, the ability of participants to apply their understanding individually in compiling SSP for STEAM-based chemical material from the SSP products produced was also seen. The results of the 27 participants who answered the questionnaire are presented in Figure 8 and Table 2.

Figure 8. Participant responses to 3 questions: teaching experience, having participated in previous STEM training, and having implemented STEAM-based in Chemistry learning

Table 2. Responses of 27 participants to 9 questions of the training implementation feedback questionnaire

Questions	Percentage of Participant Responses (%)				
	1	2	3	4	5
In your opinion, did the Community Service (PkM) Material about STEAM meet the needs of the Community?	0	0	11.11	37.04	51.85
In your opinion, did the implemented PKM activities on STEAM meet your expectations?	0	0	11.11	40.74	48.15
In your opinion, was the way the presenters presented the material interesting?	0	0	3.70	33.33	62.97
In your opinion, was the material presented clearly and easily understood?	0	0	7.41	37.04	55.55
Did Tim provide the time appropriate for delivering the material and PKM activities?	0	0	25.92	37.04	37.04
Were every complaint/question/problem submitted followed up properly by the Community Service Team?	0	0	7.41	48.15	44.44
Did you gain new knowledge and skills about STEAM implementation (SSP, Media, and Instruments)?	0	0	7.41	48.15	44.44
How interested are you in implementing the STEAM approach to the learning process at school?	0	0	11.11	44.44	44.44
How satisfied are you with the community service activities carried out?	0	0	11.11	48.15	40.74

Note: Answer Options: (1) Very inappropriate/attractive/clear and easy to understand/good/many obtained/interested/ satisfied; (2) Not appropriate/attractive/clear and easy to understand/good/many obtained/interested/ satisfied; (3) Quite appropriate/ attractive/clear and easy to understand/good/many obtained/interested/satisfied; (4) Appropriate/attractive/clear and easy to understand/good/ many obtained/interested/satisfied; (5) Very appropriate/attractive/clear and easy to understand/ good/many obtained/interested/ satisfied

Discussion

The training activities aimed to strengthen collaboration between the Research Group (RG) in the Chemistry Education study program and researchers from the ASEAN STEAM Group. The activity began with a presentation on STEAM by an ASEAN STEAM researcher from USM. He outlined and implemented a community service program designed to offer a more holistic learning and assessment approach that integrates various aspects of STEAM, incorporating art, reading, and writing into the methodology. This approach is called the STrEaM, an abbreviation for Science, Technology, Reading and Writing, Engineering, Art, and Mathematics. Professor Mageswary Karpudewan's important role in conveying her innovation regarding the STrEaM approach, which is the basis of this program is to motivate teachers and students to think more creatively and involve STEAM aspects together with art reading and writing skills in chemistry learning. This way, it is expected to help students understand chemistry concepts better and connect them to the real world.

This collaboration is an essential point in developing chemistry education in Indonesia. Chemistry teachers in various schools around UNS received intensive training in implementing the STrEaM approach in their learning. They learned how to integrate various science, technology, engineering, mathematics, art, and reading and writing concepts into their chemistry curriculum. This approach makes learning more interesting for students and helps them develop skills needed in the real world.

The RG PARM-PK Team from the Chemistry Education Study Program has tried to improve the skills of Chemistry teachers spread across fourteen provinces in Indonesia with good results shown by an increase in understanding and application of SSP for STEAM learning from the results of the pre-test and post-test (Figure 7). Community service program activities in the form of training and mentoring in making SSP in collaboration with the ASEAN STEAM Group researchers have also been successfully implemented. The results of feedback filled in by the participants showed that the training had gone well. However, not all participants filled out the feedback questionnaire or did the pre-test and post-test. However, the data shown in Figure 7 and Table 1 show that the objectives of this training have gone well in achieving the training objectives.

Based on the feedback, participants highlighted the following strengths in the delivery of the SSP STEAM material: (1) The material was presented in an engaging manner with comprehensive and easy-to-understand PPT slides, (2) The material delivery was clear, allowing even those new to STEAM to grasp the concepts. However, areas for improvement include: (1) Conducting the training regularly; (2) Providing more detailed module examples to enhance participants' understanding; and (3) Extending the duration of the training. Participants also provided suggestions and constructive criticism for future community service activities: (1) Additional guidance from lecturers on designing STEAM learning materials would be appreciated, as STEAM is exciting to implement in the classroom; (2) While the activities have been well-organized, future sessions could focus on explaining module preparation in more detail; (3) It is recommended that future activities be conducted entirely offline to improve focus and avoid disruptions due to network issues.

4. CONCLUSION AND RECOMMENDATIONS

This community service program aimed to provide secondary school chemistry teachers with skills in compiling SSP for STEAM learning, which has been held successfully. The target to be achieved was an increase in participants' understanding of SSP and its application in STEAM learning, which has also been achieved with a significant increase in the average score of 0.6. It was hoped that through this activity, secondary school chemistry teachers would be able to apply the knowledge and skills they have acquired in their daily learning.

This community service was conducted in collaboration with STEAM ASEAN researchers. However, due to time constraints, it was not possible to include participants from ASEAN teachers. Suggestions for future service include: (1) Continued collaboration with STEAM ASEAN researchers is necessary; (2) Adequate discussion time should be allocated with STEAM ASEAN researchers and relevant institutions, such as SEAMEO RECSAM; (3) Similar trainings covering a wider range of topics are still needed.

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