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Increasing Pre-service Science Teacher Creativity Through STEM Problem-Solving

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Abstract: Creativity is one of the skills that must be possessed in the 21st century, especially by pre-service science teachers. However, in fact, the quality of pre-service science teacher creativity still needs to be improved. Therefore, this research aims to increase the creativity of pre-service science teachers through STEM Problem-Solving. This research uses a one group pretest posttest design. The sample in this study was 53 pre-service science teachers in the science education department at Universitas Negeri Surabaya. Increasing the quality of pre-service science teacher creativity is measured based on pretest and posttest scores. The pretest and posttest scores were then analyzed using N-Change. Apart from that, it was also analyzed statistically using paired t-test. This is used to ensure that STEM Problem-Solving really has an effect on increasing the creativity of pre-service science teachers. The research results show that STEM Problem-Solving is proven to significantly increase the creativity of pre-service science teachers. The category of increasing pre-service science teacher creativity is in the medium category. The majority of pre-service science teachers' final creative quality is in the creative category.

Keywords: STEM; Problem-Solving; Creativity

Introduction

The 21st century is challenging when the industrial revolution is developing very rapidly. These developments have an impact on improving science and technology. Global changes in various aspects of life and rapid global development challenge the nation to prepare for the nation's next generation (Heidrich, 2021). In line with the development of the 21st-century education paradigm, education in Indonesia is faced with the challenge of producing human resources with superior competencies that can compete globally in the future (Elisa et al., 2023). One of the development challenges in the 21st century is the challenge of creative problem-solving.

This challenge is also in line with the Indonesian National Qualifications Framework, which stipulates that university graduates must be able to adapt to current conditions and use science, technology, or art in the field of problem-solving (Kemenristekdikti, 2015). Graduates are then able to formulate problem-solving processes and understand general theoretical concepts and specific theoretical concepts from various scientific fields. In addition, they can also help individuals and groups to choose alternatives and make decisions based on information and data analysis. From these hopes and challenges, someone, especially students, must be able to solve future problems and provide creative solutions from the results of the data analysis. To help meet the challenges of solving these problems requires skills that can deal with these difficulties.

Vibration concept material is one of the materials contained in science learning. In this study, the vibrational concept material was used as a basis for measuring creative thinking skills in solving questions related to the vibrational concept. The vibration concept material is often considered easy by pre-service science teachers because the vibration concept material that they

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know only calculates the frequency and period of vibration. However, in reality, when the vibrational concept is associated with a form of problem-solving in everyday life, it is found that there are still many pre-service science teachers who fail to solve it.

The skill to think creatively is one thing that can help in solving problems. Creative thinking is an important complement to cognitive processes to solve complex problems (Lucchiari et al., 2019). One needs analytical thinking based on creative thinking to solve problems. Creative thinkers, when faced with various problems, can enable someone to make decisions and act more quickly by organizing, adjusting, restructuring, or improving their thinking uniquely (Puccio, 2017). In solving problems creatively, science teachers are able to empathize with colleagues, ask open questions, make prototypes, and collaborate with others. Therefore, the ability to think creatively must be developed to help solve problems that arise later.

Creative thinking can be formulated as a skill that reflects fluency, flexibility, and originality, as well as elaboration abilities (Runco et al., 2010). Someone's creative thinking goes through the stages of synthesizing ideas, developing ideas, planning the implementation of ideas, and implementing these ideas to make something or a new product (Becattini et al., 2017). This new product is the result of someone's creativity (Hikmah et al., 2023). Thinking, in this case, refers to a person's awareness of his ability to develop various ways that can be used to solve problems. Therefore, creative thinking also refers to an individual's skills to generate and develop ideas for problems and alternative solutions (Nurdian et al., 2023). Creative thinking has specific characteristics that can form the basis of descriptive qualitative research (Sawyer, 2019).

Troubleshooting to create a new product is very compatible with STEM-based problem-solving. STEM is a multidisciplinary approach to science that becomes a complete learning approach (Jasmi et al., 2023; Mailana & Dafit, 2023; Yulyani et al., 2023). An approach to problem-solving in which students use science, technology, engineering, and mathematics is one of the modern educational concepts that develop abilities to successfully face future challenges (Nadelson & Seifert, 2017). Solving problems using STEM provides opportunities for students to integrate scientific investigations, technology, mathematical skills, and design techniques (Kelley & Knowles, 2016; Rodger W, 2013). The use of STEM in problem-solving not only allows students to acquire knowledge and skills but also processes to acquire these knowledge and skills (Breiner et al., 2012; Gale et al., 2020; Shah et al., 2018). According to Torlakson (2014), solving this problem has indicators that refer to the STEM (Science, Technology, Engineering, and Mathematics) description with the four aspects in it, namely:

Table 1. STEM-based Troubleshooting

STEM-Based Troubleshooting	Indicator
Science	Students discover concepts and apply concepts to solve problems
Technology	Students analyze and evaluate solutions to problems with the help of technology
Engineering	Students design solutions to problems
Mathematics	Students calculate the number of tools and materials used in solving problems so that they are clear and measurable

Some research results show that pre-service science teachers' creative thinking skills need attention. Among them is research that shows pre-service science teachers' creative thinking skills are in good enough criteria and for conventional learning are classified as low criteria (Habibi et al., 2020; Iskandar et al., 2020). Everyone has the potential to think creatively. Therefore, it is important to choose the right strategy to trigger it (Glăveanu, 2014). However, of the many studies that examine pre-service science teachers' creative thinking skills, there is still no analysis of these skills in solving problems related to STEM-based vibration concepts. Therefore, this research aims to examine increasing the creativity of pre-service science teachers in solving problems related to the concept of vibration through STEM Problem-Solving.

Method

This research used a one-group pretest-posttest design (see Figure 1). In this design, researchers measure the increase in pre-service science teacher creativity by giving a pretest to the treatment group. This is used to measure the quality of pre-service science teachers' initial creativity. Then implement the STEM Problem-Solving model in the concept of vibration. Finally, give a posttest to pre-service science teachers to measure the quality of their creativity after receiving treatment.

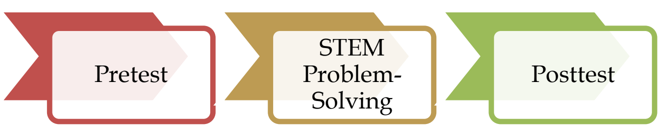

Figure 1. Research design

The research samples were 53 pre-service science teachers from the Science Education Department at Universitas Negeri Surabaya, consisting of 50 female students and 3 male students. They are students in the optical waves course. The sampling technique used was purposive sampling. The data collection technique is a measurement technique by giving a pretest and posttest of creative thinking problem solving to the pre-service science teachers. Creative thinking indicators can be seen in Table 2.

Table 2. Creative thinking skills indicator

Aspect	Indicator
Fluency	Give correct answers or ideas to questions
Flexibility	Generate varied answers with different points of view
Originality	Give answers according to their thinking
Elaboration	Detailing ideas or answers until clear

Test scores, both pretest and posttest, are used as a reference in determining the pre-service science teacher creativity category. This categorization is used to determine the extent to which pre-service science teachers have achieved their creativity skills. The creativity categories are presented in Table 3.

Table 3. Creativity categories

Test Score	Criteria
0.00 – 25.00	Not creative
25.01 – 50.00	Less creative
50.01 – 75.00	Quite creative
75.01 – 100.00	Creative

The pretest-posttest results data were analyzed using the N-change equation (see equation 1) (Marx & Cummings, 2007). The N-change score is used to determine the increase in creativity of pre-service science teacher after implementing STEM problem-solving. The N-change scores obtained were then interpreted according to the categories in Table 4. In addition, the pretest-posttest data were also tested for paired t-tests using SPSS software.

$$c = \begin{cases} \dfrac{\text{post-pre}}{100 - \text{pre}} & \text{post} > \text{pre} \\ \text{drop} & \text{post} = \text{pre} = 100 \text{ or } 0 \\ 0 & \text{post} = \text{pre} \\ \dfrac{\text{post} - \text{pre}}{\text{pre}} & \text{post} < \text{pre} \end{cases} \quad (1)$$

Table 4. N-change categories

N-change Score	Improvement Category
< 0.00	No Increase (Decrease) Occurred
0.00 – 0.30	Low
0.31 – 0.70	Medium
0.71 – 1.00	High

Result and Discussion

Pre-service science teacher creativity is measured based on scores obtained from the pretest and posttest. This score is also used to determine the increase in pre-service science teacher creativity after being given treatment, namely STEM Problem-Solving. The pretest, posttest scores and increased creativity of pre-service science teachers are presented in Table 4.

Table 4. Pretest, posttest and N-change scores

Sampel	P_0	Ctg.	P_1	Ctg.	c	Ctg.
S1	25.00	1	70	3	0.60	Medium
S2	45.00	2	75	3	0.55	Medium
S3	35.00	2	80	4	0.69	Medium
S4	25.00	1	75	3	0.67	Medium
S5	45.00	2	75	3	0.55	Medium
S6	45.00	2	80	4	0.64	Medium
S7	45.00	2	70	3	0.45	Medium
S8	50.00	2	80	4	0.60	Medium
S9	50.00	2	85	4	0.70	Medium
S10	45.00	2	70	3	0.45	Medium
S11	25.00	1	75	3	0.67	Medium
S12	45.00	2	70	3	0.45	Medium
S13	30.00	2	85	4	0.79	High
S14	45.00	2	80	4	0.64	Medium
S15	30.00	2	80	4	0.71	High
S16	50.00	2	80	4	0.60	Medium
S17	45.00	2	85	4	0.73	High
S18	50.00	2	90	4	0.80	High
S19	45.00	2	85	4	0.73	High
S20	45.00	2	85	4	0.73	High
S21	50.00	2	80	4	0.60	Medium
S22	40.00	2	80	4	0.67	Medium
S23	40.00	2	80	4	0.67	Medium
S24	25.00	1	85	4	0.80	High
S25	40.00	2	85	4	0.75	High
S26	70.00	3	80	4	0.33	Medium
S27	65.00	3	80	4	0.43	Medium
S28	65.00	3	75	3	0.29	Low
S29	65.00	3	75	3	0.29	Low
S30	60.00	3	80	4	0.50	Medium
S31	65.00	3	80	4	0.43	Medium
S32	60.00	3	85	4	0.63	Medium
S33	60.00	3	75	3	0.38	Medium
S34	60.00	3	75	3	0.38	Medium
S35	60.00	3	80	4	0.50	Medium
S36	65.00	3	80	4	0.43	Medium
S37	65.00	3	80	4	0.43	Medium
S38	65.00	3	75	3	0.29	Low
S39	60.00	3	75	3	0.38	Medium
S40	65.00	3	75	3	0.29	Low
S41	65.00	3	75	3	0.29	Low
S42	60.00	3	75	3	0.38	Medium
S43	60.00	3	80	4	0.50	Medium
S44	65.00	3	75	3	0.29	Low
S45	70.00	3	70	3	0.00	Low
S46	70.00	3	85	4	0.50	Medium

Sampel	P_0	Ctg.	P_1	Ctg.	*c*	Ctg.
S47	70.00	3	80	4	0.33	Medium
S48	70.00	3	80	4	0.33	Medium
S49	75.00	3	80	4	0.20	Low
S50	70.00	3	85	4	0.50	Medium
S51	75.00	3	85	4	0.40	Medium
S52	70.00	3	85	4	0.50	Medium
S53	70.00	3	80	4	0.33	Medium
Ave.	53.87	3	79.06	4	0.50	Medium

Information:
P0 = Pretest
P1 = Posttest
Ctg. = Category
1 = Not creative
2 = Less creative
3 = Quite creative
4 = Creative

Table 4 shows that during the pretest it was discovered that 4 students were in the not creative category, 21 were less creative, 28 were quite creative, and none were in the creative category. At the time of the posttest, it was discovered that none of the pre-service science teachers were categorized as neither creative nor less creative, 19 were quite creative, and 34 were creative. A comparison of the results of the pre-service science teacher pretest and posttest is presented in Figure 2.

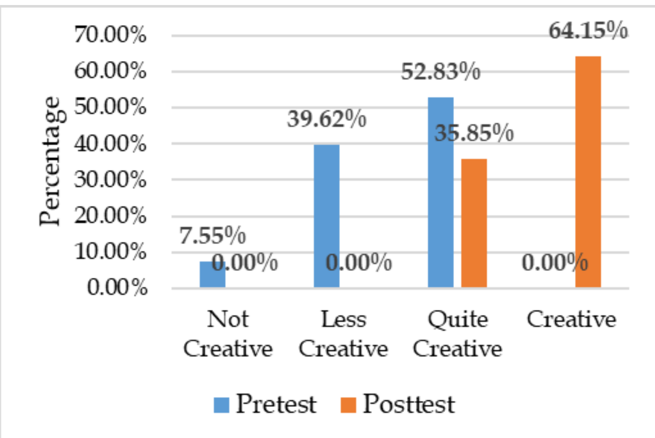

Figure 2. Comparison of pretest and posttest results

Based on the data presented in Figure 1, the pretest results show that the creative thinking abilities of pre-service science teachers are in the not creative category at 7.75%, the less creative category at 39.63%, and the quite creative category at 52.83%. Meanwhile, the posttest results showed that none of the pre-service science teachers were in the not creative and less creative categories, 35.85% were in the quite creative category, and 64.15% were in the creative category. This shows that a person's creative thinking skills have levels, according to the works produced in the field. Creative thinking can be learned, and this general aspect of cognition can be strengthened by teaching and training. A person's creative thinking skills can be improved by understanding their creative thinking process and the various influencing factors, as well as through appropriate training (Ritter & Mostert, 2017). Meanwhile, the research results show that there needs to be a particular stage to teach pre-service science teachers how to find initial ideas when facing problems that require creative thinking and how to develop appropriate strategies based on the initial ideas obtained. People who have creative thinking skills must have critical thinking skills. People with creative thinking skills, often called divergent thinking, have high creativity and are helpful to many people (Mumford et al., 2018). It is imperative to teach creative thinking skills in universities. Therefore, there is a need for continuous learning between pre-service science teachers and lecturers, practicing by working on various questions.

The pretest and posttest data in Figure 2 shows that there are differences in the quality of pre-service science teacher creativity caused by STEM Problem-Solving learning. This is reinforced by the average N-change score of 0.5 in the moderate improvement category (see Table 4). The percentage increase in the quality of pre-service science teacher creativity based on the N-change analysis is presented in Figure 3.

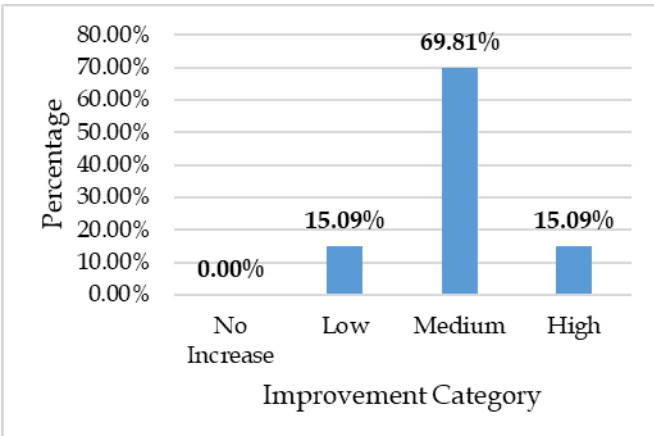

Figure 3. Percentage increase in pre-service science teacher creativity

Figure 3 shows that the majority of pre-service science teachers experienced an increase in creativity in the moderate category. This indicates that STEM Problem-Solving is proven to be able to increase the creativity of pre-service science teachers. These findings are in line with the results of previous research which stated that STEM can have a positive impact on student creativity (Aguilera & Ortiz-Revilla, 2021; Eroğlu & Bektaş, 2022; Uğraş, 2018). In addition, the use of STEM-integrated Design Thinking has been proven to help students come up with creative ideas to solve problems around them (Iskandar et al., 2020; Rabbani et al., 2023). Problem solving learning itself has advantages that are in line with the characteristics of physics, part of science, so it is relevant to physics learning (Safarati & Zuhra, 2023). Thus, STEM Problem-Solving is proven to be able to be used as a stimulus to increase pre-service science teacher creativity in learning vibration concepts.

To ensure that the treatment given, namely STEM Problem-Solving, is proven to have a significant effect on increasing the creativity of pre-service science teachers, this is then continued with statistical analysis using a paired t-test. Before carrying out the paired t-test, there are several prerequisite tests that must be met. These prerequisites include a homogeneity test and a normality test.

The homogeneity test is used to determine whether several population variants are the same or not. The homogeneity test results show that $P > 0.05$, so it can be concluded that the data meets the homogeneity assumption. The homogeneity test results are presented in Table 5.

Table 5. Test of homogeneity of variances

Pretest			
Levene Statistic	df1	df2	Sig.
.512	3	48	.676
Posttest			
Levene Statistic	df1	df2	Sig.
1.560	8	43	.166

The normality test is used to find out whether the data is normally distributed or not. The results of the normality test show that $P > 0.05$, so it can be concluded that the data is normally distributed. The normality test results are presented in Table 6.

Table 6. One-sample Kolmogorov-Smirnov test

		Unstandardized Residual
N		53
Normal Parameters[a,b]	Mean	.0000000
	Std. Deviation	14.38381837
Most Extreme Differences	Absolute	.172
	Positive	.081
	Negative	-.172
Kolmogorov-Smirnov Z		1.252
Asymp. Sig. (2-tailed)		.087

a. Test distribution is Normal.
b. Calculated from data.

Paired t-test was used to determine whether there were differences in pre-service science teacher creativity before and after implementing STEM Problem-Solving learning. The paired t-test results show that $P < 0.05$. This indicates that there is a significant difference between the creativity of pre-service science teachers before and after being given treatment, namely learning STEM Problem Solving. The test results are shown in Table 7.

Table 7. Paired samples test

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	Pretest - Posttest	-25.18868	14.96670	2.05583	-29.31401	-21.06335	-12.252	52	.000

Based on the results of data analysis using N-change and paired t test, it can be concluded that STEM Problem-Solving has a significant effect on increasing the creativity of pre-service science teachers. This is because the implementation of learning on vibration material given to pre-service science teachers is a series of processes of understanding basic physics concepts in a hierarchical manner. If pre-service science teachers experience disruption during previous learning or are unable to absorb the material well, then there will be disruption in learning higher concepts. The test questions given to pre-service science teachers require creative thinking skills and how to solve them using a STEM approach.

The posttest results show that the majority of pre-service science teachers are in the creative category (see Figure 2). Figure 4 is an example of a pre-service science teacher posttest answer after participating in STEM problem solving learning. This answer is an example of an answer with quite creative quality.

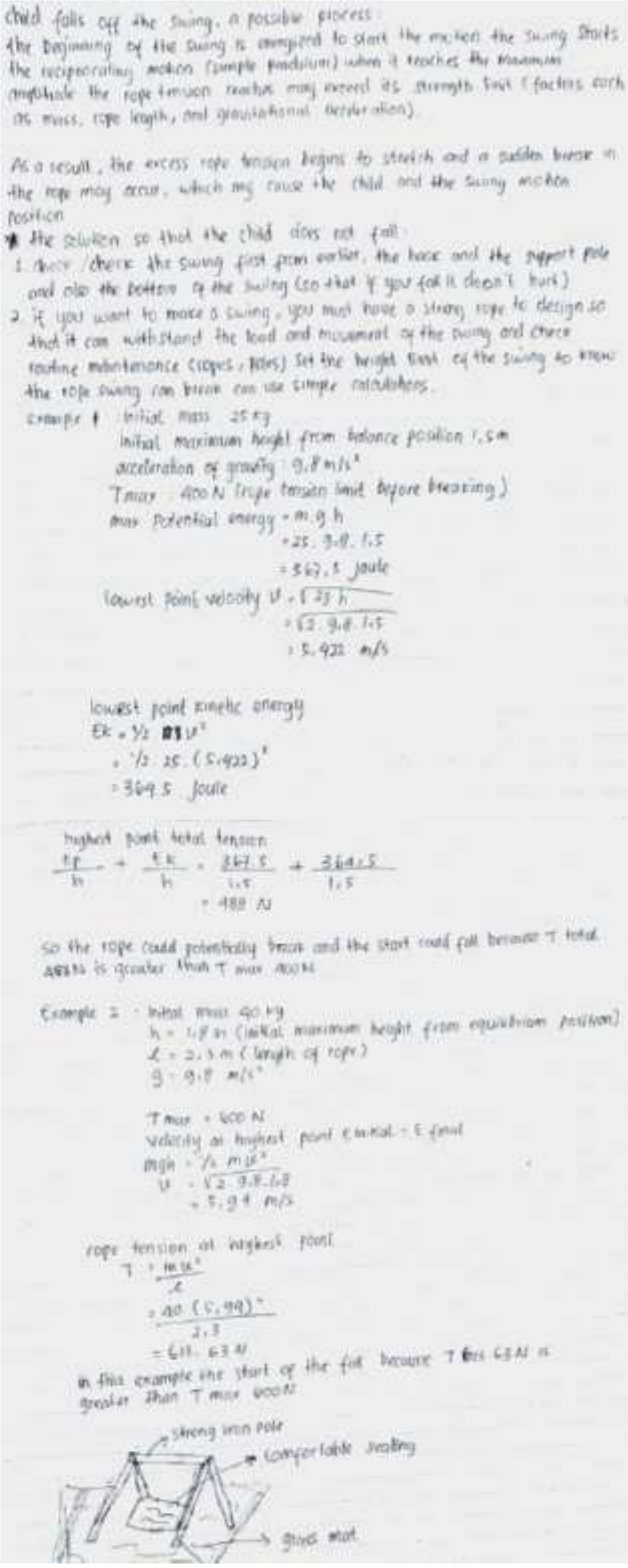

Figure 4. Examples of answers from pre-service science teachers

The strategy used by the pre-service science teacher in solving STEM-based problems is finding concepts and applying concepts to solve problems. She applies the principle of a simple pendulum and the law of mechanical energy regarding rotational motion and analyzes and evaluates problem-solving with the help of technology, such as calculating tools. The calculator will take precise measurements, design a solution by designing a swing that does not break easily, and calculate the tension in the rope to find out the cause of the swing breaking. The pre-service science teacher is quite creative and has a different strategy from other pre-service science teachers, namely looking for solutions so that children don't fall. Here, more explanation is needed about the types of strong ropes. She is quite skilled in choosing and using strategies, namely using the concept of vibration, not just frequency, period, and elasticity. She remembered to check the results obtained. So, the pre-service science teacher has reflected on his thinking by considering his gains and how to improve them. Because the pre-service science teacher's alternative solution was quite creative, a special interview was conducted with him about how he found this strategy and used it. Following are the results of the interview.

The answer given by the pre-service science teacher is an example of an answer with a quite creative level. This is because the pre-service science teacher has solved the problem with more than one solution but needs help to develop another way to solve it, and one solution meets the aspect of originality. Some solutions fulfill the flexibility aspect but require more originality and elaboration. This shows that a highly skilled pre-service science teacher at the preparation stage has identified the problem being asked well so that she will select the information that is needed and the information that is not needed in solving the problem correctly (Aydın et al., 2014).

Table 8. Interview Results

Researcher	:	Have you ever heard of questions like this?
Pre-Service Science Teacher	:	This is the first I have heard of questions like this, but they differ in the form of the questions.
Researcher	:	What strategy did you choose to get the answer to the question?
Pre-Service Science Teacher	:	How to do it by using the principle of a simple pendulum and rotational motion that I have learned before.
Researcher	:	How do you get the tension in the rope so the swing does not break?
Pre-Service Science Teacher	:	How to use the ratio of the tension in the rope between the tension in the rope before

		breaking and the total tension in the rope at the highest point.
Researcher	:	What tools do you use to calculate the tension in the rope?
Pre-Service Science Teacher	:	Yes, for calculations, use a calculator tool to produce the correct size.
Researcher	:	What do you think is the right design to do based on that question?
Pre-Service Science Teacher	:	The design uses a strong iron pole, then a strong rope is attached to it, the seat is made strong, and under the swing is given a carpet or grass mat; if a child falls, it avoids injury.

Conclusion

STEM Problem Solving has been shown to significantly increase the creativity of pre-service science teachers. The average increase in pre-service science teachers is in the medium category. This is shown by the majority of pre-service science teachers whose initial creative qualities are at the quite creative level. However, after participating in STEM Problem-Solving learning, the quality of creativity is at a creative level. Based on the results of the analysis, factors that influence the creativity of pre-service science teachers include accuracy in solving test questions and students' tendency to rely on memorization, imitation, and motivation. This can be facilitated by STEM Problem-Solving learning.

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Conflicts of Interest
The authors declare that there is no conflict of interest regarding the publication of this paper.

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