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Indonesian Preservice Primary School Teachers' Understanding of STEM Education

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Abstract. This research investigated the relationship between science content knowledge and mathematics content knowledge in relation to the preservice primary school teachers' conceptions of STEM education in Indonesia. The survey method was used to collect data about science content knowledge, mathematics content knowledge, and STEM conceptualizations. A total of 139 preservice primary school teachers participated in this study. The results indicate that science and mathematics content knowledge can influence preservice primary school teachers' conceptions of STEM education. There is no significant relationship between gender and STEM education conceptualization was detected.

INTRODUCTION

Science, technology, engineering, and mathematics (STEM) education is an educational approach, which is gaining popularity in the world. Through STEM, students learn that, not only should they use a subject, but also use an integrated form of the subjects to solve scientific problems. STEM integration also offers students the opportunity to experience real-world situations simultaneously rather than gradually, to be assimilated at a later time [28]. Several studies have found that STEM education can have a positive impact on students' careers [15], students' attitudes towards STEM subjects [27], students' interests [14] and students' outcomes [11] Hence, the goal of STEM education is to enable students to acquire and understand knowledge based on their experience for solving their problems in scientific contexts. To achieve this goal to benefit students, educators need to change their teaching style.

The aim of this research is to investigate content knowledge and skills in science and mathematics to understand the STEM concept in preservice primary school education in Indonesia. This research is guided by this

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question: what is the relationship between science content knowledge, mathematics content knowledge, and the understanding of STEM education for preservice primary school teachers? The result of this research is expected to support the preparation of the preservice teachers who will use the STEM education approach in the classroom. In addition, it might also shed light on how teachers can master content knowledge to be able to develop the STEM instructional materials.

The following section discusses the concept of STEM integration. It then presents the energy content knowledge as a component of the STEM educational material. This will be followed by preservice teachers' interpretation of STEM education.

STEM Integration

STEM integration involves a multidisciplinary approach towards science, technology, engineering, and mathematics. The approach of STEM education is believed to engage students in real-world problems. The integration of STEM subjects is challenging and complex for classroom implementation [10]. Researchers have suggested that the integrative STEM education advocates an exploratory approach to teaching and learning between any two or among several STEM subjects; it may also advocate this approach in regard to a STEM subject and one or more other school subjects [25]. STEM integration offers a natural method for developing the skills in using science, mathematics, and engineering to solve real-world problems [28]. Brown [2] has analyzed the status of STEM in educational research; his findings suggest that teachers are interested in STEM education as a method of classroom instruction that incorporates several subject areas through integrated activities.

STEM education requires that educators create activities to solve emerging problems in the classroom, which may be otherwise inaccessible in separate subjects. It needs an organization to guide how the STEM subjects will work together. Educators facilitate students' access to scientific and engineering practices, including asking questions and defining problems, developing and using models, planning and carrying out investigations, analyzing and interpreting data, using mathematics and computational thinking, constructing explanations and designing solutions, engaging in arguments backed by evidence, and carrying out evaluation and communicating information [17]. Educators concentrate on building connections between grand ideas, correcting students' misconceptions, integrating technology, and establishing real-world and cultural connections [26]. Thus, teachers in STEM education are expected to have the ability to manage STEM-based instruction effectively.

Professional development training for STEM teachers has been studied by many researchers and conducted in many institutions. However, STEM teachers' needs are growing [6]. To address the needs of teachers in STEM education, preservice teachers should develop a complete understanding of STEM education in the early stages of their career. In fact, there is limited research on preservice teachers' involvement in supporting the STEM education programmes. Some authors believe that incorporating STEM education into university curricula can effectively help preservice teachers develop a profound understanding of it. The mastery of content knowledge is a top priority, mainly because of its effective contribution to teacher confidence [1] in developing instructional materials for STEM education.

Energy Content Knowledge

Energy is a crucial concept in the Next Generation Standard (NGSS), mainly because this concept are essential to science and engineering disciplines [17]. Biology can draw on the concept of energy to explain photosynthesis, which involves the process of using light as energy and water as matter to aid the growth of plants. Physics can also draw on the concept of energy to explain the movement of particles. In chemistry, chemical reactions can cause a change in the form of energy. Engineering plays a critical role in guiding how to design and create maximum energy output using minimum input. In short, the concept of energy can be used to track the input and output of energy in relation to the system.

Driver, Asoko, Leach, Scott, & Mortimer [8] rank the concept of energy on a scale from simple to complex, ranging from energy transformation to energy dissipation and energy conservation. Some researchers [20] have used this scale as an instrument for evaluating the energy progression; they have suggested that energy instruction should not be solely organized around key concepts about energy but make use of the STEM subjects to link the key ideas to each other.

The concept of energy in Indonesia's curriculum starts from the primary school and continues to senior high school. According to Yao et al. [30], the primary curriculum focuses on the concept of energy transformation and culminates in energy conservation in the senior high school. This research concentrates on the concept of energy, mainly because energy has always been the main focus of Indonesia's curriculum, requiring that preservice primary teachers improve their understanding of energy content knowledge.

Preservice Teaching Experience in STEM Education

In a study, Radloff & Guzey [21] sought the views of preservice teachers on STEM education; they concluded that STEM education can facilitate preservice teachers' understanding of STEM. The researchers distributed open-ended questionnaires to the preservice science teachers in some universities to gain insights about STEM education. The findings illustrated that the preservice teachers who intended to apply STEM education in the classroom should start from a definite, concerted, and visual understanding of STEM education. Similarly, Bybee [4] has explained that perspectives on STEM should be included in its definition and appropriate connections be made between the elements of STEM education. Bybee has introduced nine possibilities of visualization about STEM education. Other researchers, such as Yildirim & Sevi [31], are of the opinion that the perspectives on STEM education can help preservice teachers improve their imagination. Preservice teachers' proper understanding of STEM education can generally have a positive effect on STEM education practices [9]. In another research, Radloff & Selcen [22] asked the preservice teachers to observe and analyze a video showing STEM learning. The preservice teachers who had some knowledge about STEM education subsequently expressed interest to apply STEM education in the classroom.

This study holds that an understanding of STEM education for preservice teachers is a necessary foundation for applying STEM in the classroom. The limited research on preservice teachers' understanding of STEM education justifies the focus of this research, which is on the preservice primary school teachers' preparation for STEM education in Indonesia's curriculum.

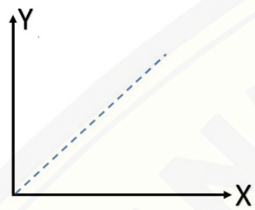
RESEARCH METHODOLOGY

A survey method was used to explore the primary school preservice teachers' understanding of STEM education in the University of Jember, Indonesia. Questionnaires have several advantages. For example, all the responses fall into categories that have been designed beforehand by the researcher, and the respondent finds the questions easy and relatively quick to answer [16]. A total of 139 participants (male = 27 and female = 112) completed four closed-ended questions about the concept of STEM. The participants were all in the third year of a four-year preservice primary education programme. The survey was conducted in 2018 summer semester.

The participants studied both science and mathematics as well as social and art subjects. The total credit for this programme is 30 of 144, which contains topics relating to science (11 credits), technology (2 credits), engineering (2 credits), and mathematics (15 credits). There is also a total credit of 52 (of 144) in educational psychology to support the preservice primary teachers' knowledge about children's behaviour and learning theory.

The instruments used in this study assessed energy content knowledge and the preservice primary teachers' understanding of the use of STEM education in the classroom. The energy content knowledge consisted of seven questions. The questions included topics in physics, chemistry, and biology (see Table 1 for the sample questions). The participants could choose between 'agree' or 'disagree' options, followed by a written opinion. The section relating to STEM understanding consisted of 11 questions. Three questions evaluated STEM definition, four questions evaluated STEM relevance, and four questions evaluated STEM visualization [20].

TABLE 1. The Example Statements of Content Knowledge

No.	Statement	Yes/No	Reason
Science Content Knowledge (Topic: Energy)			
1	Energy is a vector quantity because it can be summed algebraically.		
2	During an experiment, a student was looking at a piece of ice, which slowly changed into liquid in front of her eyes. This student wrote in her report that the ice melted and changed into liquid. Her statement is an observation [7].		
Mathematics Content Knowledge (Topic: Algebra)			
1	Is this true: 0.9999… = 1. Please explain by evidence [12].		
2	 Based on the graphic above, the slope in the graph is equal to *y/x*. This statement is always true.		

A one-way between-group analysis of variance (ANOVA) test (SPSS IBM 25) was utilized to analyze the data. Content knowledge was divided into three groups, based on the test results. The groups were identified as high, moderate, and low. The high group was for the participants who had a grade above average, and the low group was for the participants who had a grade below average. Each group was evaluated for STEM conceptualization.

RESULTS

Table 2 shows the general results of the science and mathematics content knowledge for preservice primary school teachers. The mean of science content knowledge (SCK) is 72.61, SD 7.34, and the mean of mathematics content knowledge (MCK) is 70.50, SD 6.88. The mean illustrates the grade that has been obtained about the understanding of STEM education. The minimum score of STEM education conception is 43.00, and the maximum score is 80.00.

TABLE 2. Description of the Results of Preservice Primary School Teachers' Understanding about STEM Education

	Group	N	Mean	SD
Science Content Knowledge	Low	57	65.28	0.99
	Moderate	73	69.63	0.54
	High	9	73.33	2.21
Maths Content Knowledge	Low	33	64.06	1.48
	Moderate	92	68.67	0.51
	High	14	73.79	1.47

TABLE 3. The ANOVA Result Analysis

Source	SE	df	MS	F	Sig.
Science Content Knowledge (SCK)	236.690	2	118.345	3.773	.026**
Maths Content Knowledge (MCK)	349.901	2	174.950	5.578	.005**
SCK* MCK	321.054	3	107.018	3.412	.020**
Total	650438.323	139			

a. R Squared = .308 (Adjusted R Squared = .271)

b. * interaction between variable

c. ** Correlation significant at 0.05 level (2-tailed)

Table 3 presents the test results of between-subject effect about the understanding of STEM as the dependent variable. The results indicate three significant differences. First, there are significant differences between the groups in SCK about the understanding of STEM education ($F(2.140) = 3.773$, $p = 0.026$). Second, there are significant differences between the groups in MCK about the understanding of STEM education ($F(2.140) = 5.578$, $p = 0.005$). Finally, there is an interaction between SCK and MCK ($F(3.140) = 3.412$, $p = 0.020$). Table 4 presents the data distribution and illustrates that the highest mean for understanding STEM education belongs to the preservice primary school teachers who have high SCK and high MCK.

TABLE 4. Distribution between SCK and MCK

Dependent Variable	SCK	MCK	N	Mean	Std. Deviation
Understanding of STEM Education	Low	Low	16	60.1061	10.21619
		Medium	41	67.3112	4.96801
	Medium	Low	16	68.0492	4.19595
		Medium	48	69.8567	4.65507
		High	9	71.2896	5.17617
	High	Medium	4	68.2828	4.06934
		High	5	78.3030	2.55877

Table 5 shows the influence of gender on STEM education understanding among preservice primary school teachers. No significant differences between male and female respondents' understanding of STEM education was observed.

TABLE 5. Understanding of STEM Education Based on Gender

	SS	df	MS	F	Sig.
Between Groups	3.636	26	.140	.864	.655
Within Groups	18.120	112	.162		
Total	21.755	138			

** Significant level at 0.05

DISCUSSION

The aim of this study was to explore the relationship between SCK and MCK in relation to preservice primary teachers' understanding of STEM conceptualization. The completed questionnaires described the preservice primary school teachers' SCK and MCK. The preservice primary school teachers answered the questions about their understanding of the STEM education approach, which included its definition, relevance, and visualization. This section discusses these results.

Our findings show that SCK and MCK can influence the preservice primary school teachers' understanding of STEM. Additionally, SCK and MCK interact with the preservice primary school teachers' understanding of the STEM education approach. This means that the preservice primary school teachers who have a better mastery of SCK and MCK will find it easier to organize the materials in the STEM education approach. This finding resonates with Bruner's [3] research result, in that prior knowledge and experience influence the understanding of the concept. The preservice primary school teachers' understanding of STEM education can form the basis of their current knowledge, which is constructed from the basic idea, such as SCK and MCK. This same argument was presented by Ryu, Mentzer, & Knobloch [24] who conducted STEM education professional development training for teachers. In the final part of the research, the teachers still connected STEM instruction with their academic background, even with what they had learnt in STEM training.

The training of preservice primary school teachers to implement STEM education may begin with incorporating STEM subject knowledge into the curriculum. This study supports the idea that content knowledge, particularly SCK, should form the basis of teachers' mastery of science, so that teachers who have the content knowledge will also have the confidence teaching STEM effectively [18]. Content knowledge enhanced by STEM education can increase confidence in STEM teaching, have a positive influence on attitudes towards science and science teaching, and develop potential ideas for STEM learning in the future [13].

The interaction between SCK and MCK for understanding STEM education is crucial. The results of this research suggest that the preservice primary school teachers who scored high in SCK and MCK demonstrated great understanding of the STEM education approach. The respondents indicated that they used the concept to manage the relationship between the subjects, particularly science and mathematics. In a research, Wang [29] has shown that the science and mathematics courses are linked to students' intention of studying STEM. What distinguish this research from others are its participants who were preservice primary school teachers. Having a complete understanding of content knowledge and STEM education can prepare preservice primary school teachers for the implementation of STEM in the classroom.

The issue of gender in STEM education may distinguish conceptions of the subjects using the STEM approach. The results of this research suggest that both male and female respondents have the same understanding of STEM education. This research result contrasts that of Rainey, Dancy, Mickelson, Stearns, & Moller [23] who showed that men and women understood STEM differently. The male participants expressed greater interest in STEM, while the female participants were more interested to know how STEM education could support their career. The different findings between this research and the one by Rainey et al. [23] can be explained by the dominant number of female participants in this research, who tend to pursue a teaching career compared with men who incline towards engineering or scientific careers [5]. This phenomenon resonates closely with the Indonesian context.

This research has several limitations. First, the participants were selected from only one university in Indonesia. However, one interesting finding suggests that including subject materials supporting the STEM subjects can influence the preservice primary school teachers' understanding about the STEM education approach. Second, the number of male participants was smaller than the number of female respondents; this may require an increase in the number of men in future research to understand how gender may affect conceptions of the STEM education approach. This research recommends that the preparation of preservice teachers for the use of STEM education can help organize the STEM subjects in the core curriculum.

CONCLUSION

This research emphasizes that the understanding of STEM education can determine how preservice primary school teachers can master SCK and MCK. The interaction between SCK and MCK can facilitate the understanding of the STEM education approach. No significant difference of understanding between men and women in the STEM education approach was discerned. To gain a better understanding of STEM education among preservice primary school teachers, it is necessary to observe how preservice primary school teachers implement the STEM approach in their classroom teaching.

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