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Analysis of STEM Knowledge of Pre-Service Science and Mathematics Teacher

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Abstract: This research is motivated by the importance of STEM knowledge for pre-service science and mathematics teachers in the 21st century. This research aims to analyze the STEM knowledge of pre-service science and mathematics teachers. The research method was carried out by distributing questionnaires with STEM knowledge indicators to the sample. The sample in this research was 86. They were 59 pre-service science teachers and 27 pre-service mathematics teachers, with different years of education, namely the 1st, 2nd, 3rd, and 4th year of Universitas Negeri Semarang. The results of this research show that the average understanding of pre-service science and mathematics teachers regarding to the STEM-based learning in the definition aspect is 4.11, objectives are 3.94, benefits are 3.94, aspects are 3.69, components are 3.71, characteristics is 3.75, and implementation is 3.86. This proves that pre-service science and mathematics teachers' understanding of the definition of STEM-based learning is very good, while pre-service science and mathematics teachers' understanding of the objectives, benefits, aspects, components, characteristics, and implementation of STEM-based learning is good.

Keywords: Mathematics; Pre-service teachers; Science; STEM knowledge

Introduction

One of the literacies that pre-service science and mathematics teachers must master in 21st century education is STEM literacy (Falloon et al., 2020; Ledbette, 2012; Syofyan et al., 2019). STEM literacy is the ability to read, write and speak which will create work or projects which must contain the concepts of science, technology, engineering, and mathematics in their application (Aninda et al., 2020; Ningrum et al., 2021). STEM literacy consists of scientific literacy, technological literacy, engineering literacy, and mathematical literacy (Zollman, 2012). Scientific literacy relates to knowledge and understanding of scientific concepts and processes for decision making (Hamna et al., 2022; Jufrida et al., 2019; Sutiani et al., 2021; Zollman, 2012). Technological literacy relates to the capacity to use, understand, and evaluate technology to develop solutions and achieve goals (Hamna et al., 2022; Hardhienata et al., 2021).

The next literacy is technical literacy. Engineering literacy relates to understanding how technology is developed through the Engineering Design Process (ITEEA, 2020; Lee, 2020; Triana et al., 2020). Meanwhile, mathematical literacy is related to the capacity to identify, understand, and engage in mathematics (Hwang et al., 2021; Jafar et al., 2020; Rizki et al., 2019; Umbara et al., 2019). Pre-service science and mathematics teachers also need to master the tools and technology appropriate to the industrial revolution 4.0

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era (Jafar et al., 2020). This technology is closely related to the "T" aspect of STEM. Therefore, it is important to analyze the STEM knowledge of pre-service science and mathematics teachers.

STEM literacy relates to the application of STEM in learning. The application of STEM usually uses the Project based Learning (PjBL) model. PjBL is a learning model that uses projects in implementing learning (Chen et al., 2019). Making projects by pre-service science and mathematics teacher students is carried out using learning stages using the PjBL model, including starting with basic questions as a learning stimulus, preparing a project plan, preparing a schedule for completing the project, monitoring student project progress, assessing results, and evaluating as well as experience (Yustina et al., 2020).

Analysis of science and mathematics teachers' STEM knowledge is important because in the 21st century, STEM education requires pre-service teachers to be able to apply STEM concepts in everyday life (Falloon et al., 2020; Nurlaely et al., 2017; Tati et al., 2017). This analysis can also provide follow-up actions such as increasing the STEM literacy of science and mathematics teachers themselves if necessary.

This analysis of STEM literacy knowledge is closely related to the understanding of pre-service science and mathematics teachers regarding the implementation of STEM-based learning in the classroom. The STEM literacy aspect consists of scientific literacy, technological literacy, engineering literacy, and mathematical literacy. The STEM literacy aspect will support the EDP of pre-service science and mathematics teacher students because in the process, the learning steps are related to the EDP indicators.

Previous researches have analyzed STEM literacy, including Nurlaely et al. (2017) who analyzed the STEM literacy of junior high school students in biotechnology material, found that the STEM literacy of junior high school students in Tasikmalaya was still low. Research by Tati et al. (2017) showed that there was a difference in STEM literacy between the control class and the experimental class after implementing the project to design a boat model, with the results of the experimental class being better.

Research by Ningrum et al. (2021) analyzed the need for assessing students' STEM literacy achievements in biology learning, it was found that students' STEM literacy results in biology learning were still low and students did not understand the assessment regarding STEM literacy. Other research that is still related to STEM literacy includes Yenmez et al. (2021) in their research aimed to investigate teachers' awareness of applying STEM to classroom learning.

The results showed that participants who were able to adopt STEM in learning, utilize interdisciplinary activities, and were interested in developing interdisciplinary knowledge were more aware of STEM and had positive intentions towards STEM education. So, it is important to analyze STEM literacy knowledge. This analysis can then be followed up with further action, such as increasing STEM literacy or STEM innovation in learning if needed. Thus, the aim of this research is to analyze the STEM knowledge of pre-service science and mathematics teachers.

Method

Research Context and Participant

This research aims to analyze the STEM knowledge of pre-service science and mathematics teachers. The research stages of this research consist of preparation (include prepare the instruments to measure STEM knowledge), testing (include measuring STEM knowledge of math and science teachers), and evaluation (include analyzing STEM knowledge data of math and science teachers). Demographic data for pre-service science and mathematics teachers is presented in Table 1.

Table 1. Demographic Data of the Pre-Service Science and Mathematics Teachers

Demographic data	Number of samples	Percentage of sample
Year		
Year 1	2	2.33
Year 2	11	12.79
Year 3	16	18.60
Year 4	57	66.28
Major		
Science education	59	68.60
Mathematics education	27	31.40

Table 1 is demographic data for pre-service science and mathematics teachers who filled out the STEM knowledge questionnaire. The sample for this research was 86, namely 59 pre-service science teachers and 27 pre-service mathematics teachers, with different years of education, namely the 1st, 2nd, 3rd, and 4th year of Universitas Negeri Semarang. All science and mathematics teacher candidates have read and agreed to participate in filling out the STEM knowledge questionnaire. The sample is pre-service science and mathematics teachers who have or will implement STEM in learning.

Table 1 shows that in the 1st year (semesters 1 and 2) there were 1.33% of pre-service teachers, in the 2nd year (semesters 3 and 4) there were 12.79% of pre-service teachers, in the 3rd year (semesters 5 and 6) there

were 18.60% of pre-service teachers, and in the 4th year (semesters 7 and 8) there were 66.28%. For more detail, demographic data for pre-service science and mathematics teachers by year and study program is shown in graphical figure 1 and figure 2.

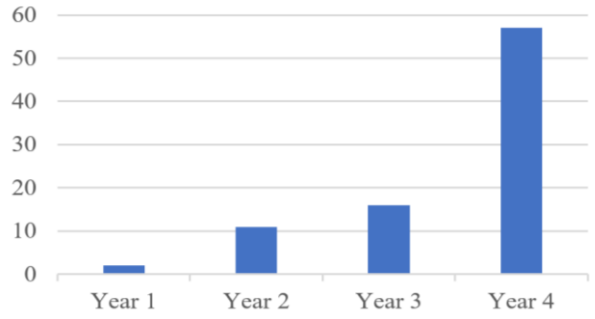

Figure 1. Demographic data of pre-service science and mathematics teachers based on year of study

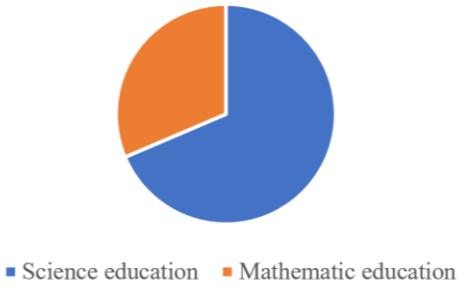

Figure 2. Demographic data of pre-service science and mathematics teachers based on study program

The largest percentage is among pre-service teachers in the 4th year, because on average pre-service teachers have taken PPL (Practical Field Experience) courses in SMP (Junior High School) or SMA (Senior High School), so they are already familiar with STEM. Pre-service teachers should implement various learning models, learning media, and approaches to learning as a form of innovation in learning, including the STEM approach. This STEM approach has become an educational trend over the last 10 years (Grahito Wicaksono, 2020), especially in science and mathematics learning. This STEM approach will support the applicable curriculum, because learning is student-centered. Apart from that, STEM allows students to apply and relate 4 fields of knowledge, including mathematics, technology, engineering, and mathematics. Science and mathematics teacher candidates should understand of STEM knowledge.

Data Collecting Tool and Analysis

STEM literacy indicators consist of science and mathematics literacy developed by PISA (PISA, 2015) and technology and engineering literacy developed by NAEP (2014). This STEM literacy indicator was adopted and adapted from research by Nurlaely et al. (2017), namely scientific literacy includes explaining phenomena scientifically, evaluating and designing scientific inquiries, and interpreting data and evidence scientifically, mathematical literacy includes formulating situations mathematically and evaluating and designing scientific inquiries, and engineering and technological literacy includes understanding technological principles, and develop solutions also achieve goals. In the STEM-based science and mathematics learning process, the resulting projects will contain STEM elements. Each data of STEM knowledge then analyzed by counting the mean.

Result and Discussion

This research aims to analyze the STEM literacy of pre-service science and mathematics teachers. There are 86 pre-service teachers consisting of 59 pre-service science teachers and 27 pre-service mathematics teachers, from the 1*st*, 2*nd*, 3*rd*, and 4*th* years. The views of pre-service science and mathematics teachers regarding STEM knowledge are presented in Table 2.

Table 2. Pre-service Science and Mathematics Teachers' Views of the STEM Knowledge

Statement	Mean	Standard deviation	Interpretation
The definition of STEM-based learning	4.11	0.69	Very good
The objectives of STEM-based learning	3.94	0.71	Good
The advantages of STEM-based learning	3.94	0.69	Good
The aspects of STEM-based learning	3.69	0.89	Good
The components of STEM-based learning	3.71	0.84	Good
The characteristics of STEM-based learning	3.75	0.79	Good
The implementation of STEM-based learning	3.86	0.78	Good

Table 2 shows the views of pre-service science and mathematics teachers towards STEM knowledge which consists of 7 aspects of statements including: definition, objectives, benefits, aspects, components, characteristics, and implementation of STEM-based learning. The first aspect is the definition of STEM-based learning which obtained an average understanding of pre-service teachers of 4.11 and a

standard deviation of 0.69 with very good criteria. This proves that pre-service science and mathematics teachers' understanding of the definition of STEM-based learning is very good. The definitions given vary, but in essence STEM-based learning is an interdisciplinary learning approach that integrates concepts, theories, and practices from the disciplines of science, technology, engineering, and mathematics in learning process. This is in line with Sartika (2019) who states that STEM education does not only mean strengthening educational practice in separate educational fields, but rather developing an educational approach by integrating several subjects such as science, technology, engineering, and mathematics.

The STEM-based learning objectives in the table show an average understanding of pre-service teachers of 3.94 and a standard deviation of 0.71 with good criteria. This proves that pre-service science and mathematics teachers understand the objectives of STEM-based learning good. The average answers to the questionnaire show that the aim of STEM-based learning is to integrate the concepts of 4 scientific disciplines to develop holistic knowledge and relevant skills for students. There is a lot of knowledge and skills that can be improved by implementing a STEM approach to learning. Improved knowledge and skills such as science learning outcomes (Diatmika, 2018), 21st century skills (Hermansyah, 2020; Mu'minah et al., 2019), critical thinking (Dywan et al., 2020), and many more.

STEM-based learning will certainly provide benefits for both students and teachers as educators. Table 2 shows that the average understanding of pre-service science and mathematics teachers towards STEM is 3.94, standard deviation 0.69 with good criteria. This proves that pre-service science and mathematics teachers understand the benefits of STEM-based learning well. The average answer in the questionnaire shows that the benefit of STEM-based learning is that learning is comprehensive and can improve students' skills and understanding. This is in line with the aim of STEM-based learning which can increase students' knowledge and skills (Diatmika, 2018; Hermansyah, 2020).

The STEM-based learning aspect resulted in an average understanding of science and mathematics teacher candidates of 3.69, a standard deviation of 0.89, and with good criteria. This proves that pre-service science and mathematics teachers' understanding of STEM-based learning aspects is good. The average answers on the questionnaire show that the STEM-based learning aspects are S (Science), T (Technology, E (Engineering), and M (Mathematics) (Niam et al., 2021; Pangesti et al., 2017). This answer is also in line with the STEM-based learning component, which resulted in an average understanding of science and mathematics teacher candidates of 3.71, a standard deviation of 0.84, and with good criteria. This proves that pre-service science and mathematics teachers' understanding of STEM-based learning components is also good.

The characteristics of STEM-based learning in Table 2 show that the average understanding of science and mathematics teacher candidates is 3.75, the standard deviation is 0.79, and the criteria are good. This proves that pre-service science and mathematics teachers understand the characteristics of STEM-based learning well. The average answer in the questionnaire shows that the characteristic of STEM-based learning is an integrated approach to science, technology, engineering, and mathematics in learning experiences which are usually carried out in the form of projects. This is also in line with the average answer in the aspect of "implementation of STEM-based learning" which states that the implementation of STEM-based learning generally uses projects. The average understanding of pre-service science and mathematics teachers in this aspect of implementation is 3.86, standard deviation 0.78, and with good criteria.

Several studies that implement or research STEM-based learning using projects include Triana et al. (2020) who examined the influence of PjBL-STEM on 21st century abilities, found effective results in improving critical thinking, creative, collaboration, and communication skills (Samsudin et al., 2020). In their research, it was found that STEM-PjBL could develop students' *self-efficacy*, especially in the concept of solving physics problems. Putri et al. (2022) in their research also stated that STEM-PjBL can influence problem-solving abilities with an N-gain of 0.59 (medium criteria).

STEM literacy skills can also be improved through STEM-based learning, which identical with project-based learning. Aninda et al. (2020) in their research implementing project-based learning on environmental pollution material, found that STEM literacy in the experimental class increased with a medium N-gain criteria. Not many research has examined STEM literacy, because this literacy is quite complex, including scientific literacy, technological literacy, engineering literacy, and mathematical literacy. So far, many research has focused just on scientific literacy.

Several studies related to scientific literacy include Handayani (2021) who developed STEM-based digital comics and found that the results could increase students' scientific literacy in the dimensions of process, content, and context with an average response of 97.85%. Ananingtyas et al. (2022) in their research also

developed Arduino-based learning media for STEM-based learning and concluded that the media developed was suitable for increasing scientific literacy with an average feasibility test result of 3.86 (very good). Irmawati et al. (2021) also developed a science module on organ system material and concluded that the module was worth implementing to increase scientific literacy.

STEM literacy skills must continue to be improved as time goes by, because through this literacy students will be able to integrate the four components of science, technology, engineering and mathematics at once in learning. Therefore, pre-service teachers also need to have STEM literacy. Increasing STEM literacy by pre-service science and mathematics teachers can be done through *Teacher Professional Development* (TPD) or what is usually called teacher professional development. This teacher professional development needs to be supported by all related parties, such as the government, MGMP, and science and mathematics teachers themselves. The design of professional development for science and mathematics teachers in STEM-based learning can be carried out as in Figure 3.

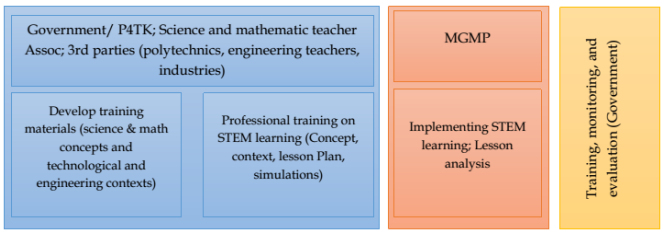

Figure 3. Design of professional development for science and mathematics teachers in STEM-based learning adapted by Permanasari et al. (2021)

Professional development of science and mathematics teachers in STEM-based learning can be done with initial steps in the form of developing learning materials, including: science, technology, engineering and mathematics concepts as well as creating a Learning Implementation Plan (RPP) (Haerani et al., 2022), teaching materials (Oktavia, 2018), and learning media (Maula et al., 2020) in STEM learning. The next step is to hold professional teacher training on STEM learning (Lo, 2021). Training can involve the Center for Development and Empowerment of Educators and Education Personnel (P4TK), Professional Associations, and MGMP. At this stage, teachers can implement STEM-based science or mathematics learning, including creating STEM-based projects by students. Monitoring and evaluation after teacher professional development is held must continue to be carried out to ensure the effectiveness of the training program (Aminudin et al., 2022; Permanasari et al., 2021). It is hoped that the results of this research analysis will provide information regarding the STEM knowledge of pre-service science and mathematics teachers, so that further research can be carried out to improve STEM knowledge or STEM literacy if necessary.

Conclusion

The pre-service science and mathematics teachers' understanding of the definition of STEM-based learning is very good, while pre-service science and mathematics teachers' understanding of the objectives, benefits, aspects, components, characteristics, and implementations of STEM-based learning is good. It can be seen from the average understanding of pre-service science and mathematics teachers regarding STEM knowledge in the definition aspect is 4.11, objectives are 3.94, benefits are 3.94, aspects are 3.69, components are 3.71, characteristics are 3.75, and implementations are 3.86.

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Conflict of Interest
There is no conflict interest in this research.

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