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Problem-Solving Skills for Middle School Students Through the STEM-Based PBL Model

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ABSTRACT

The ability of students in problem-solving skills is unevenly distributed at all levels of education. This descriptive research with a quantitative approach aims to empower junior high school students' problem-solving abilities through STEM-based PBL learning, determine gender-based problem-solving skills and describe the level of problem-solving skills based on problem-solving indicators. The research was conducted at SMP Negeri 4 Palu Class VII with a total population of 12 classes. The sample was determined randomly, and 2 classes were selected, each as the experimental and the control classes. The experimental class applies STEM-based PBL learning, and the control class uses conventional learning using discussion, question and answer and lecture methods. The research design is the Posttest Only Control Design. Data on problem-solving skills were obtained through test essays circulated after learning. The collected data were analyzed non-parametrically using the Mann-Whitney U test with the help of SPSS version 25.0. The study results show that learning by applying STEM-based PBL can empower problem-solving skills in junior high school students compared to conventional learning. The solving skills of female students were significantly better than those of male students, and the problem-solving skills of junior high school students were relatively good.

Introduction

Competition in various aspects of life in the 21st century requires the younger generation to be ready to face it with various life skills and skills. The ability to solve problems is one of the higher-order thinking skills that are needed in dealing with the complex dynamics of the future life because these skills not only have an impact on cognitive abilities but have been shown to be a protective factor for poverty and other life challenges[1]. This is closely related to problem-solving, requiring critical, analytical, and dynamic thinking, evaluative, and skilled interpretation. All of these components are used for competent problem solvers at various difficulties encountered[2]. Therefore, students who can solve problems will become more independent students, become reliable and talented human resources, and be skilled in the future[3] because they can think critically and be broad-minded, which has the potential to offer many unique solutions are needed in the digital-based world of work in the global industrial era[4].

Students who are skilled at solving problems show different characters from other students because they can understand challenges, generate lots of ideas, prepare for action, plan their approaches[5], and can work together to create their problem-solving strategies[6]. In addition, they also show a willingness to solve problems, the ability to understand and define problems, are skilled at identifying the position of problems, can describe the content of problems, are skilled at managing problem-solving processes, are skilled at choosing the right strategy for solving problems and can use prior knowledge to construct solutions for problem-solving[7]. These skills can be instilled in each student through various strategies in learning as some of the research results reported include problem-solving skills can be trained in students gradually and intensively by getting students used to generating creative ideas through the process of exploring knowledge, defining problems, and comparing various ideas to identify the most creative ideas, originality of ideas and completeness of ideas[8] applying the IDEAL concept through the identify, define, examine, act and look steps[9], apply an open approach[6] and apply to learn environment-based play methods[10]. In addition, carrying out intensive training through giving assignments or activities that involve students in thinking about solving problems from the important concepts they learn has been proven to significantly increase student understanding and performance, as well as good attitudes towards subjects[11].

The various strategies, methods, and approaches that have been applied in learning have not produced problem-solving skills evenly among all students in many countries as the results of research that report, among others, are that the problem-solving skills of prospective elementary school teachers in the North Philippines is still relatively low and not satisfactory[12] and students majoring in Physics at Piler Mandal, Chittoor district, Andhra Pradesh, India are less able to understand the problem so that it becomes a major obstacle in problem-solving skills in physics[13]. In Indonesia, students' skills in problem-solving vary, namely problem-solving skills are dominated by the low category found in class VIII B students of SMP Negeri 1 Indralaya Utara[14], students of SMP Negeri 6 Tulungagung in class VIIG have problem-solving skills classified as less able to quite capable[15], students of SMPN 1 Meulaboh have moderate to very low problem-solving skills in learning using visual and nonvisual media[16], and problem-solving skills of students of SMPN 1 Lemahabang are classified as low triangular and quadrilateral material[17]. Low problem-solving skills were also found in junior high school students in Palu City, Central Sulawesi Province, Indonesia, especially in science subjects.

Low problem-solving skills should no longer be found in Indonesia because the learning system in Indonesia implements the 2013 curriculum, which adheres to a scientific approach with a student-centered learning orientation[18]. The scientific approach has been proven successful in increasing students' problem-solving skills[19-22]. However, low problem-solving skills cannot be avoided because many research results report on influencing factors, including students not reading the questions carefully, students not being able to say what is known completely, and not identifying what they know precisely, causing misinterpretation[23], students find it difficult to understand the keywords in the problem, do not know the assumptions and information needed to solve the problem, tend to guess answers without thinking because they do not understand the essence of the problem, are impatient and do not like to read questions that complex, and do not like to read long questions[24]. In addition, carelessness or inaccuracy, errors in transforming information, process skill errors, and misunderstanding questions also affect problem-solving skills[25].

Problem-solving skills as part of higher-order thinking can be improved through innovative learning processes that prioritize content designs that are easy to understand and appropriate to students' knowledge levels and link science content to their daily lives[26]. Problem-solving skills require a learning process that can challenge students' thinking so that students actively think hard using their understanding through questions or problems that can broaden students thinking[27]. In addition, it requires a learning environment that supports creative thinking for problem-solving[28] and intensive training by implementing learning that can expose students to working in groups to trigger their potential to unleash their representational power[29]. One of the innovative learning that can meet the need to practice problem-solving skills is the problem-based learning model because this learning model supports and enhances learning, achievement, and problem-solving skills and encourages students to learn through participation and exchange of ideas with other members in the group so that it is based on efficiency. And its potential application to real-life situations, the model is considered suitable by experts[30].

Problem-based learning, abbreviated as PBL, is a learning model that can trigger students to learn while being actively involved through practice and reflection, and its benefits are effective in increasing learning outcomes. The efficacy of all phases of PBL is excellent for long-term knowledge retention and influences outcomes[31]. Student learning, although it cannot be concluded which PBL component has the most significant influence on student learning. In addition, PBL can to improve oral and written communication skills[32], can improve learning achievement and problem-solving skills[33]. However, it has not improved the learning motivation of students at Wachemo Preparatory School[34]. However, integrating technology into the PBL learning model is important because the presence of technology has the opportunity to make it easy for students to explore many things related to the problems and solutions being studied so that they have the potential to create more meaningful learning[35-37]. Learning like this can be built with a STEM approach combining science, Technology, Engineering, and Mathematics. STEM is a multidisciplinary teaching approach that is delivered in an integrated manner[38]. The STEM approach conditions student-centered learning so that it has the opportunity to create active, interactive learning to improve students' skills in terms of understanding concepts, problem-solving abilities, scientific literacy abilities[39], creative thinking and critical thinking[40,41].

The effectiveness of the STEM approach and the PBL model in learning has been widely proven, but integrating PBL with the STEM approach is important. This kind of research, especially to improve problem-solving skills, has never been done at SMP Negeri 4 Palu. This kind of research needs to be applied because it can provide information on how to improve students' problem-solving skills on real problems using technology and engineering in an integrated manner in learning science, especially Biology materials. In addition, the findings obtained can be used as a basis for development research in Biology learning. Teachers can also use the results in designing learning for other Biology materials. Therefore this research aims to empower junior high school students' problem-solving abilities through STEM-based PBL learning, determine junior high school students' problem-solving skills based on gender, and describe junior high school students'nproblem-solving skills based on problem-solving indicators.

Method

This research is quasi-experimental, a descriptive research type with a quantitative approach. Descriptive research is used to describe the problem-solving skills achieved by students. The problem-solving indicators used to follow the IDEAL steps developed by [9]. The research design is the Posttest Only Control Design. This design is used to test behavior by changing a condition and observing its effect on other things [42]. The research design is shown in Table 1.

Table 1. The research design is a posttest-only control design

Group	Treatment	Post-test
Experiment	X_1	T1
Control	X_0	T2

Information:

X_1: treatment of STEM-based PBL models in the experimental class

X_0: conventional model treatment in the control class

T1: *pretest* in the experimental class

T2: *posttest* in the control class

This research was conducted at SMP Negeri 4 Palu on Class VII students. The research population was all students of Class VII spread across 12 classes and used two classes with a total of 60 students as a sample, namely one class for experiment and one class for control, and each class consisted of 30 students. The sample is determined in a completely random manner with the assumption that all members of the population have the same opportunity to be sampled.

The research was carried out by learning the Classification of Living Things material which was applied to the experimental class using the STEM-based PBL model and the control class using conventional methods that applied lecture, discussion and question and answer methods. Data on the effectiveness of the STEM-based PBL learning model on problem-solving skills were obtained by distributing tests. The test is given once, that is, after learning is applied, it is distributed to the experimental class and the control class. The test is given in the form of an essay test totaling five questions. To ensure the validity of the test, internal validity was carried out, including construct validity and content validity in terms of cognitive structure and design aspects[43]. The analysis results show that the five items on the problem-solving test instrument are included in the valid criteria.

Problem-solving skills data were analyzed statistically using SPPS version 25.0. To find out the difference between the post-test of the experimental class and the control class, an analysis of the Mann-Whitney U test was carried out because the data of the two groups being compared were not normally distributed. Problem-solving skills data based on indicators are grouped into four categories according to the criteria used, shown in Table 2.

Table 2. Problem-Solving Skills Categories[44]

Score Interval	*Category*
$3.33 < MA \leq 4.00$	Very good
$2.33 < MA \leq 3.33$	Good
$1.33 < MA \leq 2.33$	Good enough
$MA \geq 1.33$	Low

Results and Discussion

Research on STEM-based PBL has been analyzed quantitatively and grouped into the experimental class and the control class, and gender in the experimental class and the control class. Descriptive analysis was also carried out to explain the problem-solving skills achieved by students based on indicators of problem solving skills. The results that have been obtained are described below.

Effect of STEM-based PBL on Problem-Solving Skills

The results of the normality analysis of the experimental class and control class data, as well as the results of the Mann-Whitney U test on problem-solving skills in the experimental class and control class, are shown in Table 3.

Table 3. Results of Data Normality Analysis and Mann-Whitney U Test

Variable	Group	Normality Kolmogorov-Smirnov^b			Conclusion	Mann-Whitney U			Conclusion
		Statistic	Df	Sig.		Median	U	Sig.	
Class	Control	.178	30	.016	Abnormal	4	24.000	.000	Eks > Kontrol
	Eksperiment	.214	30	.001	Abnormal	8			

The results of the analysis using the Mann-Whitney U test, as presented in Table 3, show that the problem-solving skills in the experimental class were significantly higher (*Mdn* = 8) than the control class (*Mdn* = 4), $U = 24$, $p < 0.001$. The results obtained reflect that learning in the experimental class that applies the PBL model by presenting real problems is a good way to get students to think hard about things they encounter in everyday life. In this way, various things and situations familiar to them can be used as a reference to develop their knowledge to formulate solutions to the problems they face. This finding is supported by the results of research that PBL can increase by an average of 27% in problem-solving skills with a completion rate of 47% in class VII students of SMP Negeri 18 Malang[45]. In addition, implementing PBL is an effective way to arouse students to actively think and work to help build basic skills in various curricular domains or fields[46,47].

The STEM approach also influences the effectiveness of learning in the experimental class. Science problems faced by students are supported by available technological facilities that can be used as a tool to find solutions to problems. Under the guidance of the teacher, students carry out engineering by combining previous knowledge with new knowledge to assemble ideas that are used as solutions to problems. Thus students are guided to solve science problems using technology as a tool to engineer their knowledge to solve problems. This fact is in line with the results of research which reported that STEM could significantly improve the problem-solving skills of students in Class VII SMP in Bandung, especially on the indicators of generating ideas and finding facts because students can use their knowledge in an integrated manner to solve real-world problems[48]. In addition, the contribution of STEM learning to student learning outcomes significantly occurs in conceptual understanding, critical thinking skills, creative thinking, and problem-solving[49,50].

Science learning that applies the STEM-based PBL model has proven to be effective on students' skills in solving science problems in the experimental class. Real problems in everyday life, which are used as problems in learning, are solved by students cooperatively with colleagues using technology and knowledge engineering. This way of learning can arouse learning enthusiasm and really help students think actively to build bright ideas to find solutions to every problem. The findings in this study are in line with the results of research that reported that PBL could significantly improve the problem-solving skills of SMA Negeri 13 Medan students[51]. PBL combined with STEM provides a series of problem-solving activities in a real-world context combined with science, technology, engineering, art, and mathematics so that students will be assisted in carrying out more creative thinking processes to face every challenge and get an interesting, broad learning experience, and meaningful[52,53]. The results of other studies report that combining the STEM approach with innovative learning models can improve students' skills in solving physics problems with "very large" effect sizes[54], and can support versatile professional development in encouraging creative thinking for various problem solving using the necessary modern technology to tackle complex problems [55].

Problem-Solving Skills From a Gender Aspect

The results of the normality analysis of gender data in the experimental class and control class and the results of the Mann-Whitney U test regarding problem-solving skills in terms of gender aspects in the experimental class and control class are shown in Table 4.

Table 4. Results of Data Normality Analysis and Mann-Whitney U Test

Class	Group	Normality Kolmogorov-Smirnov[b]			Conclusion	Mann-Whitney U			Conclusion
		Statistic	df	Sig.		Median	*U*	Sig.	
Experiment	Man	.330	16	.000	Abnormal	7	63.500	.043	Female > Man
	Female	.207	14	.107	Normal	9			
		Statistic	df	Sig.		Median	*U*	Sig.	
Control	Man	.266	11	.028	Abnormal	4	73.500	.173	Man > Female
	Female	.192	19	.064	Normal	3			

The results of the analysis using the Mann-Whitney U test, as presented in Table 4, show that the problem-solving skills of female students in the experimental class were significantly higher (Mdn = 9) than male students (Mdn = 7), U = 63.5, p <0.043 while the problem-solving skills of male students in the control class were significantly higher (Mdn = 4) than female students (Mdn = 3), U = 73.5, p > 0.173. Female students have a patient nature which they show when learning with STEM-based PBL since they identify problems and seek solutions to implement solutions to the problems studied. In addition, female students showed better concentration in completing their assignments, so their performance was superior to male students. This finding is in line with the results of a study that reported that statistically significant female students outperformed male students at all levels of school because of their good performance[56], they have better attention, are more focused on goals, mature psychologically, emotional and have a better work ethic and can concentrate on longer working hours[57].

Learning by applying the STEM-based PBL model also influences the concentration of female students in solving problems. The teacher's ability to provide real problems to be solved with the STEM approach will trigger the attention of female students to concentrate on the project, accompanied by their thoroughness and seriousness in solving it. This finding is supported by research results which report that the potential of female students in the learning process is strongly influenced by the characteristics of the instructor and facilitation conditions which can have a significant impact on their achievement[57]. In addition, female students have higher intrinsic motivation[58], their scientific excellence in the fields of biology and chemistry, they show a good mindset in various creative ways in the STEM approach, they have more knowledge and strong solution ideas, and it has been proven that women show their ability in the STEM field to contribute to many areas of expertise after their schooling[59].

A different situation was found in the control class which applied lecture, discussion and question and answer methods and the teacher did not interfere with students with real problems starting with problem orientation to conducting analysis and evaluation. In this study it was found that the problem-solving skills of male students were higher than female students. This finding is supported by the attitudes shown by male students in learning, including having higher courage and self-confidence than women, as well as demonstrating greater resilience and activity. These traits cause them to be tough and never give up on problems, actively seek solutions and have the courage to try to implement solutions to the problems they face. This finding is supported by the results of research, which reported that male students have a significantly higher level of resilience than female students[60]. Male students more frequently use memory, metacognitive, and social strategies in each strategy. Their studies[61] and outperform their female counterparts when they are under high pressure[62]. Not only that, the explorer nature shown by male students makes it easier for them to be agile in searching for various information through cyberspace. This fact is consistent with the results of a study that reported that male junior high school students in Taipei, Taiwan preferred to find a lot of information through internet networks than female students[63].

Problem-Solving Skills Based on Indicators

Problem-solving skills data based on problem-solving indicators in the experimental class and control class are shown in Table 5.

Table 5. Data on Problem-Solving Skills Based on Indicators

Class	Ideal Aspect	Categories									
		Very Good		Good		Enough		Low		Total	
		amount	%	amount	%	amount	%	amount	%	amount	%
Experiment	Identify the problem	4	13.3	18	60	8	26.7	-	-	30	100
	Defining the main elements of the problem	4	13.3	19	63.3	7	23.3	-	-	30	99.9
	Examine possible solutions	3	10	17	56.7	10	33.3	-	-	30	100
	Act on resolving the problem	4	13.3	20	66.7	6	20	-	-	30	100
	Look for lessons to learn	3	10	15	50	12	40	-	-	30	100
Control	Identify the problem	1	3.3	9	30	13	43.3	7	23.3	30	99.9
	Defining the main elements of the problem	1	3.3	10	33.3	11	36.7	8	26.7	30	100
	Examine possible solutions			11	36.7	9	30	10	33.3	30	100
	Act on resolving the problem	1	3.3	11	36.7	13	43.3	5	16.7	30	100
	Look for lessons to learn	1	3.3	12	40	11	36.7	6	20	30	100

The analysis results of problem-solving skills based on indicators of problem solving skills in the experimental class, as presented in Table 4, are in the very good category to the good category, while the control class is in the very good category to the less category. Overall, the average value of the five indicators of problem solving skills achieved by students in the experimental class shows that the highest percentage is in a good category, with a range of 50% - 66.7%, followed by the moderate category, which reaches 20% - 40% and the very good category is in the range of 10%. - 13.3%. The highest percentage of the five indicators of problem solving skills achieved by students in the control class was in the good category in the range of 30% - 43.3%, followed by the good category in the range of 30% - 40%, the poor category reached the range of 16.7% - 33.3% and the good category once with a range of 3.3%. All indicators of problem solving skills in the experimental class achieved the highest percentage in the good category, while the control class was in a good category.

Each indicator of problem solving skills in the experimental class after learning using the STEM-based problem-based learning model shows a better value than the control class. Students who are taught with the STEM-based PBL model have been able to identify problems and identify goals properly complemented by the variety of solutions offered and strategic plans used for problem solving. There were 13% of students who did very well at mapping out problems, identifying goals and determining several strategies to be used and all of them were explained clearly and firmly. Most students have been able to identify the problem well, although there are some students who have not described the problem in detail. Likewise, setting goals and strategies offered for solving problems. In addition, there are still 20-40% of students who have identified problems and set goals well but have not written them clearly and firmly as expected. The same thing is also found in the alternative solutions offered and the strategic plans used for problem-solving. The findings in this study are in line with the results of the study, which reported that the problem-solving abilities of the research subjects were classified as good because most of the problem-solving indicators could be fulfilled properly, namely the subjects could identify problems but had not been able to write down essential information concisely, the subjects could define goals by writing down things that asked, can explore solutions by writing problem-solving plans and formulas used and subjects can carry out strategies to communicate conclusions but encounter obstacles to writing solutions in the mathematical language[64].

Conclusion

In this study, the problem-solving skills of junior high school students through the application of STEM-based PBL were studied. The results of the study show that learning by applying STEM-based PBL is able to empower junior high school students' problem-solving skills compared to conventional learning and the solving skills of female students are significantly better than male students. In addition, the problem-solving skills of junior high school students were relatively good, which was shown by the majority of students fulfilling all problem-solving indicators well Through the findings obtained in this study, it is recommended to implement STEM-based PBL in other schools. Training on the application of STEM-based PBL and the dissemination of its benefits need to be carried out, so that science teachers do not feel foreign to this combination of learning models. In addition, further research that examines the comparison of problem-solving skills between STEM-based PBL and other learning models also needs to be done. This research will be able to provide information about the advantages or disadvantages of STEM-based PBL when compared to other learning models. In addition, studies that examine the effect of STEM-based PBL on other thinking skills also need to be carried out so that teachers can find out the benefits that can be obtained through implementing STEM-based PBL in learning.

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