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The Analysis of Students' Problem-Solving Skills About Temperature and Heat

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Abstract: This journal reviews students' problem-solving skills after participating in a problem-solving-based learning process. This study aims to determine the student's problem-solving skills and social students who follow a cross-interest program in physics. The study utilized a quantitative approach with descriptive methods and a one-group pretest-posttest research design. The research subjects were 29 students in class X Social 4 at SMAN Sambungmacan, Sragen. In this study, students were asked to complete four question descriptions after studying temperature and heat material. Student problem-solving results were analyzed using a point system. The average and percentage of student achievement were calculated for each problem and its stages of problem-solving. Analysis of problem-solving skills data revealed that the average percentage of students' problem-solving skills reached 65.3%. Based on data analysis and results, all students' problem-solving abilities have improved since the pretest. It is hoped that students will continue to be accustomed to solving problems using the stages of problem-solving in the future.

Keywords: Heat; Problem-solving skills; Temperature

Introduction

When discussing problem-solving, particularly in the context of physics problems, many people assume that physics is one complicated problem. Including people involved in the field of physics, for example, beginner teachers and students studying physics. Usually, when solving physics problems, they make use of experiences that they had before to solve problems (Safitri et al., 2023). It means that they used similar physics solutions to solve new physics problems. In other words, they imitate how to solve problems from one situation to another. If they used this method, problem-solving might produce an appropriate goal. However, not all problems can be solved this way, as it does not train students to solve the problem well. "Which equation do I use to solve the problem?" It indicated that the students did not understand the problem-solving strategy. Such questions demonstrate that the student's attention is focused on the appropriate equation for problem-solving.

That was discovered in previous studies, where students struggled to visualize the problem and identify variables that supported problem-solving. It could be due to students focusing more on the correct equation to solve the problem (Damayanti & Yohandri, 2022; Jua et al., 2018; Samsudin et al., 2023). The same thing was discovered by Jayadi et al. (2020) who discovered that among all stages of problem-solving skills, the ability to identify students' problems was the lowest. Furthermore, many students tend to answer problems using established equations without fully comprehending the problem at hand. It is not about using appropriate steps to solve the issue. Problem-solving skills are not meant to reach the goal, but problem-solving is a goal itself (Suharlan et al., 2023).

Another finding is that students are not prepared to take physics lectures and do not understand the

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fundamental concepts, principles, and laws of physics that will studied. Students often face difficulties responding to teacher inputs and problem-solving during learning process. Iftitah et al. (2023) and Wahyuni et al. (2023) discovered in their research that students who are eager to learn try to answer questions posed by the teacher. As a result, before beginning lessons, students should read ideas and basic concepts. Self-prepared students can success by effectively solving problems (Gusman et al., 2022; Kamala et al., 2022; Lasaiba & Arfa, 2023).

Problem solving skills are a mental process and a general feature of the human cognitive structure that consists of four major activities: identifying, comprehending, solving, and evaluating problems (Ling et al., 2024; Woo & Falloon, 2022; Zunanda & Sinulingga, 2015). The essential point is that teachers must familiarize students with the problem-solving stages. Analysis of problem-solving skills helps in evaluating the effectiveness of the education system. By understanding the extent to which students can solve real-world problems, it is possible to evaluate the extent to which educational goals are achieved. Problem-solving skills are not only relevant to the field of education, but are also invaluable life skills. Analyzing these skills helps in creating an educational environment that supports the development of students' life skills (Ahmar et al., 2023; Wong & Yip, 2023; Yuliasandra & Wulandari, 2023).

Problem-solving skills enable students to adapt to changes and face challenges that may arise in the future. Analyzing these skills helps measure the extent to which students have this adaptability. By analyzing problem-solving skills, educators can identify areas where students may need additional assistance. This helps in designing more effective and focused learning strategies (Amalina & Vidákovich, 2023; Li et al., 2023; Rocha & Babo, 2024; Wang et al., 2023). The goal is to familiarize students with the strategy and gradually assume that problem-solving is the ultimate goal. If troubleshooting in the usual way does not solve the problem, teachers and students should be aware of looking for other methods or troubleshooting steps.

Method

Research Approach

This study aims to evaluate and describe students' problem-solving abilities after learning about temperature and heat, in addition to problem-solving techniques. The first table depicts the problem-solving stages and their indicators. As a result, the research method employed is quantitative, with descriptive research methods, and the research design is a one-group pretest-posttest. Researchers prepare data or instruments in the form of description test questions based on the forgoing. The pretest data had already analyzed in previous studies, so this study only used students' posttest data. The results of the pretest analysis can be applied when comparing to the results of the posttest analysis (Astra et al., 2021a, 2021b).

Table 1. The Stages in Problem-solving and Development of Indicators

The Stages	Indicators
Understanding the problems	Identifying problems and converting the units of variables which was known; Determining the variables being asked; Visualizing the problem or identifying the variables which
Planning the strategy	Determining the theories and equations to solve problems
Implementing the strategy	Using theory or equation to solve problems that asked
Checking back	Re-examining the problem-solving procedure and the accuracy of the solution; Re-checking the decrease of units in solving problems when and the suitability of the final units with the variable which is being asked

Research Participants

Temperature and heat were the topics covered in this study. The sample of research participants was not selected at random classes but was chosen directly by the physics teacher based on several factors, such as the number of students being greater than in other classes, students' readiness to learn the concepts of temperature and heat, and the adjustment of research time.

Research Instruments

The instrument used is a temperature and heat material description developed from high school physics guidebooks and temperature and heat modules developed by researchers. The description test generated up to four questions about solid expansion, gas expansion, black principle, and black body radiation. Material experts, teachers, and peers validated the temperature and heat description questions alongside the temperature and heat module.

Data Collection

The posttest given after the students in class X Social 4 had completed three face-to-face sessions or had learned the temperature and heat material. The posttest given during the fourth meeting for two lesson hours. The purpose of the posttest for the teacher is to determine how well students understand the concepts of temperature and heat. The researcher is interested in how far students use the problem-solving steps as taught. The teacher and researcher directly supervised the posttest administration.

Data Analysis

Posttest problem-solving results of students were analyzed by assigning points to each indicator of the problem-solving skills stage. According to Table 1, there are seven indicators from the four stages of problem-solving skills. Each indicator has a maximum of 4 points and a minimum of 0. So, a single description question is worth 28 points, while four posttest questions are worth 112. The students' problem-solving abilities were evaluated by summing up their points and calculating the average and percentage using Equation 1. The students calculated the percentage of each stage of problem-solving. Following analysis, the percentage of all.

$$x = \frac{\text{Total student score per stage/indicator}}{\text{maximum score per stage /indicator}} \times 100 \quad (1)$$

Result and Discussion

Results of the First Research Objectives

Problem 1:

"Accidentally you burn a glass rod that is 20 cm long and 1 cm wide. As a result, the glass rod is expanding. The area of the glass rod after burning reaches 22 cm. Can you calculate the temperature increase which causes the glass to expand? Coefficient of expansion of glass length = 0.5 × 10^{-5} / ^{0}C"

Problem 1 talks about the expansion of solid that is widespread on glass. Students' achievement in solving problem 1 with problem-solving skill steps reach 80,9%. The following is an example of a student's work in problem-solving one:

$$\begin{aligned}
D_1 &: A_t = 22\ cm \\
&\quad A_0 = 20 \times 1 = 20\ cm \\
&\quad \beta = 2\alpha \rightarrow 2 \cdot 0{,}5 \times 10^{-5} \\
&\qquad \rightarrow 10^{-5} \\
D_2 &: \Delta T \\
D_3 &: A_t = A_0(1 + \beta\,\Delta T) \\
&\quad 22 = 20(1 + 10^{-5}\,\Delta T) \\
&\quad \frac{22}{20} = 1 + 10^{-5}\,\Delta T \\
&\quad 1{,}1 = 1 + 10^{-5}\,\Delta T \\
&\quad 10^{-5}\,\Delta T = 1{,}1 - 1 \\
&\quad 10^{-5}\,\Delta T = 0{,}1 \\
&\quad \Delta T = \frac{0{,}1}{10^{-5}} = 0{,}1 \times 10^5 = 10^4
\end{aligned}$$

Figure 1. Almost flawless problem-solving procedure

$$\begin{aligned}
D_1 &: A_0 = 20\ cm \\
&\quad A_t = 22\ cm \\
&\quad \beta = 10 \\
D_2 &= \cdots ? \\
D_3 &: A_t = \frac{\Delta 0A}{A_0\beta} \\
&\quad = \frac{2^1}{10^{20} \times 10^{-5}} \\
&\quad = \frac{1}{10 \cdot 10^4} \\
&\quad = \frac{1}{10^{-4}} = 10^4
\end{aligned}$$

Figure 2. The problem-solving procedure is less clear

Problem 2

"In a house, 2 liters of O_2 gas are placed in a kitchen with a temperature of 15 ^{0}C. Because the temperature in the kitchen is very low, the owner of the house turns on the furnace so that the temperature burns the kitchen reaches 25 ^{0}C. If the pressure of O_2 gas is fixed, can you calculate the volume of O_2 gas now?"

Problem 2 talks about the gas expansion at constant pressure. Student achievement when solving problem 2 reached 63,6%. The following is an example of a student's work in terms of the process of solving problem number two:

$$\begin{aligned}
&V_1 = 2L \\
&T_1 = 15\,°C \rightarrow 15 + 273 = 288K \\
&T_2 = 25\,°C \rightarrow 25 + 273 = 298K \\
&\text{P tetap} \\
&V_2 \ldots ? \\
&\rightarrow \frac{P_1 \cdot V_1}{T_1} = \frac{P_2 \cdot V_2}{T_2} \\
&\frac{V_1}{T_1} = \frac{V_2}{T_2} \\
&\frac{2}{288} = \frac{V_2}{298} \\
&298 \cdot 2 = V_2 \cdot 288 \\
&596 = V_2 \cdot 288 \\
&V_2 = \frac{596}{288} = 2{,}07L
\end{aligned}$$

Figure 3. The second coherent process of problem-solving

$$\begin{aligned}
&\frac{V_1}{T_1} = \frac{V_2}{T_2} \\
&\frac{2}{15} = \frac{V_2}{25} \\
&15 \cdot V_2 = 2 \cdot 25 \\
&V_2 = \frac{2 \cdot 25}{15} = \frac{50}{5} = 3{,}33m^3
\end{aligned}$$

Figure 4. The second process directly uses the equation

Problem 3

"You put ice of M gram -5 ^{0}C temperature into 100 grams of warm water at 25 ^{0}C in a special vessel. The vessel doesn't absorb and it does not release the heat. If $L_{f\ ice}$ = 80 kal/g ^{0}C and c_{water} = 1 kal/g ^{0}C. all the ice melts and thermal equilibrium is achieved at a temperature of 5 ⁰C. Can you estimate the mass (M) of the ace you are using, using existing data?"

Problem 3 deals with the concept of the black principle. Students' achievement in solving problem 3 reached 66.1%. Examples of student work are shown as follows:

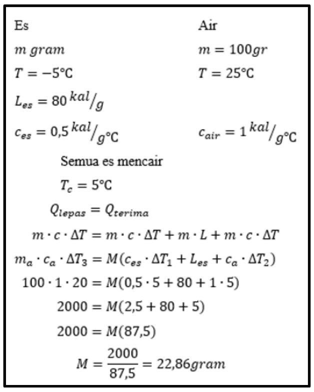

Figure 5. The process of problem-solving three which correct

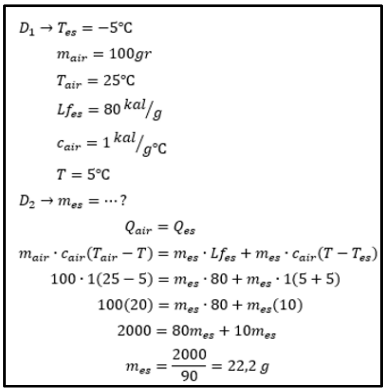

Figure 6. The process used to solve problem 3 is wrong

Problem 4

"A sphere with an area of 2 × 10⁻⁵ m² is like a black object having a temperature of 500 K. can you calculate how much heat is emitted from a black ball? δ = 5,67 × 10⁻⁸ *watt/m²K⁴*"

Problem 4 talks about the radiation of black objects. Student's achievement in problem-solving 4 reached 50.4%. Most students solve problem 4 in the following way:

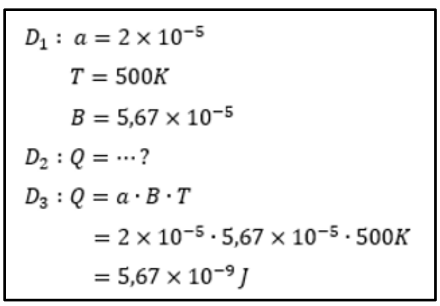

Figure 7. The process of problem-solving 4 by students

Figure 8 also shows a percentage comparison of each stage of students' problem-solving skills between the pretest and posttest.

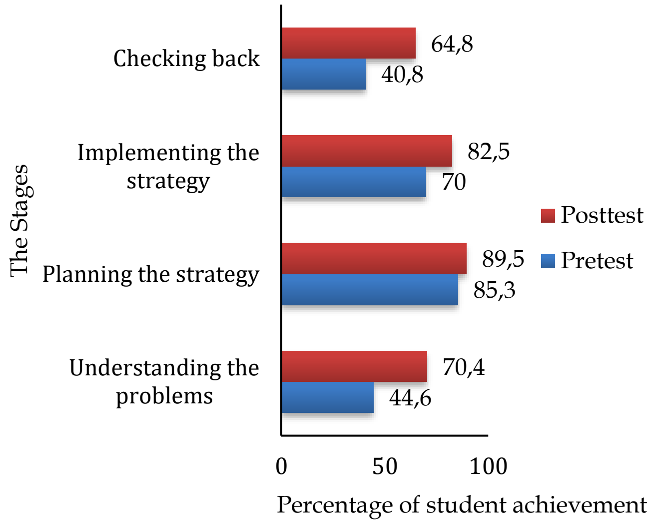

Figure 8. A comparison of students' problem-solving skills before and after the pretest and posttest

Discussion of the First Research Objectives

Figure 1 shows the best result of student problem-solving, although some steps of problem-solving skills remain unmet. It shows that students understand the problem area. Students can declare the known amount or variable and the problem asked. The student's skill in understanding the problem is also shown by processing the initial data to obtain the value of the expansion coefficient area (β) as the supporting variable of problem-solving. In addition, students define theories and equations to solve problems appropriately. Students also apply the equation well. Thus, the steps of problem-solving here may produce the appropriate objectives. However, students do not check the unit of the declining process again when solving the problem. Thus, students forget about the unit that corresponds to the problem asked on implementation of the strategy until the problem-solving results (Giacomazzi et al., 2022; Prabasari & Wahyuningsih, 2021; Rocha & Babo, 2024).

Figure 2 is one example of less precise problem-solving skills. The result suggests that students still do not understand the problem well. The proof is that students can only state a known issue but do not understand the subject in the question. The ways students identify problems like this confuse the teacher because the teacher cannot determine whether the students understand the problem or don't understand it. They stated that teachers have difficulty guessing whether students understand the problem because the student does not write down the variables that are asked

(Pardimin & Widodo, 2016). In addition, problem-solving strategies used by students to solve problems are inappropriate. The strategy implementation carried out according to the plan mentioned above, but the variables used are not clear as to where they came from. However, results varied according to the purpose of the troubleshooting. It means this student has not been able to solve broad expansion problems using stages of problem-solving skills.

In Figure 3, students use the steps of problem-solving skills well. Students describe the known variables and convert units from Celsius to Kelvin. Students also clarified the variable asked. In addition, students use and describe appropriate equations to solve problems. Thus, the final result of the problem-solving matches the variable being asked. However, students do not represent the unit when implementing a problem-solving strategy and immediately write down the team at the end of the problem-solving. In Figure 4, students directly write the equation to solve the problem without implementing the stage of understanding the first problem. As a result, the variables used at the strategy implementation stage are less appropriate because they are not the result of the conversion unit, and the problem-solving consequence is wrong. In addition, students also do not describe the team. Thus, the units declared by the student at the problem-solving end are less appropriate (Arzak & Prahani, 2023; Dewi et al., 2023; Winingsih et al., 2023).

The phase of understanding the problem is critical because it becomes the basis for solving the problem itself. Problem understanding is the process identifying variables and the conversion unit related to the principles outlined in physics. For example, the temperature unit for the force must be in Kelvin. If a student does not convert the units based on the predefined principles, there will be errors in unit placement when executing the strategy. As a result, the final problem-solving results do not match the variables being asked, and the students' problem-solving skills are considered weak. This supported by Ogunleye's statement, which states that the weakness of students in solving problems is due to the student's lack of understanding of the problems and weak physics skills (Ogunleye, 2009).

Students' habit of directly using the equation to solve problems can be fatal at the end of problem-solving. For example, the final result of problem-solving is not correct. This is consistent with the findings, which say that students directly used solutions in their mathematical solutions (Walsh et al., 2007). Such processes may produce the correct answer. However, all physics problems cannot be solved in this way. In addition, a coherent unit in executing strategies is helpful in convincing students themselves about the correctness of problem-solving. A cohesive unit demarcation convinces students about the suitability of the problem-solving answers with the variables being asked.

If observed briefly, the problem-solving process in Figure 5 and Figure 6 looks the same. Both students have a clear understanding of the problem. The difference is that the students whose work is shown in Figure 5, identify the heat released by water and the heat absorbed by the ice, so that they can conclude that all the ice melts. The heat type generally set at 0.5 kcal/g ^{0}C. In addition, the student also describes the Q release and Q receive equations by considering the process of changing the form of ice from -5 °C to ice at 0 °C. Students' consideration in this process causes them to identify the variables that have not been stated yet to help them solve the problem. Figure 6 displays issues that were not identified during problem-solving. As a result, in Figure 6, the student's approach to problem-solving is less appropriate.

Understanding students' concepts is crucial some of the problems listed above. Their problem-solving process is shown in Figure 6, and it still lacks an understanding of the basic concept of the black principle, especially in the heat transfer process between water and ice. The student whose problem-solving process is shown in Figure 5 considers some problems above because of the student's conceptual understanding of the principle. Above statement supported by the findings, which state that when students understand the underlying concepts of the problem, they can collect facts and information to solve it (Kurniawan et al., 2016), as well as students must know how to apply two types of knowledge, namely conceptual and procedural knowledge, to solve problems (Rahayu & Adistana, 2018). Based on these findings, students need to understand and master the physics concepts they learn to be more helpful in solving physics problems.

The students have a good understanding of the problem, particularly the indications that indicate known variables and variables asked. However, students do not recognize the situation. For example, a ball is like a black object with an emissivity value of 1. Next, the student is less appreciative of planning a problem-solving strategy. They have not identified emissivity materials, so they do not include emissivity in strategic planning. In addition, the rate of radiation of heat energy is not proportional to the surface area of the ball. It is also proportional to the cube of four for absolute temperature. Students do not consider it and use a known temperature value when implementing a problem-solving strategy. As a result, the problem-solving result does not match the target in question.

Students did not identify the supporting variables and plan the strategy properly because they did not understand the fundamental concept of black body radiation. Several factors should be considered before using the equation to solve the problem. The students must declare an important variable to solve the problem; Students should find out which concepts or principles of physics can be applied to determine those variables. Students should seek out what information is needed to solve the problem. In other words, identifying the supporting variables of problem-solving and understanding the principles of physics are essential to helping to solve problems (Giacomazzi et al., 2022; Şenocak & Demirkıran, 2023). If students understand the concepts of physics involved in solving problems, they will understand the problems presented to them. Thus, the problem is easy to solve and can achieve results that match the purpose of solving the problem.

Students face obstacles in problem-solving, including grasping basic concepts, identifying problems, analyzing strategies, revisiting the problem-solving process, and other factors. All these things are significant for students when solving physics problems in the learning process and dealing with issues in everyday life. The more skilled the student is in solving the problem, the more satisfactory the result will be for the student himself and others. The above statement is supported by the findings, which state that the ability to solve problems, including incredibly complex problems, must be possessed by humans (Fryda et al., 2021). It means that students must continue or try to practice these skills because, in the future, they will increasingly complex problems.

Conclusion

The From the results and explanations regarding students' problem-solving skills above, the average value of student achievement in solving temperature and heat problems with expansion material, black principle, and radiation reaches 65.3%, so it can be concluded that students are still not optimal in solving problems. Therefore, students must continue to be educated and accustomed to solving problems using the stages of problem-solving skills so that their' problem-solving skills improve.

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References

Ahmar, D. S., Magfirah, M., Poba, D., & Azzajjad, M. F. (2023). Gamification Learning Integrated with Local Wisdom Based on Character Education, is There an Effect on Problem Solving Ability? *Jurnal Penelitian Pendidikan IPA*, *9*(9), 7614–7620. https://doi.org/10.29303/jppipa.v9i9.4968

Amalina, I. K., & Vidákovich, T. (2023). Cognitive and Socioeconomic Factors that Influence the Mathematical Problem-Solving Skills of Students. *Heliyon*, *9*(9). https://doi.org/10.1016/j.heliyon.2023.e19539

Arzak, K. A., & Prahani, B. K. (2023). The Physics Problem Solving Skills Profile of High School Students in Elasticity Material and the Implementation of Augmented Reality Book-Assisted PBL Model. *Momentum: Physics Education Journal*, *7*(1). https://doi.org/10.21067/mpej.v7i1.6704

Astra, I. M., Aminudin, D., & Henukh, A. (2021a). Enhancing Students' Learning Activities Using Problem-Based Learning Model on Temperature and Heat Concept. *Journal of Physics: Conference Series*, *2019*(1). https://doi.org/10.1088/1742-6596/2019/1/012025

Astra, I. M., Henukh, A., & Algiranto, A. (2021b). Implementation of Think Pair Share Model in Physics Learning to Determine Cognitive, Affective and Psychomotor Learning Outcomes and Student Responses. *Journal of Physics: Conference Series*, *1876*(1). https://doi.org/10.1088/17426596/1876/1/012064

Damayanti, I. R., & Yohandri, Y. (2022). E-Book Development Effectiveness Problem Based Learning with Quizing in Physics Learning. *Jurnal Penelitian Pendidikan IPA*, *8*(6), 3044–3049. https://doi.org/10.29303/jppipa.v8i6.2290

Dewi, W. S., Siregar, R., Putra, A., & Hidayati, H. (2023). Effect of Problem-Based Learning Model on Students' Physics Problem Solving Ability: A Meta-Analysis. *Jurnal Penelitian Pendidikan IPA*, *9*(4), 2103–2109. https://doi.org/10.29303/jppipa.v9i4.3291

Fryda, C., Ayudha, H., & Setyarsih, W. (2021). Studi Literatur : Analisis Praktik Pembelajaran Fisika di SMA untuk Melatih Keterampilan Pemecahan Masalah. *Jurnal Pendidikan Fisika Undiksha*, *11*(1), 16–28. https://doi.org/10.23887/JJPF.V11I1.33427

Giacomazzi, M., Fontana, M., Ngina, P., & Mugo, J. K. (2022). Problem Solving in East Africa: A Contextual Definition. *Thinking Skills and Creativity*, *46*. https://doi.org/10.1016/j.tsc.2022.101180

Gusman, F., Dewata, I., Andromeda, A., & Zainul, R. (2022). Development of Problem Based Learning Based E-Modules on Salt Hydrolysis Materials to Improve Students Science Literature. *Jurnal Penelitian Pendidikan IPA*, *8*(5), 2410–2416. https://doi.org/10.29303/jppipa.v8i5.1831

Iftitah, N., Arsyad, M., & Palloan, P. (2023). The Effect of Problem-Based Learning Model and Self-Efficacy towards Creative Thinking Ability of Class XI MIPA Students at SMA Negeri 11 Takalar. *Jurnal Penelitian Pendidikan IPA*, *9*(12), 10808–10815. https://doi.org/10.29303/jppipa.v9i12.4734

Jayadi, A., Putri, D. H., & Johan, H. (2020). Identifikasi Pembekalan Keterampilan Abad 21 pada Aspek Keterampilan Pemecahan Masalah Siswa SMA Kota Bengkulu dalam Mata Pelajaran Fisika. *Jurnal Kumparan Fisika*, *3*(1), 25–32. https://doi.org/10.33369/JKF.3.1.25-32

Jua, S. K., Sarwanto, S., & Sukarmin, S. (2018). The Profile of Students' Problem-Solving Skill in Physics Across Interest Program in the Secondary School. *Journal of Physics: Conference Series*, *1022*(1), 012027. https://doi.org/10.1088/1742-6596/1022/1/012027

Kamala, I., Idayanti, Z., & Ulfah, T. T. (2022). Peningkatan Partisispasi Peserta Didik dalam Belajar IPA Melalui Model Problem Based Learning. *Jurnal Penelitian Pendidikan IPA*, *8*(4), 2362–2370. https://doi.org/10.29303/jppipa.v8i4.1850

Kurniawan, B. R., Handayanto, S. K., & Parno, P. (2016). Profil Kemampuan Pemecahan Masalah Mahasiswa Fisika Universitas Negeri Malang. In *Prosiding Seminar Nasional Pendidikan IPA Universitas Negeri Malang*, Malang (pp. 105-111). Retrieved from https://rb.gy/sn7m45

Lasaiba, M. A., & Arfa, A. M. (2023). Hubungan Kesiapan Mandiri, Kreativitas Belajar dan Motivasi terhadap Kemampuan Pemecahan Masalah. *SAP (Susunan Artikel Pendidikan)*, *7*(3), 415–422. https://doi.org/10.30998/SAP.V7I3.16020

Li, S., Pöysä-Tarhonen, J., & Häkkinen, P. (2023). Students' Collaboration Dispositions Across Diverse Skills of Collaborative Problem Solving in a Computer-Based Assessment Environment. *Computers in Human Behavior Reports*, *11*. https://doi.org/10.1016/j.chbr.2023.100312

Ling, Y., Zhou, L., Zhang, B., & Ren, H. (2024). Developing Middle School Students' Problem-Solving Ability through Interdisciplinary Project-Based Learning. *Education for Chemical Engineers*, *46*, 43–53. https://doi.org/10.1016/j.ece.2023.11.001

Ogunleye, A. O. (2009). Teachers and Students Perceptions of Students Problem-Solving Difficulties in Physics: Implications for Remediation. *Journal of College Teaching & Learning (TLC)*, *6*(7). https://doi.org/10.19030/TLC.V6I7.1129

Pardimin, P., & Widodo, S. A. (2016). Increasing Skills of Student in Junior High School to Problem Solving in Geometry With Guided. *Journal of Education and Learning (EduLearn)*, *10*(4), 390–395. https://doi.org/10.11591/EDULEARN.V10I4.3929

Prabasari, J. S. M., & Wahyuningsih, D. (2021). Pengembangan Elektronik Modul Berbasis Problem Based Learning pada Materi Zat Aditif dan Zat Adiktif untuk Meningkatkan Kemampuan Berpikir Kritis Siswa. *Jurnal Penelitian Pendidikan IPA*, *7*(SpecialIssue), 312–319. https://doi.org/10.29303/jppipa.v7ispecialissue.1233

Rahayu, I. A. T., & Adistana, G. A. Y. P. (2018). Mengembangkan Keterampilan Memecahkan Masalah melalui Pembelajaran Berdasar Masalah. *JP (Jurnal Pendidikan): Teori dan Praktik*, *3*(2), 86–91. https://doi.org/10.26740/JP.V3N2.P86-91

Rocha, H., & Babo, A. (2024). Problem-Solving and Mathematical Competence: A Look to the Relation During the Study of Linear Programming. *Thinking Skills and Creativity*, *51*, 101461. https://doi.org/10.1016/j.tsc.2023.101461

Safitri, R., Hadi, S., & Widiasih, W. (2023). Effect of the Problem Based Learning Model on the Students Motivation and Learning Outcomes. *Jurnal Penelitian Pendidikan IPA*, *9*(9), 7310–7316. https://doi.org/10.29303/jppipa.v9i9.4772

Samsudin, A., Raharjo, T. J., & Widiasih, W. (2023). Effectiveness of Contextual Teaching Learning (CTL) and Problem Based Learning (PBL) Models in Class VI Science Subjects on Creativity and Learning Outcomes. *Jurnal Penelitian Pendidikan IPA*, *9*(11), 9324–9331. https://doi.org/10.29303/jppipa.v9i11.5290

Şenocak, S. Ü., & Demirkıran, F. (2023). Effects of Problem-Solving Skills Development Training on Resilience, Perceived Stress, and Self-Efficacy in Nursing Students: A Randomised Controlled Trial.

Nurse Education in Practice, *72*. https://doi.org/10.1016/j.nepr.2023.103795

Suharlan, L. S., Arsyad, M., & Palloan, P. (2023). Influence of Problem Based Learning and Self Directed Learning Models on Students' Problem Solving Abilities. *Jurnal Penelitian Pendidikan IPA*, *9*(12), 11386–11393. https://doi.org/10.29303/jppipa.v9i12.4730

Wahyuni, S., Syamsurizal, S., Irdawati, I., Violeta, V., & Fajrina, S. (2023). Implementation of the Problem Based Learning Model to Increase the Activity and Learning Outcomes of Students in the Digestive System Material and the Human Respiratory System Class XI MAN 2 Tanah Datar. *Jurnal Penelitian Pendidikan IPA*, *9*(11), 9263–9269. https://doi.org/10.29303/jppipa.v9i11.4537

Walsh, L. N., Howard, R. G., & Bowe, B. (2007). Phenomenographic Study of Students' Problem Solving Approaches in Physics. *Physical Review Special Topics-Physics Education Research*, *3*(2), 020108. https://doi.org/10.1103/PhysRevSTPER.3.020108

Wang, Q., Mousavi, A., Lu, C., & Gao, Y. (2023). Examining Adults' Behavioral Patterns in a Sequence of Problem Solving Tasks in Technology-Rich Environments. *Computers in Human Behavior*, *147*.https://doi.org/10.1016/j.chb.2023.107852

Winingsih, P. H., Kuswanto, H., Saputro, H., Purwanto, J., Erlangga, S. Y., Purnama, A. Y., Sebastian, R., & Silvia, S. (2023). Analysis of Understanding of Physics Concepts through Problem Solving Units Review in Free Fall Motion Materials. *Revista Mexicana de Fisica E*, *20*(2). https://doi.org/10.31349/RevMexFisE.20.020205

Wong, T. T. Y., & Yip, E. S. K. (2023). What is the Unknown? The Ability to Identify the Semantic Role of the Unknown from Word Problems Longitudinally Predicts Mathematical Problem Solving Performance. *Contemporary Educational Psychology*, *73*. https://doi.org/10.1016/j.cedpsych.2023.102183

Woo, K., & Falloon, G. (2022). Problem Solved, but How? An Exploratory Study into Students' Problem Solving Processes in Creative Coding Tasks. *Thinking Skills and Creativity*, *46*. https://doi.org/10.1016/j.tsc.2022.101193

Yuliasandra, E. W., & Wulandari, F. (2023). The Influence of Problem Based Learning Model on the Critical Thinking Elementary School. *Jurnal Penelitian Pendidikan IPA*, *9*(8), 6610–6618. https://doi.org/10.29303/jppipa.v9i8.3766

Zunanda, M., & Sinulingga, K. (2015). Pengaruh Model Pembelajaran Berbasis Masalah dan Kemampuan Berpikir Kritis terhadap Keterampilan Pemecahan Masalah Fisika Siswa SMK. *Jurnal Pendidikan Fisika*, *4*(1), 63–70. https://doi.org/10.22611/jpf.v4i1.2570