



## IMPROVING TEACHERS' UNDERSTANDING AND READINESS IN IMPLEMENTING STEM THROUGH SCIENCE LEARNING SIMULATION

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### ABSTRACT

This study expects to discover the improvement of science teachers' comprehension of the STEM concept, the improvement of teachers' readiness in implementing it, and the relationship between the comprehension of STEM concepts and readiness in implementing it in learning science. The participants were 50 science teachers from a few junior high schools in Ciamis who joined the workshop and simulated natural science learning dependent on STEM concepts in the Galuh University in Ciamis, Indonesia. The method of study used descriptive utilizing instruments of questionnaires and interview guide. The data were investigated using descriptive statistics with SPSS version 25.0. In addition, data from interviews were analyzed qualitatively (as complementary data). The exploration results show an increase in understanding of the STEM concept of science teachers and an increase in teacher readiness to implement it in science learning. This increase in understanding of STEM concepts and readiness to implement them is strengthened by developing a plan for implementing STEM-based learning and observing STEM-based science learning simulation activities conducted by several workshop participants. In addition, there is also a high correlation between understanding the STEM concept and the teacher's readiness to implement it in science learning.

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Keywords: STEM; comprehension; readiness; simulation

### INTRODUCTION

In the 21<sup>st</sup> century, the development of science and technology, information, and communication is fast. This phenomenon is indicated by the increasingly short transition period of the industrial revolution. Recently, Japan has mingled the industry era 5.0, showing how fast the Industrial Revolution's transition is. Nevertheless, this paper still centers around the industrial revolution 4.0 since we are simply crawling in this era. Industrial revolution 4.0, known as the digital era, expects to increment industrial competitiveness in the face of a very dynamic worldwide market. The condition is brought about by the rapid advancement of the utilization of di-

gital technology in various fields. Current rapid scientific and technological developments require critical thinking, problem-solving skills, and cooperation, called the 21<sup>st</sup>-century skills (Yildirim, 2018).

In this industrial era 4.0, all elements can communicate with each other based on internet technology. The goal is to accomplish new value manifestations and optimize the existing values of each process in the industry. However, the industrial revolution 4.0 also had a disrupting impact on people's lives. We will look later on numerous challenges, such as adjusting and taking advantage of globalization opportunities in various fields, including education. Therefore, as educators, we must prepare students to become qualified and competent human resources. Devi

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et al. (2018) expressed that qualified and proficient human resources unequivocally decide the advancement of a nation or a country.

Every individual in the global competition should get ready mentally and have competitive superiority over the others. The provision of self-preparation with long-life education and self-concept through experience in cross-disciplinary collaboration. As stated by Kelly and Knowles (2016) that the process of integrating Science, Technology, Engineering, and Mathematics in legitimate settings can be pretty much as unpredictable as the worldwide challenges that demand a new generation of STEM experts. Therefore, the concept of learning and education should construct skills needed by students to prevail in the 21<sup>st</sup> century. It is essential to set up our students to welcome their future (Scott, 2012). Diekman et al. (2011) stated that Learning through STEM integration can improve students' arrangement in the STEM field occupations. Moreover, studies on strategies that can cater for STEM education and the development of more significant interest among students to pursue a future career in STEM fields (Rasid et al., 2020).

This 21<sup>st</sup>-century skill is the expectation of the 2013 Curriculum with the advancement of an integrated STEM approach (Devi et al., 2018). A few references revealed that integrated STEM (Science, Technology, Engineering, and Mathematics) is an approach that explores learning between at least two STEM subject areas and/or between STEM subjects and other subjects (Wang et al., 2011; Roberts, 2012; Kelly & Knowles, 2016; Ismail et al., 2016; Dare et al., 2018; Margot & Kettler, 2019). Moreover, STEM is a hot global topic in education (Ramli & Talib, 2017). STEM education likewise fosters students' creativity by solving problems in everyday life, creating STEM literacy that empowers students to contend in the new economic era. Based on the explanation above, it can be summarized that STEM learning integrates at least two fields of learning Science, Technology, Engineering, and Mathematics to construct students' knowledge independently through the process of problem-solving in everyday life. Therefore, quality Science, Technology, Engineering, and Mathematics (STEM) education is indispensable for students' future achievement (Stohlmann et al., 2012; Komarudin et al., 2021).

The aim of STEM education fits with a 21<sup>st</sup>-century education, which anticipates that students should have scientific and technological literacy; they can foster the competencies they have to apply in managing problems in everyday

life. Moreover, the advantages of STEM education make students tackle issues, innovators, investors, independent, logical thinkers, and technological literacy. Therefore, STEM education could be an approach to overcome any issue between education and the required workplace of 21<sup>st</sup>-century skills (Ramli et al., 2017; Mutakinati et al., 2018). In line with this statement, Appianing & Eck (2018) stated that Science, Technology, Engineering, and Math (STEM) occupations are required to make up a significant portion of the U.S. workforce.

The characteristics of comprehensive STEM education provide opportunities for students to rehearse their thinking skills. The utilization of STEM education has an excellent opportunity to prepare students' thinking skills to accommodate their characteristics. STEM education is a way to deal with a multidisciplinary study where there is a concept of integration between science, technology, engineering, and mathematics (El-Deghaidy & Mansour, 2015; Wisudawati, 2018). Information and communication technology have changed the human lifestyle, both in work, socializing, and learning. Technological advances in the 21<sup>st</sup> century have entered various aspects of life, and according to predictions, the positions in STEM (Science, Technology, Engineering, and Mathematics) areas will increase in the following decade more than occupations in other sectors (Mutakinati et al., 2018).

In 21<sup>st</sup> century education, a few challenges and opportunities must be faced by students and teachers in order to survive in this information age. Accordingly, teachers are required to carry out STEM-based learning and STEM education. Teachers are required to be able to connect STEM disciplines in their learning. Baber (2015) argued that STEM education is an arising pattern for assisting teachers with meeting this challenge. However, in practice, STEM educators lack a cohesive comprehension of STEM education (Saxton et al., 2014). The level of STEM integration that occurs in instruction may be related to teachers' explicit connections among the disciplines (Dare et al., 2018). A struggle is needed so that teachers can associate any discipline with STEM. Saxton et al. (2014) stated that educational researchers indicate that teachers struggle to make connections across STEM.

The teacher can comprehend the STEM concept through various activities such as discussions, seminars, training, workshops, and many more. The skills for preparing STEM-based learning plans also need to be owned by teachers to have the availability to implement STEM in their

learning. Thus, expectations can be achieved to improve the quality of learning, following the various challenges faced by students in the 21<sup>st</sup> century (Devi et al., 2018). STEM exercises give an intentional setting to developing literacy and math, and science skills and concepts (National STEM Education Center, 2014).

Based on the background above, there are three problems formulated in this study as follows: (1) how to increase the science teachers' understanding of STEM concepts?; (2) how is the readiness of science teachers to implement STEM in Science Learning?; and (3) how is the correlation between understanding STEM concepts and readiness to implement them in science learning?. Therefore, this study aims to determine the increase of science teachers' understanding of STEM concepts, determine the readiness of Science teachers to implement STEM in science learning, and determine the correlation between understanding STEM concepts and readiness to implement them in science learning.

## METHODS

This study used a descriptive method. Fraenkel et al. (2011) stated that descriptive studies have essential roles in education research; they have significantly increased our knowledge of schools. The respondents of his study were 50 (fifty) science teachers of junior high school in Ciamis Regency, Indonesia, who participated in the "Workshop and Simulation of STEM-Based Science Learning" at Galuh Ciamis University, Indonesia. The activities of Workshop and Simulations of STEM-Based Science Learning are carried out for 5 (five) days consisting of in-service activities in Galuh University Campus for 2 (two) days and on-service activities in each participant's school for 3 (three) days. In-service activities in the Galuh University deliver not only material and discuss STEM concepts, but also STEM-Based Science learning simulations carried out by 3 (three) groups consist of 2 (two) representative groups of Workshop participants and 1 (one) group of Biology Education Study Program students who are researching their final study project. Each group consists of 4 (four) group members. STEM-based science learning carried out by the three groups, each using the following learning model: STEM-based PBL (Problem Based Learning) Model on Pollution material, STEM-Based PjBL (Project Based Learning) Model on Ecosystem material (with a

simple aquarium as product), and PjBL (Project Based Learning) Model on Static Electricity material (with an electroscope simple as product). The three groups took turns carried out a STEM-Based Science learning simulation with each learning model in front of the participants while the other participants observed the learning simulation activities. After the STEM-Based Science Learning Simulation was completed, it was continued with a discussion. Before the STEM-Based Science Learning Workshop and Simulation activities, most of the respondents participated in the impacting activities of the Referral School on the surrounding schools so that they are familiar with the STEM concept in science learning through these activities. It should be noted that Referral Schools are schools that have met the National Education Standards and have advantages in the provision of education that can increase competitiveness, play a role in influencing the implementation of the National Education Standards and their advantages to other schools (Kemendikbud, 2016)

The instruments in this study were questionnaires and an interview guide (as a supplement). Previously, questionnaires were distributed to respondents and analyzed for their validity and reliability. At first, the questionnaire was judged by 2 (two) Science Education experts at Galuh University, then tested outside of the respondents. As stated by Fraenkel et al. (2011), that all researchers, therefore, want instruments that permit them to draw warranted or valid conclusions about the characteristics (ability, achievement, attitudes, and many more) of the individuals they study.

The statements in the questionnaire were developed based on indicators that contain STEM factors referring to the STEM factors proposed by Devi et al. (2018), which consists of STEM definition, the purpose of STEM, the benefit of STEM, aspects of STEM, components of STEM, characteristics of STEM, and models of learning in the STEM. Statements to measure understanding of STEM concepts and readiness to implement STEM in science learning with a 5 (five) point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree). Questionnaires are distributed to respondents after the respondents participated in the workshop. In comparison, the other instrument is the interview guide (as a compliment). In practice, the interviewer brought a guideline that was only an outline of the questions asked, es-

pecially regarding the STEM-based science learning process. In STEM-based science learning simulations, data not taken shows the qualifications of performance displays, but simulations to strengthen understanding of STEM concepts and their readiness to implement them. Likewise, the respondent's ability to prepare lesson plans only strengthens the abilities studied, namely understanding STEM concepts and readiness to implement them. The data that is processed is only data obtained through the distribution of questionnaires.

The data obtained based on the distribution of questionnaires was analyzed based on percentage. Meanwhile, in determining the correlation between moment correlation coefficient or Pearson-r was used stated by Gall et al. (2017). That correlation coefficient sometimes is called

a Pearson-r because Karl Pearson developed it. The correlational coefficient was calculated using the SPSS version 25.0 program with a significance level of  $\alpha = 0,05$ .

**RESULTS AND DISCUSSION**

Based on the data obtained, it is known that, in general, junior high school science teachers have increased comprehension of the STEM concept by 10.8%. Likewise, an increase in readiness to implement STEM was 18.9%. Furthermore, as stated by Widiyatmoko (2018), simulations work to improve understanding of the concept. The results of pretest and posttest, as well as the improvement of teacher understanding of the STEM concept, are presented in Table 1.

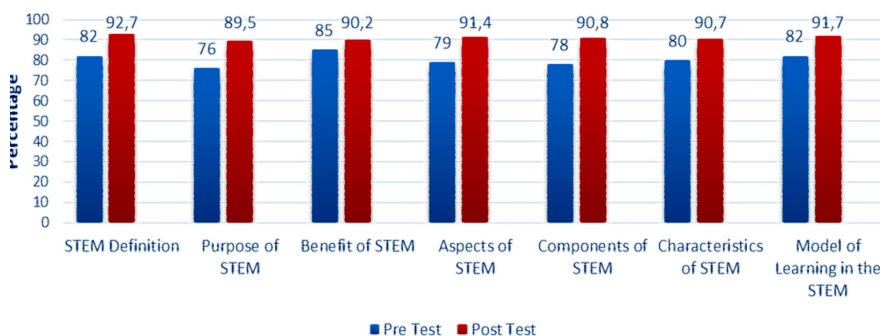
**Table 1.** Increase of Understanding the STEM Concept

STEM Factors	a* (%)	b* (%)	$\Delta^*$ (%)
STEM definition	82	92.7	10.7
Purpose of STEM	76	89.5	13.5
The benefit of STEM	85	90.2	5.2
Aspects of STEM	79	91.4	12.4
Components of STEM	78	90.8	12.8
Characteristics of STEM	80	90.7	10.7
Models of Learning in the STEM	82	91.7	9.7
Average	80.2	91.0	10.8

a\* = pretest  
 b\* = posttest  
 $\Delta^*$  = Improvement

The comparison of comprehension of STEM concept between pretest dan posttest can be seen in Figure 1. One of the activities to strengthen the comprehension of science teachers on the STEM concept, Galuh University held a STEM-Based Science Learning Workshop and Simulation. Then a study was conducted on the comprehension of the STEM concept and rea-

diness to implement it for the Workshop participants. Based on the study results, it was revealed that the comprehension of science teachers on the concept of STEM was 91%. In comparison, the pretest by 10.8%. Thus, it shows the teacher's efforts to increase his comprehension of the STEM concept to harmonize 21<sup>st</sup>-century educational characteristics.



**Figure 1.** Comprehension of the STEM Concepts



The teacher's comprehension of the STEM concept is described based on sub-concepts or some factors related to the STEM concept, namely the definition of STEM, STEM goals, the benefits of STEM, STEM aspects, STEM components, STEM characteristics, and appropriate learning models use the STEM approach. Based on the study results, it was revealed that science teachers understood the definition of STEM by 92.7%. In contrast, the pretest was 82%. Thus, there is an increase in teachers' comprehension of the STEM definition of 10.7%. Based on limited interviews, it was revealed that this percentage increase was due to efforts to study references about STEM besides the material presented in the workshop. They also obtained the STEM definitions from the internet to understand the STEM concept even more comprehensively.

Kessels et al. (2014) stated that the primary purpose of STEM education is an attempt to show holistic knowledge between STEM subjects. This study revealed that the purpose of STEM was understood by science teachers in the amount of 89%. At the same time, the acquisition in the pretest regarding the purpose of STEM was 76%. Thus, from the two data results of the study, it was seen that there was an increase in teachers' comprehension of the STEM goal, which was 13.5%. Science teachers have understood the benefits of STEM in science learning. The percentage is 90.2%. In comparison, the results of the pretest show a percentage of 85%. It means an increase in teachers' comprehension of the benefits of STEM is 5.2%. Some of the STEM approach benefits make students better, innovators, independent, logical thinkers, and literate (Afriana et al., 2016).

What aspects of STEM should be understood by the teacher to incorporate them into the STEM-Based Science Learning Plan? Question aspect; defining problems; plan and carry out investigations; use mathematics, and communicating information is mainly understood by the teacher and incorporated into the Lesson Plan. The study results revealed that the teacher's comprehension of STEM aspects was 91.4%. In contrast, the pretest was revealed 79%. It means an increase in teacher's comprehension of the aspects present in STEM-based science learning. Based on interviews, this statement reinforces that these aspects must be contained in STEM-based science learning after they practice making STEM-Based Learning Implementation Plans. One of their difficulties is analyzing which topics (in the syllabus) are suitable for the STEM approach.

Regarding the STEM component, Stohlmann et al. (2011) identified something that needs to be considered for educators so that STEM learning takes place successfully. These aspects are support, teaching, efficacy, and material. Components of support relate to various supporting STEM learning activities such as training, collaborating with other teachers in the same school and other institutions (schools, institutions, universities, industries, and many more). The teaching component focuses on the implementation of STEM in classroom learning. The efficacy component is related to educators' self-confidence in implementing STEM learning (Strimel & Grubbs, 2016; Rukoyah et al., 2020). Material components related to facilities and infrastructure to support learning. The efficacy Because science teachers have not implemented STEM-based science learning yet. Based on limited interviews, it was revealed that the components had not yet been felt as a component that must be fulfilled in STEM learning. The study results revealed that the teacher's comprehension of the STEM components was 90.8%. While the results of the pretest were 78%, so there was an increase of 12.8%.

The STEM characteristics are also understood by most teachers (90.7%) higher than pretest studies (80%), so there is an increase of 10.7%. With the increase in teachers' comprehension of the characteristics of STEM, it is expected that it can motivate teachers to implement it in the science learning that they manage. The comprehension of science teachers on the concept of STEM relating to the characteristics of sub-concepts, including the characteristics of STEM learning are: (1) STEM lessons focus on real-world issues and problems; (2) the engineering design process guides STEM lessons; (3) STEM lessons immerse students in hands-on inquiry and open-ended; (4) STEM lessons involve students in productive teamwork; (5) STEM lessons apply rigorous math and science content the students are learning; (6) STEM lessons allow for multiple correct answers and references to failure as a necessary part of learning (Jolly, 2014).

Science learning models that the teacher considers appropriate, which are considered to implement the STEM approach, have been mastered theoretically by the teacher. In implementing the STEM approach, respondents have included the selection of learning models in the lesson plan. The study results revealed that the teachers' comprehension of the selection of learning models was 91.7%. In comparison, the results of the pretest showed comprehension of 82%.

Generally, teacher readiness to implement the STEM approach in science learning is 86.7%. This teacher's readiness includes readiness in planning the implementation of STEM-based science learning. In addition, mental readiness

is revealed through a questionnaire, besides the readiness contained in the lesson plan. At the same time, the results of the pretest revealed that the readiness of teachers to implement STEM in Science Learning was 67.8%.

**Table 2.** Teachers' Readiness towards STEM Implementation

	a* (%)	b* (%)	$\Delta^*$ (%)
Lesson Plan STEM- Based	71	91.4	20.4
Integration STEM in the 2013 Curriculum	69	87.2	18.2
Analysis STEM in the 2013 Curriculum	64	81.4	17.4
Assessment STEM – Based	67	86.8	19.8
Average	67.8	86.7	18.9

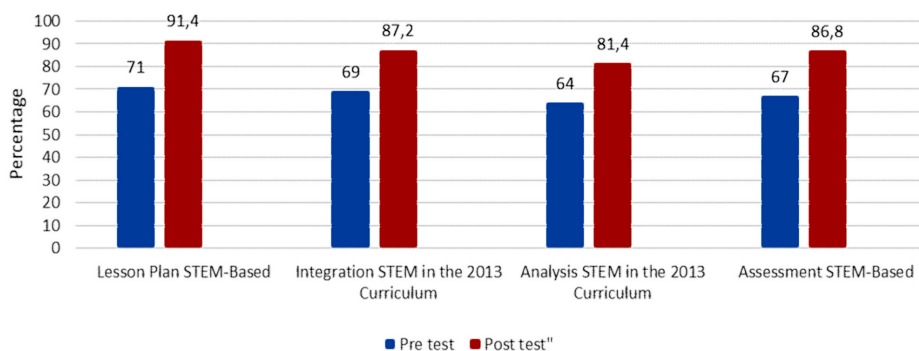
a\* = pretest

b\* = posttest

$\Delta^*$ = improvement

The STEM-based Lesson plan is developed from the syllabus. In STEM-based Lesson Plan, there is a component of STEM integration in the 2013 curriculum; STEM analysis in the 2013 curriculum; and STEM-based assessment (Devi et al., 2018). Based on the study results as shown in Figure 2, it was revealed that teacher readiness indicated by the preparation of lesson

plans was 91.4%. At the same time, the results of the pretest study were 71%. Therefore, there is an increase in readiness to plan to implement learning by 20.4%. This increase is because, in the workshop, the teachers are allowed to prepare a lesson plan for 3 (three) days in their schools (on service).



**Figure 2.** Teachers' Readiness towards STEM Implementation

Teachers have mastered integrating STEM components (Science, Technology, Engineering, and Mathematics) to have the readiness to implement it in learning. The study results revealed that the readiness to integrate STEM in the 2013 curriculum was equal to 87.2%. While the results of the pretest were 69%, so there was an increase of 18.2%. The results study of the STEM analysis in the 2013 curriculum revealed 81.4% while the test results were 64%, so there was an increase in STEM analysis of 17.4%. The teachers conduct the 2013 curriculum analysis of Basic Competencies, Science topics that can be designed for

learning with the STEM approach and develop Indicators of Competency Achievement. STEM-based assessments are listed in the Lesson Plan. The types of assessment are attitude assessment (self-assessment, peer assessment, journal assessment); knowledge assessment (cognitive); and skills assessment. The teacher's readiness study results to assess STEM-based learning in science were revealed at 86.8%. In contrast, the results of the previous study were 67%. Therefore, there is an increased score of 19.8%. Assessment instruments have been prepared in the lesson plan, which they arrange.

The teachers' comprehension of the STEM concept is correlated with their readiness to implement it in science learning, and it has a correlation coefficient of  $r = 0.856$  (high) as shown in Table 3. This result shows that the readiness of teachers to implement the STEM approach in science learning needs to be supported by the mastering of concepts related to STEM, following the statement of Wang et al. (2011) that

teachers' perceptions of STEM integration strongly influenced how they designed their STEM integration unit. In this case, another meaning of readiness to implement STEM is identical to readiness to design in integrating STEM in learning. While Abdullah et al. (2017) stated that the implementation would be delayed if the teachers' cognitive aspect does not quite meet the level required in the curriculum.

**Table 3.** Correlations

		Comprehension	Readiness
Comprehension	Pearson Correlation	1	.856
	Sig. (2-tailed)		.000
	N	51	51
Readiness	Pearson Correlation	.856	1
	Sig. (2-tailed)	.000	
	N	50	50

The aspects that support the success of teachers in implementing STEM-based science learning are mastery of concepts related to STEM and the readiness to implement them in learning. However, the willingness and motivation factor to implement it is considered to contribute. Of course, it needs further study.

### CONCLUSION

Based on the research results and discussion above, it was concluded that there is an increase in science teachers' understanding of STEM concepts and an increase in teacher readiness to implement them. The STEM-based science learning simulation activity assisted this increase at the "Workshop and Simulation of STEM-Based Science Learning." By paying attention to simulation activities of STEM-based science learning carried out by several groups, it can improve both understandings of STEM concepts and teacher readiness to implement them. In addition, there is a high correlation between teacher's understanding of STEM concepts and their readiness to implement STEM in science learning.

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