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Interpreting Teaching STEM Education to Pre-service Elementary Teachers Through Online Course

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Abstract.
Insufficient comprehension of integrated STEM learning has become one of the main difficulties for teachers in implementing STEM lessons at school due to lack of integrative STEM curriculum in teachers' education programs. Therefore, the Elementary Teacher Education Program Universitas Pendidikan Indonesia in Purwakarta offers STEM Education for Elementary course as an optional course to support 21st-century education at the elementary school level. However, due to the continued Covid-19 pandemic, during the second semester of the academic year 2020/2021, all courses in our program were entirely carried out online. Through the descriptive analysis method, this paper details how the 16-weeks course was enacted online with a varied delivery form. Forty-two pre-service teachers enrolled in the course. Data on the course implementation were gathered in the form of video recordings of the lesson, while students' perception of the course delivery was captured through a course evaluation questionnaire. Results imply that the course includes a theoretical and practical session with teaching simulations and engineering challenges to model STEM teaching and learning to develop pre-service teacher's STEM pedagogical and content knowledge. In addition, course evaluation suggests that after enrolling in the course, the pre-service teacher has positive perceptions of the course delivery.

Keywords: STEM education, pre-service elementary teachers, online course

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1. INTRODUCTION

Many studies prove that STEM learning can positively influence the knowledge and skills of school-age children. [1] revealed that STEM-based learning could help students develop various 21st-century skills. STEM learning familiarizes children with solving problems that resemble real-world problems. Real problems, or what is known as real-world problems, are usually complex and require critical and creative thinking

to solve. Such learning activities certainly train various 21st-century skills, such as problem-solving skills [2], critical thinking [3, 4], creative thinking [5], and collaboration [6]. Several other research results show that participation in STEM learning also increases students' awareness of careers in the STEM field [7–9]. Knowledge of careers in STEM fields can motivate students to pursue careers in these fields.

In addition, when involved in STEM learning, students could explore understanding concepts from various interrelated disciplines through collaboration and teamwork. So that students can show better academic achievement seen from the acquisition of subject test scores on certain materials. Learning that integrates engineering activities can improve student achievement in the field of science because students become more enthusiastic about being involved in learning [1]. In addition, student involvement in STEM learning could reduce the achievement gap between groups of high achievers, middle achievers, and low achievers [10]. Positive influences also occur in non-academic aspects, such as student attitudes toward learning that are increasingly positive [11] and the emergence of various collaborative behaviors when students are involved in STEM learning [6].

Due to its advantages, various countries have adapted STEM education as a blueprint for educational innovation to bridge the need and availability of skilled experts needed for economic development in the 21st century. Indonesia needs skilled human resources in the STEM field to support government programs in terms of infrastructure development. However, the number of experts in this field is still considered insufficient. Therefore, STEM education development is being promoted at varied school levels and universities throughout Indonesia with the support of the ministry of education and non-government institution.

Although STEM education practices have improved in Indonesian schools, preparation for quality STEM teachers through teacher education programs in universities is still limited. As science, math, and technology are often taught in separate courses during teacher education study, teachers might find it challenging to teach them in an integrative manner. In addition, integrating STEM education with engineering is also needed [12], as engineering is regarded as the catalyst of integration among the other disciplines. Nevertheless, in many universities in Indonesia, engineering practices are only expected for those who take engineering majors. Integrative STEM is not emphasized in the curriculum in many teachers' education programs and has just become a topic being discussed in some courses. Only a few teacher education programs have specific STEM courses to help pre-service teachers develop STEM pedagogical and content knowledge. Insufficient comprehension of STEM has become

one of the main difficulties for teachers in implementing STEM lessons at school [13]. Therefore, there is a need to implement a specific STEM preparation program for pre-service teachers [14–16] as it is essential to STEM reforms [12].

Therefore, Elementary Teacher Education Program Universitas Pendidikan Indonesia in Purwakarta offers STEM Education for Elementary course as an optional course to prepare pre-service teachers with sufficient knowledge and skills to design and implement STEM lessons at the elementary school level. However, due to the continued Covid-19 pandemic, during the second semester of the academic year 2020/2021, all courses in our program are entirely carried out online. This study will then figure out how the course was enacted online and what pre-service teachers perceived after taking the course.

2. RESEARCH METHOD

This study used a descriptive analysis method to address the research problem, as this type of study could give information on a basic understanding of a phenomenon. When STEM for the elementary course was first introduced in our study program, we wanted to evaluate its implementation and students' perception of the course delivery. Here, the descriptive analysis will clarify a basic understanding of the critical aspects of that new phenomenon, as it gives access to descriptive details that accurately and thoroughly characterize the conditions and context of a study [17].

Through the descriptive analysis method, this study describes the implementation of and students' perception of the delivery of STEM for elementary school courses which is carried out on an online platform throughout the second semester of the academic year 2020/2021. The participants in this study are 42 students studying in the elementary teacher education program enrolling in STEM for the elementary course. The course enrollment is based on students' interests since the course is included in the optional course. The implementation of the course is documented in the form of video recording. Students' perception of the course delivery is measured using 20 items course evaluation questionnaire with a scale ranging from one to nine. This questionnaire is believed to be valid and reliable since the university has used it as one of the instruments to evaluate the instructional process in each semester.

3. result and discussion

STEM for elementary school is one of the optional courses in the elementary teacher education study program that is included in courses related to 21st-century learning. This three credits course was open to 6th-semester pre-service teachers and was first offered in January 2021 within the second semester of 2020/2021. Within this course, pre-service teachers are expected to understand the history, urgency, and underlying theory of STEM education. In addition, they are expected to analyze existing STEM educational practices in elementary schools and apply this knowledge to design STEM learning that can be implemented in elementary schools relevant to the 2013 national curriculum.

This course aims to prepare teachers who can design and implement STEM lessons at the elementary school level based on their STEM pedagogical and content knowledge. Therefore, the course comprised theoretical and practical sessions that exposed pre-service teachers to STEM-based activities. Outline of STEM for elementary course shown in Table 1.

Two lecturers with science education and mathematics education backgrounds teach this course with a team-teaching method along the course. Team teaching provides opportunities for students to learn in more relevant and stimulating interdisciplinary experiences. Pre-service STEM teachers need support to help them understand integrated STEM through exposure to interweaving interdisciplinary processes among the four disciplines [18]. The learning recourses used were textbooks [19–23], YouTube, teachengineering.org, Indonesian national curriculum documents, and other relevant sources.

(a) (b) (c) (d)

Figure 1: STEM challenges in week 3 and week 4 (a) measuring the height of paper tower, (b) group discussion during solving tallest paper tower challenge, (c) using books as weight to test the strength of the building, (d) the weight that strongest structure can withstand.

Due to the Covid-19 pandemic, the course was conducted online with the asynchronous method and synchronous using Zoom Meeting or Google Meet. Even though the pre-service teachers learn in their respective houses separately, they can discuss

Table 1: Outline of STEM for elementary school course.

Week	Topic	Activities
1	Course Orientation	Identification of students' initial understanding of STEM education Informing outline of the course and expected outcomes Discussion about a class agreement
2	History and Urgency of STEM Education	Explanation of STEM education history Explanation of urgency of STEM education Discussion on STEM education movement in Indonesia
3	Learning Science and Mathematics through STEM	Identifying characteristics of STEM Lesson Integration model for STEM Lesson Explanation of science and mathematics learning goals. Identify topics and skills related to science and mathematics from STEM Challenge: Tallest Paper Tower.
4	Learning Technology and Engineering through STEM	Discussion on the nature of technology and engineering Learning theory underlying engineering design Introduction to Engineering Design Process through STEM Challenge: Strongest Building
5	Assessment in STEM Learning	Students present their identification of possible assessment procedures and instruments suitable for STEM Learning in elementary school from literature reviews.
6	STEM Learning in Lower Elementary	Students present their analysis of STEM Learning samples in Lower Elementary that can be seen from teachengineering.org.
7	STEM Learning in Upper Elementary	Students present their analysis of STEM Learning samples in Upper Elementary that can be seen from teachengineering.org.
8	Mid-term Exam	
9-15	Design and Simulation of STEM Learning in Elementary School	Students design STEM learning for elementary level and do simulation via zoom meeting. Discussion on best practices of simulation and possible improvement
16	Final Exam	

and work collaboratively using the breakout room feature in zoom meetings to let them individually and socially construct their understanding of STEM learning. It is due to the STEM learning approach continuing the constructivist education approach [21, 24].

The course length is 16 weeks, with 150 minutes (3 credits) each week. The 16 weeks outline of STEM for elementary school course can be seen in Table 1. The first week of the course was meant to identify pre-service teachers' initial understanding of STEM education through discussion and menti.com. The lesson is then followed by an explanation of the course outlines and expected outcomes, a discussion about the class agreement, and group formation, as they will mainly work in groups during the course. Each group comprises six students at most. Within the second week, the pre-service teachers discussed STEM education history and the underlying urgency, including at the elementary level. The lesson ended with open-ended questions as the catalyst to discuss the STEM education movement in Indonesia.

(a) (b) (c)

Figure 2: STEM teaching simulations and its engineering challenges (a) constructing straw bridge (b) finding the best insulator, (c) making air powered car.

The third week's activities consist of lecturing about the nature of science and mathematics, the goals of learning science and mathematics, and how STEM-based lessons can help elementary students to achieve those goals. Prior to the lecturing, the pre-service teachers were given a video showing examples of STEM lessons in elementary school and were asked to identify characteristics of STEM lessons. To let the pre-service teachers have the idea of how students can learn science and mathematics through STEM lessons, they were given the "Tallest Paper Tower" challenge that they must solve collaboratively with their groups, as seen in Fig. 1(a) and Fig. 1(b). Through this challenge, pre-service teachers need to construct a stable tower as tall as possible using only six A4 paper and one-meter tape. The tower should withstand self-weight and lateral wind load coming from the surrounding. At the end of the session, they need to present their tower, measure it using a measuring tape and explain possible science and mathematics topics associated with the challenge. Some topics identified by students include geometry, properties of matter, force, measurements, etc.

Within the fourth week, pre-service teachers learn about the concept of technology and engineering and the learning theory associated with engineering design. In addition, they also learn about the engineering design process and try to apply their understanding through the "Strongest Building" challenge. Within this challenge, students need to follow engineering design processes to construct a building from ten sheets of A4 paper and tape that must hold weight as much as possible (see Fig.1(c) and (d)). At the end of the session, students discuss how a very light paper sheet can hold much more weight than its weight by recalling mathematics and science conceptual understanding of geometrical shapes and their properties, pressure, weight distribution, etc. Prior to week 5, pre-service teachers were assigned to do a literature study about possible STEM learning assessments that will later be presented by two

groups, which were chosen randomly, to the classroom. Through the presentation, pre-service teachers identified that STEM lessons could employ a varied type of assessment, including product and performance assessments. Once the presentation and discussion finished, pre-service teachers were allowed to collaboratively design their assessment rubric regarding their previous STEM challenges with their groupmates.

In weeks 6 and 7, pre-service teachers alternatively presented the example of STEM lessons relevant to national curriculum standards that they chose from the teachengineering.org website. This website can explore STEM teaching resources for K-12, including introduction or motivation, lesson background and concepts for teachers, lesson closure, assessments, worksheets, engineering videos, vocabulary, associated extension activities, and many more. From the information provided on the website, it is expected that pre-service teachers can identify the interweaving concepts among each STEM discipline, 21st-century skills and attitudes fostered, and the flow and assessment of a STEM lesson. In week eight, pre-service teachers had their mid-semester exam through a google form, where the lecturers played a role as the invigilator via zoom meeting.

After the mid-semester exam, the activity from weeks 9 to 15 focuses more on training pre-service teachers' skills to design and implement STEM-based lessons. Each week, they must design STEM lessons based on Muslim scientists' expertise: Al Thusi, Al Khwarizmi, Abbas bin Firnas, Al Biruni, Al Haytham, Al Dinawari, and Piri Reis. In synchronous sessions, they did teaching simulations through zoom meetings. Pre-service teachers need to be allowed to design and teach integrated STEM as early as during their studies [14]. If the lesson requires tools and materials, pre-service teachers need to inform their classmates earlier so that they can engage and participate in the lesson activities. The teaching simulation activities aim to model STEM teaching and learning. Modeling integrative STEM activities will increase pre-service teachers' understanding of STEM teaching and learning [12]. Samples of teaching simulations and their engineering activities can be seen in Fig.2. In the last week, students have their final examination with the exact mechanism as the mid-semester exam.

After pre-service teachers finished their course, they were individually required to fill in an evaluation questionnaire regarding the delivery of the course and the lecturers' performance within the course. The results of the evaluation questionnaire can be seen on Tabel 2.

According to Tabel 2, pre-service teachers have positive perspectives toward the course delivery as indicated by the mean score of each aspect.

TABLE 2: The results of course evaluation questionnaire.

No	Aspects	Pre-service teacher Perception	Mean
1	Delivering syllabus and course outline	Well planned	8.33
2	Lecture content knowledge	Mastered	8.31
3	Relevance to content and aims of the course	Relevant	8.29
4	Instructional approach and methods	Varies, innovative and creative	8.45
5	Instructional tools and media	Varies, effective and efficient	8.33
6	Learning resources	Varies, up to date and contextual	8.29
7	Evaluation of learning outcomes (mid-term test and final test)	Relevant to learning materials and very objective	8.33
8	Assessment of learning process (discussion, observation, practical activities)	Students' activities within discussion, observation and practicum were assessed	8.26
9	Assignments or tasks	Clear and structured	8.31
10	Classroom management	Managed regularly and conducive	8.21
11	Teaching Enthusiasms and motivation	Very enthusiastic and eager to teach	8.29
12	Learning ambience	Generating student enthusiasm and a conducive atmosphere for learning	8.21
13	Disciplines	High	8.38
14	Enforcement of class agreement	Clear and firm	8.33
15	Students' character development (good attitudes and behavior)	The learning develops students' character	8.26
16	Exemplary in attitude and action	Good role model	8.33
17	Emotional maturity	Able to control emotion	8.12
18	Communication skills	Communicative	8.38
19	Written and oral language	Clear and comply to EYD	8.33
20	Interaction with students	Good social interaction	8.33

4. CONCLUSION

Our study program offers STEM for Elementary courses in the second semester of the academic year 2020/2021 to prepare teachers who can design and implement quality STEM lessons. Forty-two pre-service teachers were enrolling in the course. The course includes theoretical and practical sessions with teaching simulations and engineering challenges to model STEM teaching and learning as a way to develop pre-service teachers' STEM pedagogical and content knowledge. In addition, course evaluation suggests that the pre-service teacher has positive perceptions of the course

delivery after enrolling in the course. Future studies regarding STEM pre-service teacher preparation can be implemented to examine the improvement of pre-service teachers' attitudes, skills, and conceptual understanding of STEM education. Another research may focus on media that can be used to make the online STEM course more effective and collaborative.

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References

[1] Guzey SS, Moore TJ, Harwell M, Moreno M. STEM integration in middle school life science: student learning and attitudes. J Sci Educ Technol. 2016;25(4):550–60.

[2] Yanyan L, Zhinan H, Menglu J, Wen CT. He effect on pupil's science performance and problem-solving ability through lego: an engineering design-based modeling approach. J Educ Technol Soc. 2016;19(3):143–56.

[3] Hartini S, Mariani I, Misbah M, Sulaeman NF. Developing of students worksheets through STEM approach to train critical thinking skills. J Phys Conf Ser. 2020;1567(4):42029.

[4] Siekman G. What is STEM? The need for unpacking its definitions and applications. Adelaide (SA): National Centre for Vocational Education Research; 2016.

[5] Hanif S, Wijaya AF, Winarno N. Enhancing students' creativity through STEM project-based learning. Journal of Science Learning. 2019;2(2):50–7.

[6] Nuraeni F, Permanasari A, Riandi. "Collaboration skills of 8th grade secondary students in science learning with engineering design activity.," Proceeding of the 4th International Conference on Education. vol. 4, no. 2, pp. 153–161, 2018.

[7] King D, English LD. Engineering design in the primary school: applying STEM concepts to build an optical instrument. Int J Sci. 2016;38(18):2762–94.

[8] Moreno NP, Tharp BZ, Vogt G, Newell AD, Burnett CA. Preparing students for middle school through after-school STEM activities. J Sci Educ Technol. 2016;25(6):889–97.

[9] Barrett BS, Moran AL, Woods JE. Meteorology meets engineering: an interdisciplinary STEM module for middle and early secondary school students. Int J STEM Educ. 2014;1(1):1–6.

[10] Han S, Capraro R, Capraro MM. How Science, Technology, Engineering, and Mathematics (STEM) Project-Based Learning (PBL) affects high, middle, and low achievers differently: the impact of student factors on achievement. Int J Sci Math Educ. 2015;13(5):1089–113.

[11] Lai E, DiCerbo K, Foltz P. Skills for today: What we know about teaching and assessing collaboration. London: Pearson; 2017.

[12] Berisha F, Vula E. "Developing pre-service teachers conceptualization of STEM and STEM pedagogical practices.," Frontiers in Education. vol. 6, no. 585075, p. 2021.

[13] Diana N, Turmudi T, Yohanes Y. "Analysis of teachers' difficulties in implementing STEM approach in learning: A study literature,." Journal of Physics: Conference Series. p. 2021. https://doi.org/10.1088/1742-6596/1806/1/012219.

[14] Bartels SL, Rupe KM, Lederman JS. "Shaping preservice teachers' understandings of STEM: A collaborative math and science methods approach," ... Science Teacher Education. p. 2019.

[15] English LD. Advancing elementary and middle school STEM education. Int J Sci Math Educ. 2017;15(S1 no. S1):5–24.

[16] Shernoff DJ, Sinha S, Bressler DM, Ginsburg L. "Assessing teacher education and professional development needs for the implementation of integrated approaches to STEM education," (2017). https://doi.org/10.1186/s40594-017-0068-1.

[17] Loeb S, Dynarski S, McFarland D, Morris P, Reardon S, Reber S. "Descriptive analysis in education: A guide for researchers," (2017).

[18] Pimthong P, Williams PJ. Methods course for primary level STEM preservice teachers: constructing integrated STEM teaching. Eurasia J Math Sci Technol Educ. 2021;17(8):1996.

[19] Isabelle AD, Valle NZ. Inspiring STEM minds: Biographies and activities for elementary classrooms. Rotterdam: Sense Publisher; 2016. https://doi.org/10.1007/978-94-6300-352-0.

[20] Nuraeni F. Aktivitas desain rekayasa untuk pembelajaran STEM di SD. UPI Sumedang Press; 2020.

[21] Texley J, Ruud RM. Teaching STEM literacy: A constructivist approach for ages 3 to 8. Redleaf Press. Yorkton Court; 2018.

[22] Moomaw S. Teaching STEM in the early years. Redleaf Press. Yorkton Court; 2013.

[23] Nuraeni F. Strategi integrasi desain rekayasa pada pembelajaran IPA. UPI Sumedang Press. Sumedang; 2019.

[24] Akran SK, Aşiroğlu S. "Perceptions of teachers towards the stem education and the constructivist education approach: Is the constructivist education approach

preparatory to the STEM education?" Universal Journal of Educational Research. vol. 6, no. 10, pp. 2175–2186.