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STEM-PBL-Local Culture: Can It Improve Prospective Teachers' Problem-solving and Creative Thinking Skills?

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Abstract: This study aims to analyze the effect of applying problem-based learning with a STEM approach integrated with local culture (STEM-PBL-local culture) on improving creative thinking and problem-solving skills and determine the relationship between creative thinking and problem-solving skills. This research is an experimental study with a pretest-posttest non-equivalent control group design. A total of 72 prospective teachers who attended introductory chemistry courses at teacher education institutions were selected by purposive sampling. The test instrument is validated open-ended questions. Data analysis used an independent t-test. Pearson's product-moment correlation test is used to determine the relationship between problem-solving and creative thinking skills. The results show significant differences between the experimental and control groups. Students in the experimental group who received STEM-PBL-local culture experienced an improvement in creative thinking and problem-solving skills in the medium category, while the control group experienced an improvement in the low category. The Pearson product moment correlation test show that the correlation coefficient is 0.657* and the -value in the Sig (2 tailed) column is 0.000<0.052 . This means that there is a significant correlation with a high correlation level of 65.7% of students' creative thinking abilities contributing to their problem-solving abilities.

Keywords: creative thinking skills; local culture; problem solving; STEM; STEM-PBL

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INTRODUCTION

Everyone, including prospective teachers, must possess 21st-century skills. These skills include critical thinking skills, creative thinking, problem-solving, collaborative learning, student-centered teaching, and using technology (Kennedy, et al., 2016). Prospective chemistry teachers, for example, must have faced chemistry teaching that provides realistic problems that challenge and motivate them to be involved in the problem-solving process (Ulger, 2018). The provision of these problem-solving skills will support their future tasks (Dogru, 2008). These skills are related to the effectiveness of learning by teachers and will impact the students' problem-solving skills (Mauke & Sadia, 2013).

Problem-solving skills must be trained in learning (Mukhopadhyay, 2013). The training is intended to prepare students to solve various problems, such as structured, unstructured, complex, and various problems (Dixon & Brown, 2012). Students must have the skills to identify and understand patterns between problems and choose the best way to solve them (Bachtiyar & Can, 2016). Teachers with good problem-solving skills can manage the learning process and improve students' achievement (Adeyemo, et al., 2013). Teaching that does not equip problem-solving skills will not improve these skills to students. As a result, students will not have sufficient skills to solve complex problems in their daily life (Ulger, 2018).

This condition is indispensable. However, unfortunately, teaching at the higher education level is not optimal in improving problem-solving skills (Nuswowati, et al., 2017) (Nurita, et al., 2017). Studies related to students' problem-solving skills show that they are still in the low category due to the lack of knowledge, motivation, and emotional aspects (Dostal, 2015). The learning model used also does not require students to be problem solvers (Davis, et al., 2019).

As a cognitive skill to solve problems related to real life, of course, problem-solving requires new, creative, systematic, and analytical ways (Bachtiyar & Can, 2016). Experience, knowledge, and intuition applied simultaneously to a problem result from creative thinking that can be used quickly and effectively. According to Polya, as quoted by (Selcuk, et al., 2008), problem-solving consists of four steps: (1) Understanding the problem. Students will not solve the problem correctly if they do not understand it, (2) Planning a solution. This step is very dependent on students' experience in problem-solving. The more experience they have, the more creative they will be in planning the solution, (3) Solving the problem. This step is the suitability of the planning step, and the problem-solving is carried out based on the plan, (4) Reviewing. This step is carried out by re-evaluating what has been done from steps 1 to 3.

Problem-solving skills relate to critical thinking, creative thinking, analytical thinking, and creating productively. These skills involve quantitative skills, communication skills, and critical response skills (Chang, 2010). Referring to what was stated by Polya, one of the skills needed to solve problems properly is creative thinking skills (Heong, et al., 2011). Thinking differently is essential because it determines direction when faced with multiple options (Fields & Bisschoff, 2014). Creative thinking includes synthesizing ideas, generating new ideas, and determining the effectiveness of existing ideas.

Creative thinking is a mental process for using various strategies to solve problems, analyze various points of view, adapt ideas, create new solutions, and evaluate ideas in problem-solving (DeHaan, 2009) (Kaufman & Sternberg, 2007). This skill can train students to develop ideas and arguments to be open and responsive to different perspectives (Anwar, et al. 2012). Creativity plays a crucial role in invention, innovation and problem solving that improves the quality of human life (Fields & Bisschoff, 2014). For example, creative thinking skills in chemistry lessons can open new perspectives for students to answer problems (Hadzigeorgiou, et al., 2012) (Turkmen, 2016).

Like problem-solving skills, creative thinking skills will develop well if the teacher intentionally encourages students' thinking potential and manages it in a planned manner with good lesson planning (Anwar, et al., 2012). Learning activities foster students' creativity in solving problems if students are trained to develop original ideas to decide problem-solving in certain situations (Wardani, et al., 2017) (Diki, 2013) (Kutlu, 2015).

One learning model that trains students to be creative and become problem solvers is problem-based learning (Wartono, et al., 2018). In this study, the problem-based learning model was implemented in an integrated manner with a STEM approach and local culture, after this referred to as problem-based learning with STEM approach integrated with local culture (STEM-PBL-local culture) (Sumarni, W.; Kadarwati, S., 2020) (Ariyatun, 2021) (Saefullah, et al., 2021) (Sukmawijaya, et al., 2019). With this STEM-PBL-local culture, students' creativity and problem-solving skills can be improved. Through scientific process skills, teachers can ask students to do independent research or engage in divergent thinking training. Students are encouraged to make scientific observations, classify, ask scientific research questions, form hypotheses, plan scientific tests and measurements, utilize instruments, and draw conclusions from empirical data (Cheng, 2011). Research by (Ardianti, et al., 2019) finds that local culture-based learning can make it easier for students to understand concepts because they find examples in the environment. Students' analytical skills improved after learning, indicating that the concepts taught enter students' cognitive structure so that the information obtained will last longer.

STEM-PBL-local culture connects science, technology, engineering, and mathematics with local culture as an innovative form of science learning. The integration of culture in various professions will determine the meaning of professional services, including educational services (Nieto & Booth, 2010). Learning integrated with the local culture can be felt directly and is often encountered, thus providing meaningful learning for students (Darling-Hammond, et al., 2020). In addition, this contextual learning helps students understand the material. STEM teaching that integrates local culture that connects scientific concepts with indigenous knowledge of society, technology, engineering, and mathematics is proven to improve the skills of problem-solving (Margot & Kettler, 2019), creative thinking (Khoiri, 2019), critical and creative (Sumarni, W.; Kadarwati, S., 2020) (Piirto, 2011) (Sener, et al., 2015) (Kutlu & Gökdere, 2015).

Referring to the background presented, to provide debriefing and train problem-solving skills and creative thinking skills for prospective teachers, STEM-PBL-local culture is applied, and the relationship between creative thinking and problem-solving skills is studied. This study aims to analyze the effect of applying STEM-PBL-local culture on increasing creative thinking and problem-solving skills and determine the relationship between creative thinking and problem-solving skills.

METHODS

This research is an experimental study with a pretest-posttest non-equivalent control group design. Measurement of research variables was done by measuring N-Gain, conducting independent tests, and looking for patterns of relationship between problem-solving and creative thinking skills.

Population and Sample

The population in this study were first-year students in the introductory chemistry course at a teacher education institution. The sample was not determined randomly because it was not possible to change the established class structure, but two classes with the same level of ability were selected based on data from the lecturer's assessment. The research sample was 72 prospective teachers divided into 36 students in the experimental group and 36 students in the control group. The experimental group was given STEM-PBL-local culture learning, while the control group was given problem-based learning.

Research Procedure

The research procedure begins with preparation, including research instruments and learning tools. In the first stage, the procedure includes coordination with the team, the licensing process, and the selection of research samples. In the second stage, local culture was selected, integrated into learning, material analysis, and topic determination based on the literature study results. The local culture was also integrated to prepare several documents: semester lesson plans, teaching materials, student activity sheets, and assessment instruments, including examination content outline, problem-solving and creative thinking test questions, answer keys and discussion, and expert validation sheets.

The next stage is the validation process of semester learning plans, teaching materials, activity sheets, and assessment instruments to experts related to construction and content. The test instrument for measuring problem-solving and creative thinking skills is semi-open-ended essay questions. Each aspect is measured by 5 item questions validated in the content and construction by the expert. A limited trial was conducted after the expert declared the instrument valid.

After that, a limited trial was conducted to get responses from potential users. Validity tests are also conducted simultaneously on items, difficulty level, item discrimination, and reliability. From the results, the reliability of the problem-solving test was 0.81, and the reliability of the creative thinking test was 0.75. In this study, the measurement of problem-solving skills refers to Polya's Steps (Polya, 1985), which consists of understanding the problem, planning, solving problems, and evaluating problem-solving solutions (Kourmousi, et al., 2016) (Istiyono, et al., 2019) (Selcuk, et al., 2008). The measurement of creative thinking skills refers to Torrance's creative thinking dimensions: fluency, flexibility, elaboration, and originality (Fields & Bisschoff, 2014).

In practice, using learning tools declared valid by experts, a pretest is carried out first. The learning process was carried out for eight meetings. At the end of each learning topic, an assessment (posttest) of problem-solving and creative thinking skills was carried out. The processing time for one question number was 10 minutes. This test is assessed separately between problem-solving and creative thinking skills. The score calculation includes the total problem-solving/creativity score and each problem-solving/creativity indicator. A t-test was conducted on an independent sample to test the hypothesis after confirming that the scores were normally distributed to determine whether there was a significant difference in scores of creative thinking skills and problem-solving skills. Levene's Test for Equality of Variances was used to test the homogeneity of the data. The Kolmogorov-Smirnov test was conducted to test the normality of students' problem-solving and creative thinking skills scores. The significance level was accepted as $p<0.05$.

Data Analysis

The results of the study were in the form of pretest and posttest scores and data analysis in quantitative form in the form of percentage N-gain (Hake, 1998) to assess the improvement of problem-solving and creative thinking skills. The overall N-gain (%) obtained is categorized as in Table 1.

Table 1. Criteria of The Improvement of Students' Critical and Creative Thinking Skills

Percentage (%)	Criteria
$70 < \% \leq 100$	High
$29 < \% \leq 70$	Moderate
$\% \leq 29$	Low

Pearson's product-moment correlation test was used to determine the relationship between problem-solving and creative thinking skills with the help of SPSS. Table 2 is the classification of Pearson's r correlation coefficient values.

Table 2. Classification of Pearson's r Correlation Coefficient Values

Coefficient Interval	Correlation Level
0,80 – 1,000	Very High
0,60 – 0,799	High
0,40 – 0,599	Moderate
0,20 – 0,299	Low
0,00 – 0,199	Very Low

RESULT AND DISCUSSION

STEM-PBL-local culture learning was carried out synchronously using the Zoom Cloud Meeting platform and asynchronously using Elena, WhatsApp Group, and email. The applied STEM-PBL-local culture discusses three topics, including the concepts of colloids, redox and solubility, and solubility results. The experimental group's creative thinking skills data was measured after implementing STEM-PBL-local culture, while the control group after implementing PBL. The calculation results of the average problem-solving skill score for the experimental and control groups are presented in Figure 1, while the average score for creative thinking skills after implementing STEM-PBL-local culture is presented in Figure 2.

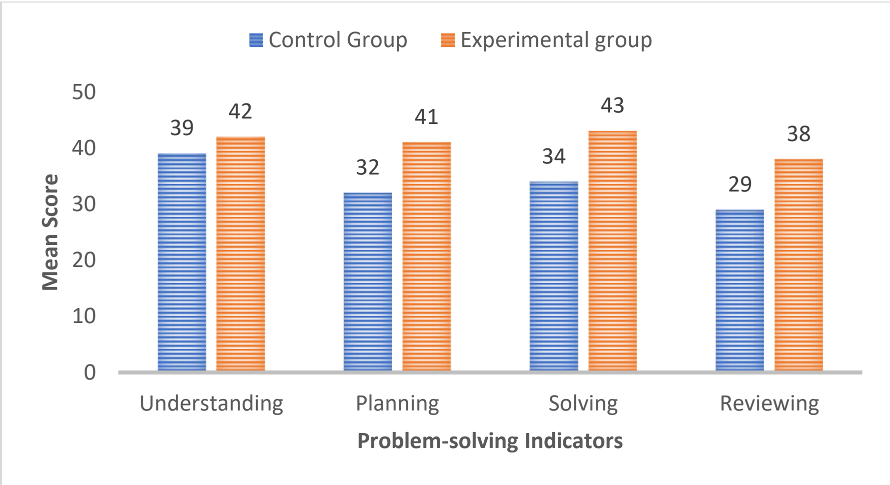

Figure 1. The average problem-solving skill score for the experimental and control groups

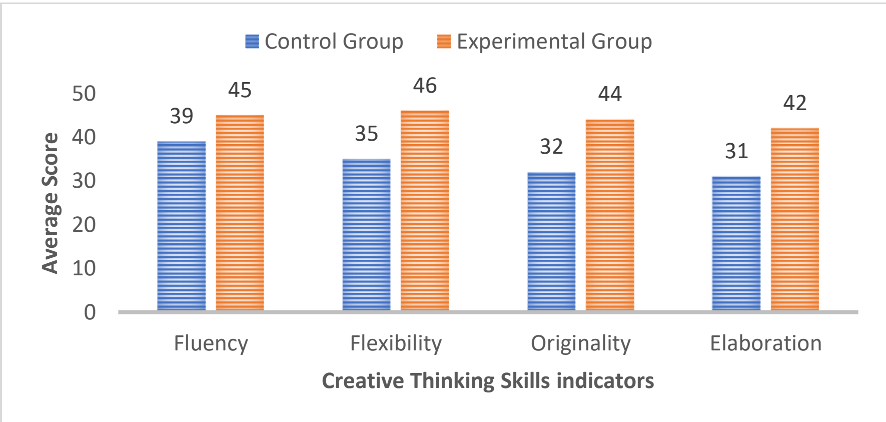

Figure 2. The average creative thinking score for the experimental and control groups after implementing STEM-PBL-local culture

From Figure 1 and Figure 2, the results obtained by the experimental group on all indicators of problem-solving and creative thinking are higher than the control group. The N-gain score is calculated from the data obtained to know the difference. The results are presented in Table 3.

Table 3. Creative Thinking and Problem-solving Skills in Experimental and Control Groups

Variable	Subject	Average Pretest	Average Posttest	Average N-Gain	Achievement Level
Creative Thinking	Experimental Group	56,17	73,32	0.54	Moderate
	Control Group	34,22	63,14	0.24	Low
Problem-solving	Experimental Group	46,40	72,62	0.51	Moderate
	Control Group	30,45	62,26	0.23	Low

In Table 3, prospective teachers' improvement of problem-solving and creative thinking skills in the experimental group after applying STEM-PBL-local culture is in the medium category, while the control group is in a low category. This result is also supported by independent t-test results for the two groups, which show differences in creative thinking and problem-solving skills with a significance level of 5% (Table 4).

Table 4. Independent t-test Results of Creative Thinking Skills in Experimental and Control Groups

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	Df	Sig.(2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Creative Thinking Skills	Equal variances assumed	36.898	.000	27.025	58	.000	27.40000	1.01389	25.37048	29.42952
	Equal variances not assumed			27.025	31.778	.000	27.40000	1.01389	25.33421	29.46579

Table 3 presents the results of the independent t-test of creative thinking skills for the two groups. The homogeneity test of creative thinking data based on Levene's Test for Equality of Variances is 0.342 or > 0.05, so all data are homogeneous. The significance value of Shapiro-Wilk is > 0.05, so all data are also normally distributed. Based on the sig (2-tailed) value of 0.00 < 0.05, it was concluded that there was a difference in the improvement of creative thinking skills between the experimental group and the control class.

Similar to creative thinking skills, the results of the homogeneity test of problem-solving skills based on Levene's Test for Equality of Variances obtained a significance of 0.171 (> 0.05), meaning that all data were homogeneous. The results of the Shapiro-Wilk significance test obtained results > 0.05, so all data were normally distributed. Thus, the t-test was carried out, and the sig (2-tailed) result was 0.00 < 0.05, which means a difference between the experimental and control groups.

The hypothesis test results of the two variables above show a significant difference in the improvement of problem-solving and creative thinking skills. The correlation test results for problem-solving and creative thinking skills are presented in Table 5.

Table 5. Correlation Test for Problem-solving and Creative Thinking Skills

Parameter	Creative Thinking	Problem-solving	Levene's Test	Pearson's Correlation Test	Sig (2-tailed)	Description
N	36	36	0,219 (homogeneous)	0,657** (High)	0.000	There is a significant relationship with a high level of correlation.
Mean	0,54	0,52				
SD	0,049	0,060				
Kolmogorov-Smirnov Z	0,849	1,059				
Asymp Sig (2 tailed)	0,467	0,212				
Decision	Normal	Normal				

In Table 5, Pearson's product-moment correlation test results show that the correlation coefficient is 0.657*, and the -value in the Sig (2 tailed) column is 0.000 <0.052. These results show a significant correlation in moderate levels between creative thinking and problem-solving improvement. The correlation between creative thinking and problem-solving is 0.657, indicating that 65.7% of students' creative thinking skills contribute to their problem-solving skills. From the positive correlation of the statistical test results, the high value of problem-solving skills is followed by the high value of creative thinking skills. The meaning of the sign "*" is that if the creative thinking skills are high, it will result in high problem-solving skills or vice versa. This result can be illustrated in Figure 3.

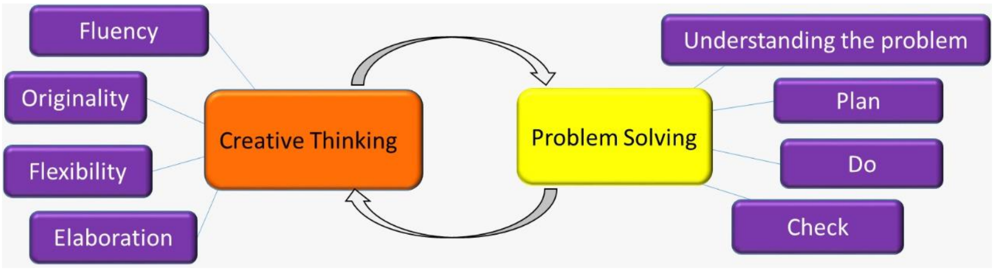

Figure 3. Correlation of Problem-solving and Creative Thinking Skills

In problem-based learning, the problems solved must be closely related to everyday life (Jonassen, 2011). Referring to this statement, the learning carried out is problem-based learning with a STEM approach that integrates local culture (STEM-PBL-local culture). It begins by presenting problems related to the limestone burning culture in Karangdawa Village, Margasari District, Tegal Regency, and making clay bricks in the Penggaron, Semarang City, Central Java. Students watch and observe the local cultures in groups to be reconstructed into scientific knowledge. Problems in each local culture are also solved during class learning. The process of observation and reconstruction consistently links science, technology, engineering, and mathematics. Examples are presented in Table 6.

Table 6. The Integration of Limestone Burning Culture in Chemical Equilibrium Learning with STEM Approach

STEM components	
Science	Limestone combustion chemical reaction: $CaCO_{3(s)} \leftrightharpoons CaO_{(s)} + CO_{2(g)}$ Homogeneous and heterogeneous equilibrium Factors that affect the direction of the shift in equilibrium
Technology	Technology in limestone mining and kiln ICT to find learning resources
Engineering	Design an experiment to determine the factors that affect the shift in equilibrium Creative ideas to get as many products as possible Creative ideas to minimize environmental damage due to limestone quarrying
Mathematics	Calculate the value of the equilibrium constant Calculate the volume of CO2 gas (g). Determine the relationship between Kp and Kc Process experimental data Represent experimental data in tables or graphs

Table 6 refers to the knowledge of the community regarding the local culture of the limestone burning process in Karangdawa associated with the concept of chemical equilibrium. Students then reconstructed and studied the local culture's science, technology, engineering, and mathematics from the limestone burning industry observations. The learning was done by presenting problems that must be solved through literature studies, question and answer, group discussions, and investigations to find solutions. This series of activities is proven to facilitate creative thinking processes in problem-solving.

The improvement of problem-solving and creative thinking in the experimental class that applies STEM-PBL-local culture is possible because the designed learning activities facilitate developing these two thinking skills. The improvement in scores in the experimental group, which is higher than the control group, shows that STEM-PBL-local culture can train students to think creatively in solving real problems. Likewise, the existence of a local culture that has been neglected so far will make learning more meaningful if integrated into learning. Table 7 presents the integration of brick-making culture in Penggaron.

Table 7. The Integration of Brick-making Culture

STEM components	
Science	Clay contains Kaolinite ($Al_2Si_2O_5(OH)_4$). The particle size of clay < 0.002 mm Sand, rice husk, husk ash, sawdust
Technology	Ethnotechnology of printing, drying, burning Quality test of bricks Determine the heat of combustion Burning temperature measurement ICT for literature study
Engineering	Creative idea of producing super quality bricks Creative ideas to produce highly-persistent bricks against shrinkage and cracking
Mathematics	Calculate the composition of raw materials Calculate compressive strength Calculate the heat of combustion

The integration of local culture in the learning process is proven to facilitate students in improving their creative thinking and problem-solving skills. Presentation of real problems succeeded in generating motivation and interest in students to take a role in the problem-solving process and construct their knowledge (DeHaan, 2009) (Han, et al., 2016). STEM-PB learning integrated with local culture makes it easier for students to explore facts and phenomena in society related to the concepts they are learning (Ariyatun, 2021) (Sumarni, W., 2018).

At the same time as the problem-solving process, investigating and finding problem-solving solutions encourages creative thinking (Wartono, et al., 2018) (Bachtiyar & Can, 2016). Creative students must process information, create, discover, explore and imagine, present, apply, and transform scientific knowledge. Students are encouraged to develop a variety of scientific observations, perform classifications, ask scientific research questions, develop hypotheses, plan trials and measurement methods, use tools, and conclude empirical data (Rubenstein, et al., 2019) (Cheng, 2011).

The success of implementing STEM-PBL-local culture cannot be separated from the integration of local culture, which is proven to train and improve creative thinking (Khoiri, 2019) (Sener, et al., 2015) and problem-solving skills (Supriyadi, et al., 2016) (Widyawati, et al., 2021). The stages of problem-based learning also determine the success of this research. With STEM-PBL-local culture, every student can develop their creative thinking skills in solving problems. This activity also equips students to collaborate and communicate to solve real problems (Rush, 2016) (Hsia, et al., 2021). STEM-PBL-local culture is proven to be an innovative learning model to improve problem-solving skills requiring collaboration, peer communication, and independent learning (Capraro, et al., 2013).

Based on the findings of this study, creative thinking has a high correlation with problem-solving. This statement is in line with the findings of (Barutcu, 2017), which show that individuals with high creative thinking skills can solve non-routine problems and choose alternative problem-solving according to their knowledge (Boldt, 2019). Individuals should be encouraged to think creatively. Success in developing creativity largely depends on the applied learning system (Anwar, et al., 2012). Students must adopt change and innovation, solve problems using questionable creative thinking, and expose creative action as a professional trait (Şen, et al., 2013).

As we know, humans constantly face problems, so that a creative thinking process is needed to solve these problems (DeHaan, 2009) (Barutcu, 2017). Therefore, students need to understand how to solve a problem, be skilled in choosing the relevant concepts needed, and think flexibly in preparing a settlement plan. Creative thinking and problem-solving skills are complex cognitive skills. Thus, the results of this study can theoretically contribute to the existing literature and explain the nature of these two skills.

Nonetheless, a positive relationship between creative thinking and problem-solving skills is revealed here. The results of this study may not be generalizable to other populations because the relationship between the selected variables and scores of students' creative thinking and problem-solving skills investigated in this study is based on a correlational research model. Since this is a correlational study, only the relationship between the selected variables is examined, and the causal relationship is not investigated.

CONCLUSION

Based on the results of research and discussion, it can be concluded that problem-based learning with a STEM approach integrated with local culture (STEM-PBL-local culture) is effective to improve the creative thinking and problem-solving skills of prospective teachers with N-gain in the medium category. From the study results, it is also known that there is a significant positive relationship between scores of creative thinking and problem-solving skills with a correlation of 0.657. Based on the literature and the results of this study, creative thinking skills and problem-solving skills are mutually reinforcing, mutually nurturing, and interrelated in cognitive development. These results indicate an inseparable relationship internally between creativity and problem-solving. The active involvement of students in the problem-solving process helps them be curious about scientific concepts, encourages them to investigate the cause and effect of their observations, and facilitates the development of their creativity. Conversely, creative activities can also improve problem-solving skills.

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