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Implementation of STEM-PBL Design Based Students E-Worksheet to Improve Problem Solving Skills

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Abstract: Problem solving skills is an ability that students have to learn in the 21st century. Problem solving skills can be improved through a combination of learning activities including media, models and learning approaches. This study aims to determine the enhancement of students' problem solving skills through the implementation of STEM-PBL based e-worksheet on energy and its change material in grade VIII middle school. This research type is pre-experimental with a one group pretest-postest design. The research sample consisted of one class VIII of SMPN 2 Badau totaling 25 students was determined by random sampling. Data collection using a problem solving skills test instrument with 4 essay questions. Data analysis using descriptive analysis of the data collected. Analysis of feasibility data obtained through validation questionnaire validated by three expert validators meanwhile data on the improvement of problem solving skills obtained through the pre-test and post-test results given to students before and after the implementation of STEM-PBL design based e-worksheets. The results of the validity of the STEM-PBL design e-worksheet from this study were obtained an average assessment score from the three expert validators of 96.9% with very valid criteria so that STEM-PBL design based e-worksheets can be applied to science learning. Problem solving skills indicators that experienced the highest to lowest increase due to the implementation of STEM-PBL design based e-worksheet were understand the problem by 0.83; plan the solution by 0.71; execute the solution by 0.63; and reflect on the problem solving solution by 0.37. The results showed an N-Gain of 0.56 with a medium category. Based on the results of the N-Gain percentage of 56.52%, it can be concluded that the implementation of STEM-PBL design based e-worksheet on energy and its change material is effective enough to increase students' problem solving skills.

Keywords: e-worksheet, problem based learning, problem solving skills, STEM-PBL.

▪ INTRODUCTION

The twenty-first century demands a variety of skills that learners must master to survive the challenges of life. Critical thinking and problem solving, communication, collaboration, and creativity are 21st century skills that students must master. 21st-century education placed a strong emphasis on students' ability to learn from a variety of sources, including books, the internet, print and visual media, and more. It also emphasized student ability to formulate problems, think critically, be creative, and collaborate with others to solve problems (Sholihah & Lastariwati, 2020).

Problem solving skills a is a strategic ability in the form of applying concepts and skills in understanding solution strategies until the problem is solved (Rosdianaa et al., 2019). Students gaining experience of using the knowledge and skills they already have to apply to solving non-routine problems (Sudarsono et al., 2022). Program for International Student Assessment (PISA) and Trends in International Mathematics and Science Study (TIMSS) indicated that in general the students problem solving skills in Indonesia are relatively low (Ionita & Simatupang, 2020). Learning process that only teach factual knowledge and without connecting learning topics to real-life problems or phenomena and do not conduct experiments to further investigations in the problem

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solving process is the cause of students' poor problem solving skills (Simanjuntak et al., 2021).

Problem solving skills can be increased through learning activities that integrates theory and real phenomena (Martaningsih et al., 2022). Problem solving skills in the learning activities can be improved through the support of the implementation of media, approaches and learning models (Komarudin et al., 2021). Media that can be used such as students worksheet. Student worksheet is a teaching material that contains structured activities during the learning process students task. The student tasks included in the worksheets can be in the form of sample questions or practice questions that are structured by paying attention to the stages of problem solving so that when students faced with an assessment test, students are already used to solve problems (Widodo et al., 2023). The presentation of students worksheet in the rapidly developing digital era can be done electronically, known as e-worksheet.

Learning models that supports problem solving activities is problem based learning (PBL) (Seyhan, 2016; Simanjuntak et al., 2021). As a student-centred pedagogical learning, PBL involves students in small groups to discuss specific challenge with the intent of finding a solution to the problem (Aidoo et al., 2016). PBL can be collaborated with the STEM which is a comprehensive approach where the learning process focuses on solving real-world problems (Suratno et al., 2020). STEM is student centered learning that has the capacity to increase and improve achievement (Usman et al., 2023). Teaching content with a STEM integrated approach will make students see the connection between context and real life (Kelley & Knowles, 2016).

STEM research trends in Indonesia are implemented in various topics dominated by learning strategies, learning media, and teaching materials. STEM integration with PBL learning models (STEM-PBL) is one of the most frequent research trends (Ilma et al., 2023). STEM-PBL learning is intended so that students can build knowledge independently to understand a concept in implementing and monitoring problem solving through learning that combines aspects of science, technology, engineering and mathematics in an activity (Triana et al., 2020). Students with STEM-PBL learning are more engaged in activities to find and explore knowledge to solve problems (Parno et al., 2020). Moreover, STEM-PBL can develop students collaborative skills and encourage independency while motivating students to become longlife learners (Rehmat & Hartley, 2020).

Previous research have shown that the application of STEM-PBL in learning more effective at improving student knowledge, skills and interest than traditional methods (Zeng & Ruannakarn, 2023). The development of STEM-PBL-based teaching materials resulted in teaching materials that were feasible to improve creative thinking skills with a score of 81.66% (Pangestu & Hidayah, 2024). Learning that gives students the opportunity to identify real problems through STEM-PBL applications can improve student' critical thinking skills (Wahdaniyah et al., 2023). The implementation of STEM-PBL assisted by worksheets has a positive effect on student' discipline, curiosity, communication, and cooperation skills (Shamdas et al., 2023; Yulianti et al., 2019). Real problems in STEM-PBL worksheets make it easier for students to process information and analyze problems (Usman et al., 2023). Students actively solve real problems in their environment through learning using STEM-PBL with the support of worksheets so that students can focus on solving problems (Rosiningtias et al., 2023). Meanwhile, research

conducted Dotimineli & Mawardi (2021) claimed that STEM-PBL based student worksheet is effectively used in the learning process. Currently, there has been no specific research to increase students' problem solving skills using STEM-PBL design based e-worksheet on energy and its change material. This fact provides an opportunity for the integration of STEM-PBL into worksheets to improve the teaching and learning process in the classroom and enhancing students' problem-solving skills.

Based on the various problem studies that have been described, the researchers are interested in conducting experimental research using STEM-PBL worksheets on the topic of energy and its changes. The implemented STEM-PBL design based e-worksheet is presented online so that it can be accessed anywhere and anytime by students. The material chosen is energy and its changes because there are so many real life problems related to this material. This study aims to determine the improvement of students' problem solving skills through the implementation of STEM-PBL design based e-worksheet on energy and its changes material.

▪ METHOD

Participants

This research was conducted at SMPN 2 Badau, Belitung Regency. The research time was conducted in the first semester of the 2024/2025 academic year in class VIII. All 100 students in grade VIII were the research population. The research sample was decided by random sampling. Students of grade VIII consisting of 4 classes were drawn, so that one class was obtained as an experimental class. The number of samples available is 25 students with 12 male and 13 female. External factors such as variation between groups in this study are minimised by appropriate research methods as well as valid and reliable research instruments.

Research Design and Procedures

This research used pre-experimental research with a one group pretest-postest design. This research was conducted in one experimental class consisting of 25 students for four meetings on energy and its changes material. At the first meeting, students were given pretest. In the second and third meetings, learning was carried out by giving treatment using STEM-PBL designed e-worksheet. STEM-PBL has 5 syntaxes. The first stage is orient the problem to students. The STEM aspects involved in this step are science, technology and mathematics. The second stage, organize students to study. The next step, group investigation. In these stage, the three STEM aspects such as science, technology and engineering were applied. The engineering aspect is the most prominent aspect among others. In the fourth stage, students develop and present work that involve the three aspects of science, technology, and engineering. The last step is to analyze and evaluate the problem-solving process involving all aspects of the STEM. In the last meeting, students are given a posttest to measure their problem solving skills after the treatment.

The research flow carried out by the researcher is as follows: (1) Interview with science teachers, (2) Monitoring learning activities to analyze student needs, (3) Development of STEM-PBL based e-worksheet, (4) Validation of STEM-PBL based e-worksheet by expert lecturers, (5) Pretest related to students' problem solving skills, (6) Implement learning activities using STEM-PBL design based e-worksheet, (7) Posttest related to students' problem solving skills after treatment, (8) Analysis of data acquired.

Instruments

The instruments used were interview guidelines, validation sheets, and student pre-test and post-test forms. Interviews conducted to science teachers in this research using unstructured interviews. The interview was conducted as an preliminary needs analysis and to find out the characteristics, learning models and the students' abilities. The validation sheet was used to obtain data on assessments, comments, and suggestions from expert validators on the worksheets. The students' pre-test and post-test questions consisted of 4 essay questions developed according to the problem solving skills indicators which are 1) understand the problem, 2) plan the solution, 3) execute the solution, and 4) reflect on the problem solving solution.

Table 1. Indicators of problem solving skills

No	Indicators	Explanation	Question Number
1	Understand the problem	able understanding what is known in the problem and understanding what is asked in the question given	1. 2. 3. 4
2	Plan the solution	able to define the formula/method for solving the given problem	1. 2. 3. 4
3	Execute the solution	able to carry out the formula/method for solving the given problem	1. 2. 3. 4
4	Reflect on the problem solving solution	able to reflect or recheck the answer they have given in solving solution to confirm the answer	1. 2. 3. 4

Validity and reliability tests of the problem solving skills instrument were done before the instrument was used in this study. The problem solving skills test instrument was tested on 30 students who had studied energy material. The validity test is used whether the instrument used is valid, that is, the instrument can be used to measure what is actually measured. While the reliability test is used to test whether the instrument used is reliable, which is consistent for each measurement. The instrument is said to be reliable if the Cronbach's Alpha value is > 0.6.

Data Analysis Technique

Data analysis includes worksheet validity and worksheet effectiveness. Worksheet validity was obtained through an expert validation instrument consisting of 2 expert lecturers and 1 science teacher. The percentage score results obtained are then categorized in the table 2.

Table 2. Criteria for data validation results

No	Percentage	Validity Criteria
1	$84\% < p \leq 100\%$	Very Valid
2	$68\% < p \leq 84\%$	Valid
3	$52\% < p \leq 68\%$	Quite Valid
4	$36\% < p \leq 52\%$	Less Valid
5	$20\% < p \leq 36\%$	Not Valid

Problem solving skills data were obtained by giving pretest and posttest questions analyzed using the N-Gain test. The improvement of students' problem solving skills was analyzed by N-Gain (Hake, 1998). The effectiveness of e-worksheet is said to be fairly effective if the percentage increase in N-Gain exceeds 56% (Sukarelawan et al., 2024).

▪ RESULT AND DISSCUSSION

The implementation of STEM-PBL based e-worksheet was carried out on 25 students of class VIII SMP N 2 Badau. Students are given pretest questions before implementing STEM-PBL based e-worksheet to investigate students' initial problem solving skills. The design of of STEM-PBL based e-worksheet can be access through the link https://bit.ly/3BGTWIC. The design of STEM-PBL based e-worksheet shown in the table 3.

Table 3. STEM-PBL based e-worksheet design

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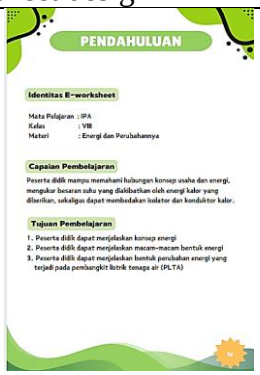
<td> 
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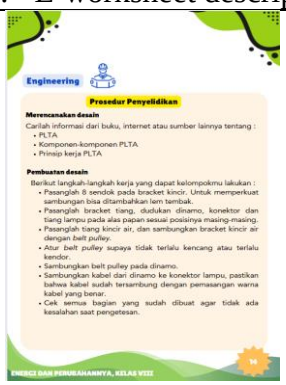
<td> 
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<td>e. Learning activity</td>
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The test instrument was tested before used in this study to find out its validity and reliability. Based on the analysis using SPSS statistics 25, it is known that the problem solving skills instrument that consists of 4 essay questions are all valid. Meanwhile, the Cronbach's Alpha value of the instrument is 0.677, indicated that the instrument is reliable.

Expert validation is carried out to assess the feasibility of the STEM-PBL e-worksheet used. The validity of the STEM-PBL e-worksheet was evaluated based on content validity divided into content, presentation, and language suitability. The results of expert validators show that STEM-PBL e-worksheet is feasible to use with a percentage of 96.9% (very valid criteria).

Learning activities of STEM-PBL on the experimental class consist of 3 stages: introduction, main activities and closing. The introduction stage begins with greetings, prayers, apperception and motivation. The core activity of learning uses STEM-PBL syntax, namely: (1) Orient the problem to students, (2) Organize learners to study, (3) Group investigation, (4) Develop and present work, and (5) Analyze and evaluate the problem solving process. Before starting the core activities, students open the STEM-PBL based e-worksheet link with their mobile phones. The teacher gives learners about 10 minutes to read the subject matter in the STEM-PBL based e-worksheet.

The first stage of the main activity, where students are oriented to the problem, begins by asking students to observe and understand the pictures and stories in e-worksheet. The images and stories observed are the existence of areas that do not have access to electricity, even though the area has dams and abundant water potential, but the existing water potential has not been utilized to generate electricity. Through the problem oriented stage, it is supposed to increase students' learning motivation (Yulianti et al., 2019). In line with research conducted by Parno (2019), it is known that STEM-PBL learning is better than PBL-conventional in involving student motivation and activeness in learning.

The second stage is the organization of learners to learn in groups. Learners are divided into 5 groups consisting of 4-5 learners. Through group discussions, learners make several questions related to the problems given at the orientation stage. Group discussions in the PBL model can strengthen communication, collaboration and student responsibility in solving problems (Seyhan, 2016). These groups engage in discussions and report on various achievements during the learning, ensuring a smooth link between the summary and design progress, ultimately resulting in a comprehensive design (Zeng & Ruannakarn, 2023).

The third stage is guiding group investigation. The investigation stage begins with preparing the tools and materials for the investigation. The investigation stage in this research is the application of the engineering stage in the STEM model. The engineering component of STEM can be used as learning activity design (Su, 2022). The investigation that will be carried out is to make a simple hydropower plant design. This investigation activity aims to enable learners to solve problems in the orientation stage through the STEM approach. In this investigation, learners look challenged to produce a good and correct simple hydropower plant design. After the process of assembling a simple hydropower plant, each group then conducted a trial of the design made. The investigation stage trains students to be active researchers to find the right way to solve the problem being explored. PBL which has a student-centered pedalogigal learning, makes students

more active in developing responsibility and cooperation (Kök & Duman, 2023). The exchange of opinions between students is an advantage of learning in small groups (Yulianti et al., 2019).

Figure 1. Assembly and testing the simple hydropower design

The stage of presenting the work began with group presentations in classrooms. Each group presented their work and other groups responded by asking questions about the work presented. Initially students had difficulty presenting their thoughts in class but through the teacher's direction students became accustomed. Students actively asked and answered questions so that the class became conducive. Students understand the meaning of the material deeply when they are the center of learning (Rihhadatul'aysi et al., 2020). STEM-PBL can help encourage students to actively apply aspects of engineering and science, and to gain depth science and math knowledge to improve students' skills and experience to apply their knowledge in everyday life (Parno et al., 2019).

The last stage is the analyze and evaluate the problem-solving process. Students have a group discussion and make conclusions about the results of problem solving. The teacher's role at this stage is to assist in clarifying the problem-solving process carried out by the students. Implementation of STEM-PBL helps students combine several disciplines that enable problem solving through small group collaboration so their learning becomes more meaningful (Smith et al., 2022). STEM integrated PBL allows students to connect one subject area to another easier (Navy & Kaya, 2020).

The implementation of STEM-PBL based e-worksheet learning is considered by students fun to do, because students can do experiments in solving the problems given. The implementation of STEM-PBL based e-worksheet was carried out enthusiastically by students, with the results that have been presented. The existence of e-worksheet supports students in solving the problems posed, makes students focus on problem solving activities and trains student independence (Swiyadnya et al., 2021). However, it cannot be denied that STEM-PBL is new to students so it requires better habituation for better results. Lack school facilities and limited learning time are factors that do not optimise the implementation of STEM learning (Diana et al., 2021).

Students are given posttest questions after all learning activities are implemented. The posttest is to determine students problem solving skills after being treated. N-Gain

analysis score of students' problem solving skills based on problem solving skills indicators are shown in Figure 2.

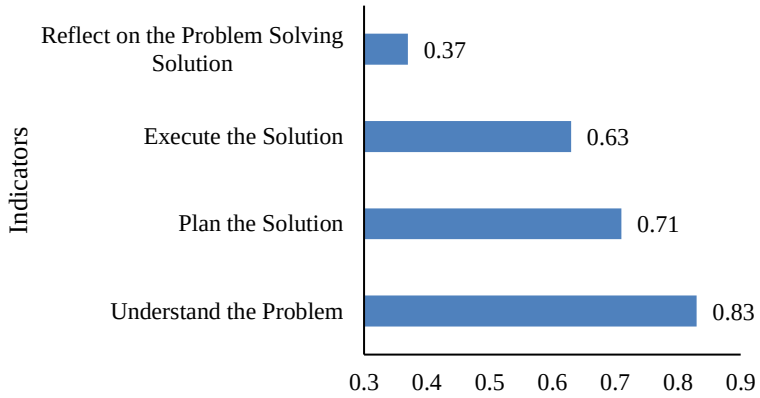

Figure 2. N-Gain score of each problem solving skills indicators

The question instrument used in the study consists of 4 essay questions in the form of case studies, where each question consists of 4 problem solving skills indicators. The questions arranged are systematic and interrelated with each other. Students can be said to be skilled in solving problems if students are able to solve problems based on each stages in solving problems (Heller & Heller, 2010). Based on figure 2, each problem solving skills indicators have increased from after being given treatment. The description of each problem solving skills indicator is as follows:

Understand the Problem

In the indicator of understand this problem, it includes the student's ability to understand the problem and understand what is asked in the problem. The indicator of understanding the problem acts as the first question of each case given in the problem. The result of the N-Gain for the indicator of understanding this problem is 0.83 which can be categorised as high. The indicator of understanding the problem has the highest N-Gain result compared to other indicators. The high category on the indicator of understanding the problem shows that it is concluded that students can understand the problem well. Students have the ability to explain the problem in their own sentences. The ability to understand the problem is the first step needed to solve problems effective and efficient. In line with research conducted by Hidayatulloh et al. (2020), that students had no difficulties in answering questions with indicators of understanding the problem. Based on the results of interviews with several students, they stated that if the case in the question is read carefully, they will be able to understand the problem easily.

Plan the Solution

The second indicator is planning the solution, which is an indicator that requires students to determine the method/formula that can be used to solve the problem. The analysis of N-Gain showed a result of 0.71 with a high category. This result shows that students can summarize the problem and determine the solution that works in relation to the problem to be solved. Research conducted by Sudarsono et al. (2022) in the

experimental class had an increase in the ability to develop a plan after STEM-based learning model. Based on the results of interviews with several students, they stated that if the subject matter is well understood, they will be able to plan solutions to the problems given.

Execute the Solution

The third indicator is executing the plan, which is an indicator that requires students to be able to formulate any solutions that can be used to solve the problem presented. The analysis of N-Gain showed a result of 0.63 with a medium category. This result shows that students still have difficulties in implementing the plan that has been made. The difficulties experienced can be caused by problem solving planning which is sometimes irrational and not in accordance with existing theories, so the students' answers become incorrect. The results obtained were also confirmed by Hidayatulloh et al. (2020) which states that students have difficulty in implementing problem solving solutions because the solutions given in the previous stage are irrelevant to the problems given. Based on the results of interviews with several students, they stated that there were difficulties in stating the solution plan of the solution offered due to the lack of insight they had.

Reflect on the Problem Solving Solution

The fourth indicator, namely reflect at the problem solving solution, is an indicator that requires students to double-check the answers given. This indicator is the indicator with the lowest N-Gain result of 0.37 in the low category. This shows that students are less able to check the information and logicality of the solution, and pay less attention to whether the solution given has answered the problem. The indicator of reflect on the problem solving solution is the final step of problem solving, if students cannot understand the problem well, cannot make a solution plan/strategy appropriately and have difficulty in implementing the problem solving plan, students are inaccurate in solving the problem (Tanjung et al., 2024).

The lack of achievement in the fourth indicator can be caused by several factors. Based on the results of interviews with several students, they stated that they did not understand the question instructions well, besides that students also admitted that they were sure of the answers given so they did not have other solutions to give. In line with research conducted by (Tanjung et al., 2024) which obtained the result of evaluate the answer in the low stage. The solution that can be done to overcome the low increase in this indicator is to make more practice problems in the final stage of the e-worksheet.

The average pretest and posttest score of student’ problem solving skills shown that there is a significant increase between students problem solving skills after being treated. The average score of pretest is 45,68 and the average score of posttest is 76,84. The total students average score increase is 31.16. The problem solving skills test data obtained was then analyzed into N-Gain data to determine the enhancement of students' problem solving skills after learning shown that 5 students (20%) were in the high category, 18 students (72%) were in the medium category and 2 students (8%) were in the low category.

The N-Gain score between pretest and posttest was 0.56 (medium category). These results indicate that learning with STEM-PBL based e-worksheet is able to improve students' problem solving skills significantly. The implementation of STEM-PBL based

e- worksheet on energy and its change material is in the effective enough category to improve student' problem solving skills with a percentage of 56.52%. The improvement of students' problem solving skills is facilitated by the STEM-PBL syntax in the e-worksheet (Parno et al., 2019). This is in line with research conducted by Kamila et al. (2020), stating that STEM-PBL worksheet can improve problem solving skills on wave material. Ramadhani & Nurita (2023) also stated that the implementation of STEM PBL assisted worksheet can improve students' problem solving skills on pressure material.

▪ CONCLUSION

The implementation of STEM-PBL based e-worksheet on energy material is effective enough to improve students' problem solving skills. All stages in the STEM-PBL syntax can facilitate students' problem solving skills as evidenced by the increase in problem solving skills scores after treatment in the experimental class. The implementation of STEM-PBL design based e-worksheet on energy and its change material is in the effective enough category to improve student' problem solving skills with a percentage of 56.52%.

This research provides learning media solutions and references integrated with STEM in science learning that can have a positive impact on improving students' problem solving skills and learning habits that are in line with real problems in life. A wide implementation by comparing treatments in classes has not been carried out in this study. For future research, a comparative study of the effectiveness of STEM-PBL design based e-worksheet with other learning media that can cover students' cognitive and affective abilities can be conducted.

▪ REFERENCES

Aidoo, B., Boateng, S. K., Kissi, P. S., & Ofori, I. (2016). Effect of problem-based learning on students' achievement in chemistry. Journal of Education and Practice, 7(33). www.iiste.org

Diana, N., Turmudi, & Yohannes. (2021). Analysis of teachers' difficulties in implementing STEM approach in learning: A study literature. Journal of Physics: Conference Series, 1806(1). https://doi.org/10.1088/1742-6596/1806/1/012219

Dotimineli, A., & Mawardi, M. (2021). Development of STEM integrated PBL-Based student worksheets in energetic materials of first-year students. Journal of Physics: Conference Series, 1788(1). https://doi.org/10.1088/1742-6596/1788/1/012045

Hake, R. R. (1998). Interactive-engagement versus traditional methods: A six-thousand-student survey of mechanics test data for introductory physics courses. American Journal of Physics, 66(1), 64–74. https://doi.org/10.1119/1.18809

Heller, K., & Heller, P. (2010). Cooperative problem solving in physics a user's manual. us : department of education.

Hidayatulloh, R., Suyono, & Azizah, U. (2020). *Analisis keterampilan pemecahan masalah siswa sma pada topik laju reaksi.* Jurnal Penelitian Pendidikan Sains), 10(01). https://journal.unesa.ac.id/index.php/jpps

Ilma, A. Z., Wilujeng, I., Widowati, A., Nurtanto, M., & Kholifah, N. (2023). A systematic literature review of STEM education in indonesia (2016-2021): contribution to improving skills in 21st century learning. Pegem Egitim ve Ogretim Dergisi, 13(2), 134–146. https://doi.org/10.47750/pegegog.13.02.17

Ionita, F., & Simatupang, H. (2020). *Pengaruh model problem based learning terhadap kemampuan pemecahan masalah materi pencemaran lingkungan siswa sma negeri 13 medan.* Jurnal Biolokus, 3 (1).

Kamila, A. U., Rahmawati, R. G., & Jumadi. (2020). Development of worksheet based on stem-pbl with phet simulation to improve student's problem solving during the covid-19 pandemic. Advances in Social Science, Education and Humanities Research, Volume 541 Proceedings of the 6th International Seminar on Science Education.

Kelley, T. R., & Knowles, J. G. (2016). A conceptual framework for integrated STEM education. In International Journal of STEM Education (Vol. 3, Issue 1). Springer. https://doi.org/10.1186/s40594-016-0046-z

Kök, F. Z., & Duman, B. (2023). The effect of problem-based learning on problemsolving skills in English language teaching. Journal of Pedagogical Research, 7(1), 154–173. https://doi.org/10.33902/JPR.202318642

Komarudin, K., Suherman, S., & Anggraini, A. (2021). Analysis of mathematical concept understanding capabilities: the impact of makerspae stem learning approach models and student learning activities. Journal of Innovation in Educational and Cultural Research, 2(1), 35–43. https://doi.org/10.46843/jiecr.v2i1.21

Martaningsih, S. T., Maryani, I., Prasetya, D. S., Prwanti, S., Sayekti, I. C., Aziz, N. A. A., & Siwayanan, P. (2022). Stem problem-based learning module: a solution to overcome elementary students' poor problem-solving skills. Pegem Egitim ve Ogretim Dergisi, 12(4), 340–348. https://doi.org/10.47750/pegegog.12.04.35

Navy, S. L., & Kaya, F. (2020). PBL as a pedagogical approach for integrated STEM: Evidence from prospective teachers. School Science and Mathematics, 120(5), 221–232. https://doi.org/10.1111/ssm.12408

Pangestu, A. M., & Hidayah, I. (2024). Development of PBL STEM-Based teaching materials with ethnomatematics nuances for students' creative thinking ability. Anatolian Journal of Education, 9(1). https://doi.org/https://doi.org/10.29333/aje.2024.915a

Parno, Yuliati, L., Hermanto, F. M., & Ali, M. (2020). A case study on comparison of high school students' scientific literacy competencies domain in physics with different methods: PBL-stem education, PBL, and conventional learning. Jurnal Pendidikan IPA Indonesia, 9(2), 159–168. https://doi.org/10.15294/jpii.v9i2.23894

Parno, Yuliati, L., & Ni'Mah, B. Q. A. (2019). The influence of PBL-STEM on students' problem-solving skills in the topic of optical instruments. Journal of Physics: Conference Series, 1171(1). https://doi.org/10.1088/1742-6596/1171/1/012013

Ramadhani, F. A., & Nurita, T. (2023). Implementation of STEM-Integrated problem based learning to improve students' problem solving skills in liquid pressure. Jurnal Pendidikan MIPA, 24(1), 349–358. https://doi.org/10.23960/jpmipa/v24i1.pp349-358

Rehmat, A. P., & Hartley, K. (2020). Building engineering awareness: Problem-based learning approach for STEM integration. Interdisciplinary Journal of Problem-Based Learning, 14(1), 1–15. https://doi.org/10.14434/ijpbl.v14i1.28636

Rihhadatul'aysi, F. A., Feronika, T., & Sapinatul Bahriah, E. (2020). Problem based learning model integrated with science, technology, engineering, and mathematics

(stem) on students' science competency ability. 38–44. https://doi.org/10.5220/0009914100380044

Rosdianaa, L., Ubay, A. N., Martini, & Sabtiawan, W. B. (2019). Analysing problem solving skills of secondary school students by using a student worksheet. Journal of Physics: Conference Series, 1317(1). https://doi.org/10.1088/1742-6596/1317/1/012204

Rosiningtias, W., Rosana, D., & Ningseh, E. L. (2023). Junior high school students' problem solving skill: pbl-stem model implementation. Jurnal Penelitian Pendidikan IPA, 9(9), 7658–7664. https://doi.org/10.29303/jppipa.v9i9.4259

Seyhan, H. G. (2016). The efficacy of problem-based learning in an instrumental analyse laboratory. Higher Education Studies, 6(4), 100. https://doi.org/10.5539/hes.v6n4p100

Shamdas, G., Bialangi, M., & Buntu, A. (2023). Application of problem-based learning model stem-based on biology lessons for high school students communication skills. Jurnal Pendidikan Sains Indonesia, 11(2), 345–359. https://doi.org/10.24815/jpsi.v10i4.28541

Sholihah, T. M., & Lastariwati, B. (2020). Problem based learning to increase competence of critical thinking and problem solving. Journal of Education and Learning (EduLearn), 14(1), 148–154. https://doi.org/10.11591/edulearn.v14i1.13772

Simanjuntak, M. P., Hutahaean, J., Marpaung, N., & Ramadhani, D. (2021). Effectiveness of problem-based learning combined with computer simulation on students' problem-solving and creative thinking skills. International Journal of Instruction, 14(3), 519–534. https://doi.org/10.29333/iji.2021.14330a

Smith, K., Maynard, N., Berry, A., Stephenson, T., Spiteri, T., Corrigan, D., Mansfield, J., Ellerton, P., & Smith, T. (2022). Principles of problem-based learning (PBL) in STEM Education: Using expert wisdom and research to frame educational practice. Education Sciences, 12(10). https://doi.org/10.3390/educsci12100728

Su, K. D. (2022). The effects of cross-disciplinary life science innovation implemented by students' simulated strategies for PBL-STEM Self-Efficacy. Journal of Baltic Science Education, 21(6), 1069–1082. https://doi.org/10.33225/jbse/22.21.1069

Sudarsono, Kartono, Mulyono, & Mariani, S. (2022). The effect of STEM model based on bima's local cultural on problem solving ability. International Journal of Instruction, 15(2), 83–96. https://doi.org/10.29333/iji.2022.1525a

Sudijono, A. (2015). *Pengantar statistik pendidikan.* PT Raja Grafindo Persada.

Sukarelawan, M. I., Indratno, T. Ku., & Ayu Suci Musvita. (2024). *N-Gain vs Stacking: Analisis perubahan abilitas peserta didik dalam desain one gropu pretest-posttest.* Suryacahya.

Suratno, Wahono, B., Chang, C. Y., Retnowati, A., & Yushardi. (2020). Exploring a direct relationship between students' problem-solving abilities and academic achievement: A STEM education at a coffee plantation area. Journal of Turkish Science Education, 17(2), 211–224. https://doi.org/10.36681/tused.2020.22

Swiyadnya, I. M. G., Wibawa, I. M. C., & Sudiandika, I. K. A. (2021). *Efektivitas model problem based learning berbantuan LKPD terhadap hasil belajar muatan pelajaran IPA.* 9(2), 203–210. https://ejournal.undiksha.ac.id/index.php/JJPGSD

Tanjung, Y. I., Festiyed, Diliarosta, S., Jubaidah, & Sanjaya, A. P. (2024). Analysis of students' problem solving skills based on heller indicator. Pegem Journal of Education and Instruction, 14(4). https://doi.org/10.47750/pegegog.14.04.40

Triana, D., Anggraito, Y. U., & Ridlo, S. (2020). Effectiveness of environmental change learning tools based on stem-pjbl towards 4c skills of students. JISE, 9(2), 181–187. http://journal.unnes.ac.id/sju/index.php/jise

Usman, G. B. T., Ali, M. N., & Ahmad, M. Z. (2023). Effectiveness of STEM problem-based learning on the achievement of biology among secondary school students in Nigeria. Journal of Turkish Science Education, 20(3), 453–467. https://doi.org/10.36681/tused.2023.026

Wahdaniyah, N., Agustini, R., & Tukiran, T. (2023). Analysis of effectiveness pbl-stem to improve student's critical thinking skills. IJORER : International Journal of Recent Educational Research, 4(3), 365–382. https://doi.org/10.46245/ijorer.v4i3.312

Widodo, S. A., Wijayanti, A., Irfan, M., Pusporini, W., Mariah, S., & Rochmiyati, S. (2023). Effects of worksheets on problem-solving skills: meta-analytic studies. International Journal of Educational Methodology, 9(1), 151–167. https://doi.org/10.12973/ijem.9.1.151

Yulianti, D., Wiyanto, Rusilowati, A., Nugroho, S. E., & Supardi, K. I. (2019). Problem based learning models based on science technology engineering and mathematics for developing student character. Journal of Physics: Conference Series, 1170(1). https://doi.org/10.1088/1742-6596/1170/1/012032

Zeng, X., & Ruannakarn, P. (2023). Development of problem-based learning management activities to enhance the knowledge, skills, and interests of students. Higher Education Studies, 13(4), 149. https://doi.org/10.5539/hes.v13n4p149