STEM LEARNING ENVIRONMENT: PERCEPTIONS AND IMPLEMENTATION SKILLS IN PROSPECTIVE SCIENCE TEACHERS

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ABSTRACT

The STEM learning environment is the practice of students' class solving problems. They use two or more STEM disciplines to solve the problem. The study aims to analyze the perceptions and implementation skills of the STEM learning environment in science education students before and after teaching internships. Perceptions and implementation skills of STEM in prospective teachers or initiatives about STEM are essential in shaping prospective teachers' characters in facilitating their students as the 21st-century generation. This research used a qualitative approach with descriptive statistical analysis. The data had been retrieved since 2019, then in 2020 after teaching internship. The total of students in this study was 86 from the 2018 class. The students came from three Islamic State Universities in Indonesia. Data collection was carried out through interviews, surveys, and pictures of perceptions and the implementation skill of STEM. The STEM learning environment instruments used were based on integration, personal experience, realistic problems, multiple representation, collaboration, student-centered instruction, and the engineering design process. The results of this study indicated that there is a significant increase in the perception and implementation skill of the STEM learning environment in science education students after teaching internship, indicated by the result of the paired sample t-test were the Asymp Sig. $\alpha < 5$ for each indicator. Perceptions and skills of implementing STEM learning environments in students' science education increased from before and after the teaching internship. It shows that the curriculum of the science education study program must be designed with a STEM learning environment approach to have good teaching skills. Curriculum design that leads to increased understanding has pedagogic and professional courses, especially pedagogical courses which include strategic subjects, learning models, learning media, and learning tools.

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Keywords: STEM learning environment; perception; implementation skill of STEM

INTRODUCTION

The wave of civilization continues to develop so that the world is currently facing the era of industrial revolution 4.0 in the 21st century. This era forces every element of life to adapt to a fast-paced and competitive framework in various fields, including education (Gleason, 2018; Kuper, 2020). Education quality is something that cannot be denied in this era. The previous learning system, which only focused on the content of knowledge material, can no longer equip students. This century requires not only humans to have knowledge but also the skills to collaborate, communicate, solve problems, think critically, and work in teams (Hughes et al., 2018; Rosa & Orey, 2018). Thus, 21st-century learning must present knowledge integration, problem-solving with problems that are contextual to students' life, motivations for students to construct knowledge independently, technology to solve problems, work collaboratively with colleagues, and so on (Gu & Belland, 2015; Wang et al., 2020).

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One of the learning approaches that can shape generations in facing the challenges of the 21st century is the STEM (Science, Technology, Engineering, and Mathematics) learning model. The STEM model is a learning approach that encourages students to be able to face such complex contexts using knowledge and skills from various disciplines (Honey et al., 2014; Surya & Wahyudi, 2018; English & King, 2019; Hong et al., 2019; Margot & Kettler, 2019; Permanasari et al., 2021). Research conducted by Nadelson and Seifert (2017) stated that the STEM learning model is very suitable to be applied by teachers to form a quality generation, then Baker and Galanti (2017) tried to STEM learning on elementary students. Ejiwale (2012) stated that implementing the STEM learning model must be at various levels, from elementary, high school to university.

The STEM approach has several functions. These functions include training students to combine four different disciplines, science, technology, engineering, and mathematics, to solve problems related to the students' own experiences or real-life (Moore & Smith, 2014; Baker & Galanti, 2017; Estapa & Tank, 2017; Dare et al., 2018). Struyf et al. (2019) found that the STEM approach is an excellent approach to promote student involvement in learning because students are physically and emotionally involved in the learning environment. Shin et al. (2018) and Lou et al. (2011) revealed that this approach also helps students explore future career options. In line with that, Blotnicky et al. (2018) and Duran et al. (2014) also reported that it could inspire students about their future and suggested to schools to implement different strategies, which is in extracurricular learning.

The STEM learning model was first initiated in the United States by combining four disciplines (science, technology, engineering, and mathematics) in an integrated manner into problem-based learning methods (Kelley & Knowles, 2016). The learning model applies knowledge and skills together in solving a particular case. STEM learning has been developed in many countries, such as Taiwan (Chen & Lin, 2019; Lee et al., 2019; Thi & Loan, 2019), Switzerland (Hinojo-Lucena et al., 2020), Japan (Yata et al., 2020), United States (Gonzalez & Kuenzi, 2012) and many more.

The learning environment needs to be considered in implementing STEM. Learning in this environment is a way of integrating meaningful subjects, encouraging collaborative activities, providing students with authentic and realistic situations involved in STEM content. Students' experience in accessing their old knowledge also needs to be considered in applying to the learning environment (Glancy & Moore, 2013; Micari & Pazos, 2020). Singer et al. (2020) provided a theoretical basis that an effective learning environment is not only regulated in each scientific discipline but also to maximize the interdisciplinary relationship in an integrated manner.

The STEM learning environment is the practice of one class of students dealing with problems, and they use two or more STEM disciplines to solve these problems (Glancy & Moore, 2013). The statement is confirmed by Ayar and Yalvac (2016) that students can deal with a specific topic and then try to solve it through several different disciplines in a STEM learning environment. However, authenticity, interdisciplinarity, and mentoring are three essences that teachers need to maintain. Also, there is learning designed by a teacher with several related subjects, or the teacher makes several teams where each team consists of students with different skills, or one discipline is represented by a team that will work together with another team with different discipline mastery in solving a particular problem (Hobbs et al., 2018).

Based on several studies, STEM learning has proven successful in improving human resources quality in the future (Stohlmann et al., 2012). However, many researchers only focus on STEM teaching to enhance STEM teaching skills in particular. There are only a few who discuss the STEM learning environment. Meanwhile, according to Singer et al. (2020) and Maltese and Tai (2011), the main contributor to successful STEM learning is the learning environment aspect.

Research in the context of science education is also widely carried out. The examples are research conducted by Firat (2020), Akaygun and Aslan-Tutak (2016), Parmin and Sajidan (2019), Sumen and Calisici (2016), and Matawali et al. (2019). Research by Firat (2020) in Turkey found the perspective of science teachers in Turkey is not ready to integrate Science, Engineering, Technology, and Mathematics. However, they have the confidence to do so if they are trained and accustomed to integrating the STEM curriculum. Akaygun and Aslan-Tutak (2016) examined the perceptions of Prospective Chemistry and Mathematics Teachers about STEM. The results showed that after the STEM training, the understanding of STEM was better than before.

Likewise, research conducted by Parmin and Sajidan (2019) measured how the effect of STEM learning affected students' entrepreneurial attitudes. The results of this study suggested that the STEM approach could influence students' entrepreneurial attitudes. Sumen and Calisici (2016) found about the association skill of elementary school teachers through the science education program using STEM. They argued that the application of STEM needs to be implemented in science learning in elementary schools. Likewise, Matawali et al. (2019) also found that Biology learning carried out with PBL integrated with the STEM approach increased students' scores who studied biology using the PBL model with the STEM approach.

The implementation of STEM in learning frameworks varies widely. Hobbs et al. (2018) stated that schools or teachers must decide for themselves the definition and framework of STEM learning. Teachers or prospective teachers have different perceptions and initiatives about implementing the STEM approach in their respective learning. Therefore, several studies have been conducted to determine STEM perceptions by visualizing them in pictures (Wu & Rau, 2019). Dye (2001) used the Draw a Science Teacher Test (DASTT) to document the teachers' knowledge and beliefs in learning methods. The same thing was done by Moseley et al. (2010) using the Draw-An-Environment Test and Rubric (DAET-R) to measure teachers' mentality. Rellensmann et al. (2017) used images to develop student learning and determine student performance during learning. Hong et al. (2021) used images to measure student learning progress and determine students' perceptions of their learning needs. Farmer et al. (2016) used student images to determine how the classroom community could be used as material for teachers to improve pedagogical skills.

In previous research, many researchers have found about how superior STEM is. However, not many have specifically discussed the learning environment and how the perception and the skill to implement it through image visualization is. Thus, this research's novelty lies in the findings of perceptions and the implementation skill in the learning environment, the conception of understanding the learning environment through images, and the research subject is science education students. This study aims to analyze the perceptions of prospective science teachers and the implementation skill of the STEM learning environment before and after teaching internship. The perception in question is the students' understanding and implementation skill of the STEM learning environment before and after completing pedagogical, professional, and microteaching courses after the teaching internship.

METHODS

The research method used is qualitative using a case study approach (Cobern & Adams, 2020) to analyze perceptions and implementation skills of STEM learning environment for prospective science. Survey research is used to describe a large population's characteristics because not all research methods can provide this broad capability. Survey research can ensure a more accurate sample for gathering targeted results to conclude more easily (Jones et al., 2013). The survey research design was used because of the following considerations: (a) high representation; (b) low cost; (c) easy data collection; (d) good statistical significance; (e) the researcher's small subjectivity; and (f) the accurate result (Cobern & Adams, 2020).

The survey was conducted on science education students on three campuses in Indonesia. There were 86 respondents in this study, consisting of 33 respondents from UIN Sunan Syarif Kasim Riau, 21 respondents from UIN Sunan Ampel Surabaya, and 32 respondents from IAIN Parepare. The development instrument was based on the rubric of elements of an effective STEM learning environment according to Glancy and Moore (2013), English (2016), Vasquez et al. (2013), and Jolly (2017). The rubric was developed based on several indicators: integration, realistic problems, collaboration, personal experiences, multiple representations, student-centered learning, and the engineering design process. The instrument was made with a 3-1 Likert scale. Number 3 indicates "highly understand," number 2 indicates "understand," number 1 indicates "do not understand." The instruments were distributed to all science education students on the three campuses via Google Form. The instrument was analyzed based on images made by students to perceive the STEM learning environment. Image is an indicator in measuring concept understanding (Chigeza & Sorin, 2016; Kose & Bayir, 2016; Bulunuz, 2019; Turgut & Turgut, 2020).

Table 1. The Example of Indicator and Description

Indicators	Description
Integration	Students work on tasks in the context of complex phenomena or situations that require them to use knowledge and skills from multiple disciplines
Personal experience	Students learn through situation-based assignments from their knowledge and personal experience
Realistic problems	Students learn based on/ through complex problems/ projects that relate to real-life experiences or students outside of school
Multiple representations	Students learn based on present experiences, which will influence their future experiences
Collaboration	Students become part of the learning community and learn through teamwork
Student center instruction	Students become learning centers, active in learning, act as collaborators, planners, experimenters, and produce work due to learning. The teacher or lecturer becomes the facilitator for all student activities
Engineering Desain Proses	Students learn through defining problems, researching/gathering information, imagining possible problem solutions, planning product designs, testing and evaluating, redesigning, and communicating

Data collection techniques in research are documentation, observation, and interviews. The documentation referred to in this research is a curriculum document that has been developed by the science education study program on three campuses that are respondents to this study. Documentation data were also obtained from the image of prospective teachers' perceptions and implementation skills of the STEM learning environment. Observation data were obtained from survey instruments, while interviews were conducted through zoom meetings. Data collection was carried out twice. The first was in December 2019. The data is taken as pretest data before the science education students undertook the teaching internship when they had not yet received pedagogical, professional, and microteaching courses. The second was taken in December 2020. The data is taken as a posttest after the science education students undertook the teaching internship when prospective teachers had received pedagogical, professional, and microteaching courses.

After the data collection process is complete, the data instrument from the observation results is statistically analyzed to determine the data's validity and reliability. The results of the validity test are analyzed using the statistical analysis methods of the product-moment correlation test. The results of the analysis show that r count> r table. Besides, the value of sig. (2-tailed) <0.05 This indicates that each statement item in the questionnaire is declared valid. Furthermore, the results of the reliability test are analyzed by calculating the value of Cronbach alpha. If Cronbach's alpha value is >0.60, then the questionnaire or questionnaire results of observation are declared reliable or consistent (Peters, 2014). Based on the results of statistical analysis, it shows that the Crombach alpha values for the pretest and posttest items are 0.601 and 0.878, respectively. Thus, it can be concluded that the data is reliable. The pretest and posttest question items refer to the indicators above. These items are the same as the question items.

After the data is declared valid and reliable, the next step is to perform statistical analysis using paired Sample t-test. The Paired Sample t-test is a comparative hypothesis test that aims to determine whether there is a difference in the mean of two pairs of paired or related samples (Samuels, 2015). If, $\alpha < 0,05$, H_0 is rejected, so it can be concluded that there is a significant difference between the perceptions and the implementation skill of STEM environment of prospective teachers before and after teaching internship.

The study also developed a D-STEM rubric based on a literature review to analyze images that have been made by the prospective teachers about their perceptions and implementation skill of STEM learning environments. The literature review was developed into a rubric covering the elements of the effective STEM learning environment identified in Glancy and Moore (2013), English (2016), Vasquez et al. (2013), and Jolly (2017). In particular, the researchers seek evidence to what extent indicators (integration, personal experience, realistic problems, multiple representation, collaboration, student center instruction, and engineering design processes) can be implemented in image visualization. Each indicator was dissected and analyzed through indicator

descriptions, then analyzed the extent to which these indicators appear in the image. The indicator description instrument was coded on a 3-1 Likert scale described in the research instrument above. These indicators also serve as indicators for surveys and interviews.

Data triangulation was carried out in this study to obtain valid data. The data obtained from this image was cross-checked with the curricula owned by each study program on three campuses, survey results, and interview results.

RESULTS AND DISCUSSIONS

The perception and implementation skill of STEM Learning Environment in 86 science education students based on seven indicators before and after teaching internships can be seen in Table 2. Based on Table 2, most of the respondents before teaching internship answered "Understand" and "Do not Understand" on each indicator.

Table 2. The Perception and Implementation Skill of STEM Learning Environment in Science Education Students

Indicator	Do not understand		Understand		Highly Understand	
	Before	After	Before	After	Before	After
Integration	50	0	36	36	0	50
Personal experience	53	0	33	29	0	57
Realistic problems	48	0	38	30	0	56
Multiple representation	51	4	31	33	0	53
Collaboration	54	1	31	26	0	60
Student-centered instruction	48	0	38	30	0	56
Engineering Design Process	48	0	38	27	0	59

None of the respondents answered, "Highly Understand." It shows that none of the students master the STEM learning environment. It is different from the student's answer after teaching internship. Most of the students answered "Understand" and "Highly understand." Only on the multiple representation indicator, four respondents answered: "Do not understand." For more details, Figure 1 shows the percentage results of perceptual understanding and application of the STEM learning environment in science education students.
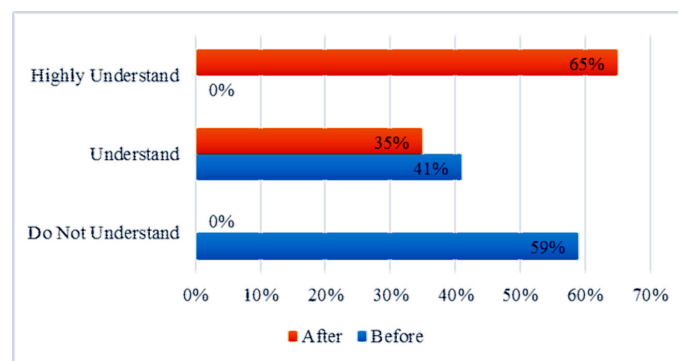

Figure 1. Graphic of the Percentage of Perception and Implementation Skill of the STEM Learning Environments in Science Education Students

Based on Figure 1, it can be seen that the difference in the percentage of perceptual understanding & application of the STEM learning environment before and after doing fieldwork practices is quite unequal. In the figure, it can be seen that before students did a teaching internship, 59% of students did not understand and implement the STEM learning environment. However, after they did a teaching internship, their understanding and application of the STEM learning environment increased dramatically. 65% of them stated that they understood, and 35% of them stated that they understood. Furthermore, from the observation data, it will be statistically analyzed using the Paired Sample t-test. It is in line with the results of the Paired Sample t-test in Table 3.

Table 3. The Results of the Paired Sample t-test

Indicator	Asymp Sig.
Integration	0,001
Personal experience	0,002
Realistic problems	0,000
Multiple representation	0,012
Collaboration	0,010
Student-centered instruction	0,000
Engineering Design Process	0,003

Based on Table 3, it can be seen that the Asymp Sig for each indicator is $\alpha<5$. Thus, it can be concluded that there are significant differences in the perceptions and implementation skills of the STEM learning environment before and after teaching internship. It shows that the inclusion of pedagogic, professional, and microteaching courses before teaching internship is beneficial as a provision for them to understand the STEM learning environment.

The following will present two respondents' drawings before and after the teaching internship to represent the seven indicators above.
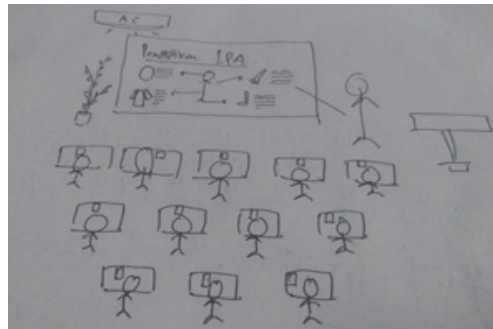

Description:The teacher explains the science learning material using an LCD projector. Students listen to the teacher's explanation.
Figure 2. The Example of Respondents' Drawing before Teaching Internship

Based on Figure 2, it can be seen that students do not understand the STEM learning environment. Students understand that the STEM learning environment is only limited to technology in the learning process, such as LCD projectors. However, the STEM learning environment is not only interpreted narrowly like that. In the image, it is still clear that the learning environment is teacher-centered, while the STEM learning environment creates a student-centered learning environment. Like the indicators mentioned above, this is in line with Table 2, the student-centered instructions indicator. More than 50% of students do not understand the STEM learning environment regarding student-centered instruction indicators. Forty-eight students stated "do not understand," and 38 other students stated, "understand." Apart from the Student-centered Instruction indicator, the other six indicators are not shown in Figure 1. As a comparison to find out the differences before and after teaching internship are shown in Figure 2.
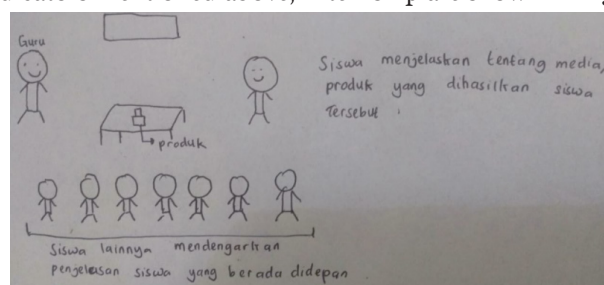
Description: The teacher assigns all students to make a project. The teacher asks students to present the resulting product in front of the class. Other students listened to the explanation of the student's product presentation.
Figure 3. The Example of Respondents' Drawing after Teaching Internship

Figure 3 shows that the Integration indicator is well-fulfilled after the teaching internship. Of the 86 respondents, 36 respondents stated "understand," and 50 respondents stated, "highly understand." As seen in Figure 2, students work on assignments given by the teacher following the context of a complex phenomenon or situation. It, of course, requires them to use knowledge and skills from various disciplines, under the explanation of the STEM concept that the implementation of this learning involves several disciplines. In Figure 3, an example of STEM learning implementation involves multidisciplinary disciplines, namely science, technology, engineering, and mathematics. The represented learning environment shows students working collaboratively to solve problems. Referring to the collaboration indicator, 33 respondents stated "understand," and 53 respondents stated, "highly understand." As seen in Figure 2, students must be part of the learning community and learn through group work. Besides, various materials and resources such as construction tools, electronic materials, or other materials used in the design are available in most of the drawings, so the Engineering Design Process indicator is well-fulfilled. In Figure 3, students learn through defining problems, researching, or gathering information, imagining possible problem solutions, planning product designs, testing, evaluating, redesigning, and communicating. The inclusion of engineering design process indicators is a novelty in this study, where these indicators are an essential part of the STEM environment. Several related studies on the STEM environment did not include this indicator in their research. However, in this study, the researcher attempted to examine more deeply the understanding of the STEM environment when viewed from the engineering design process indicator.

In Figure 3, there is also a student-centered instruction indicator, showing that 30 respondents stated "understand" and 56 other respondents stated, "highly understand." In most of the respondents' images, this aspect is well-fulfilled, where students develop, design, test, and revise the problems given. The learning environment shown in the figure indicates that student-centered learning has been well-implemented, where students have an active role in this learning. In addition to listeners or recipients of knowledge, students also act as planners, experiments, and the teacher's role serves as a guide or facilitator of learning.

Based on the results of the perception and implementation skills of the STEM learning environment in science education students based on the seven indicators in Table 2, it can be seen that most science teacher candidates have a good understanding of the STEM environment after teaching internships. Before that, many of them did not understand, but after, most of them answered: "highly understand." It is influenced by the curriculum applied at UIN Riau, UIN SunanAmpel Surabaya, and IAIN Parepare, which have similarities in determining the course distribution of courses, so there is no significant difference in the results of the perception survey and the skills in implementation from the three campuses. As research conducted by Thi To Khuyen et al. (2020) showed that 186 science teachers in Vietnam fully support the implementation of STEM learning, proving that effective teacher professional development is necessary to sustain STEM learning. The same case in research conducted by Stubbs and Myers (2016) stated that according to teacher perceptions, STEM learning describes an increase in student interest, motivation, and career readiness. Thus, it can be concluded that the perception of the implementation of STEM learning is very positive. In the context of science learning, it is also strengthened by the results of researches by Firat (2020), Akaygun and Aslan-Tutak (2016), Parmin and Sajidan (2019), Sumen and Calisici (2016), and Matawali et al. (2019).

These studies have differences and similarities with the findings of this study. The difference side lies in the object of scientific study, but the resemblance is that they associate the object of study with STEM. Firat (2020) in Turkey found the science teacher unpreparedness in implementing STEM, while Akaygun and Aslan-Tutak (2016) found that prospective chemistry and mathematics teachers could improve their understanding of STEM after receiving STEM training. Likewise, Parmin and Sajidan (2019) found the effect of STEM learning on student entrepreneurial attitudes. Sumen and Calisici (2016) found the skills of the elementary school teacher association through the science education program using STEM. The same finding in a different context is in Matawali et al. (2019) that Biology learning carried out with PBL integrated with STEM approach increased students' scores who studied biology using the PBL model with the STEM approach.

This study shows that STEM learning is synonymous with integration, where students use various scientific disciplines integratively to solve problems in learning. However, how the exact form of the integration of knowledge might invite some differences in understanding and implications, one teacher and another teacher can be different about integrating different disciplines into a single learning unit, some think that by using problem-solving methods, the integration of other fields of science can be implemented. However, with a note that there must be a priority in specific disciplines, for example, mathematics (Stohlmann et al., 2012), and even so, teachers will face several challenges because integrating these different disciplines is not easy (Ryu et al., 2019). On the other hand, STEM learning can be applied in two ways. The first is the correlated curriculum in which each discipline is taught separately, but it tries to meet its relationship, and the second is the curriculum field board where a group of different subjects is arranged into one field of study (Herschbach, 2011). The second way requires special skills for teachers. Therefore, the implementation of STEM learning depends on a teacher's skill to master the content of science, technology, engineering, and mathematics and how a teacher's perceptions and beliefs about how to integrate these different scientific fields into learning.

What needs to be underlined is that this integration will find a solution when the teacher presents complex problems but is still close to students' personal experiences (Glancy & Moore, 2013; Micari & Pazos, 2020). Complex problems certainly require mastery of several disciplines to solve them. However, not all kinds of problems are complicated, but problems that are still close to students so that they can still reach them. Therefore, to support the integration of knowledge in STEM learning, it is natural that STEM learning itself often encourages students to learn through assignments based on situations based on their knowledge and personal experience. Wells (2019) agreed that STEM learning with integration conditions must present a personal approach, one of which is to present problems that are related to the personal experience of students. It will provide opportunities for students to make knowledge connections in ways that are familiar to them. Even if necessary, STEM learning can present experiences close to students (personal experience) and real or related to students' real-life outside of school (Schmidt et al., 2020).

The presence of complex problems that students face in STEM learning indicates that STEM learning is a multiple representation learning style. The central concept is that students can solve these complex problems using several methods and scientific disciplines in STEM learning (Izzo & Bauer, 2015), demand teamwork or collaboration (Burrows et al., 2018), even if necessary, both teachers and schools must collaborate with specific communities that master specific disciplines to strengthen the implementation of STEM learning (So et al., 2020). It must be student-centered, where students are active in learning, act as collaborators, planners, experimenters, and produce work as learning outcomes, while the teacher switches roles to become providers of learning structures, supporters, or facilitators (Ejiwale, 2013; Chen & Lin, 2019).

However, the problem in STEM learning is the experience and perception of the teacher itself. Of course, a teacher must have related experiences and perceptions about specific problems before presenting them to students (Thibaut et al., 2018), and the teacher must be able to translate them into a STEM learning flow that is suitable and close to the students. Thus, teachers face two challenges in STEM learning, first their own experiences and perceptions of STEM, and second, how to make it happen and ensure that realization is by student experiences. Thibaut et al. (2018) strengthened the results of this study that prospective teachers with a good understanding of STEM will help teachers implement STEM.

Teachers with a good understanding of STEM will lead to implementing a good STEM learning environment because STEM is part of educational technology innovation (Keane & Design, 2016; Shatunova et al., 2019). This STEM innovation can also be taught to preschools (Awang et al., 2020) and early grade (DeJarnette, 2018). Thus, the perceptions of teachers and prospective teachers regarding STEM need attention. Teaching with the STEM environment is evident not only in the teaching and learning process at universities but also in preschool and early grade in primary education.

Likewise, teacher perceptions visualized in images are also an interesting finding in this study. The same is the case with other studies that use images to describe a concept or perception, such as Chigeza and Sorin (2016) about the concept of numeration for kindergarten children, Kose and Bayir (2016) about the perception of peace for students, Turgut and Turgut (2020)

about the perception of learning mathematics for elementary students, and Martínez-Peña and Gil-Quílez (2014) about geology understanding. These studies were conducted to find students' conceptions or understandings, or perceptions about the studied object. However, there has not been much research on science students' perceptions of the STEM learning environment. Thus, the STEM learning environment for science education students is a new finding in this study. Given that prospective science teachers are responsible for leading their students to practice scientific thinking both in content and in an approach to learning.

CONCLUSION

Perception and implementation skill of STEM learning environment in science education students increased from before and after teaching internships. It indicates that the curriculum in science education study programs must be designed using the STEM learning environment approach to have good teaching skills. The curriculum design that leads to an increase in understanding has pedagogic and professional courses, especially pedagogic courses that include strategic courses, learning models, learning media, and learning tools.

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