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Effects of 7-step Problems Based Learning and Scientific Reasoning on Problem Solving Abilities

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Abstract: The end of this study to decide how the differences in problem-solving abilities of students who take part in learning using 7-step PBL and conventional methods are reviewed from high and low scientific reasoning ability. The sample in this study (N) numbered 125 students who were selected using convenience sampling statistical techniques. The method used in this study is a quantitative research method with a factorial 2 x 2 research design. Data on problem-solving ability was analyzed using a two-way ANOVA statistical test. The results of the study show that the learning method provides statistical differences in students' problem-solving abilities. This is due to several reasons, the first PBL 7-step learning in terms of clarification of terms and concepts provides an opportunity for the teacher to intervene if students provide incorrect explanations of the problem given. Second, students are given the opportunity to establish agreed problems not only to mention them but to discuss the problem formulation and also to examine broader relevance. Third, the ability to apply the knowledge gained during learning to new situations/problems in the PBL 7-step class is better than the conventional class.

Keywords: Problem-solving abilities, 7-step PBL, Scientific reasoning ability.

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INTRODUCTION

Help out students to develop problem solving skills (not to gather information) is one of the goals of physics education (Rees et al., 2013). Problem solving has long been the focus of physics education research because problem solving is a cognitive domain that includes all content domains (Harks et al., 2014).

Problem solving imply a process of unrelenting improvement and adaptation in facing intricate challenges to produce deep instruction (Harnett, 2012). Giving problem solving duty also provides an occasion for students to modify or replace previous knowledge with scientific concepts in order to successfully answer the problems faced by students (Loyens et al., 2015). Scientific concepts do not appear out of nowhere but elaborated in the troubleshooting process involving the prectice of various procedures. This process is referred to as the process of scientific reasoning (Magnani, 2002). Findings of Wuriyudani et al., (2018) showed that problem-solving abilities influence on scientific reasoning ability of students.

As cognitive load increases during the learning process, students often have difficulty finding solutions to solve problems (Smart & Marshall, 2013). Even students who studied physics at the seat of learning level often have hardship in resolving the problem in spite of the obviousness that solving the problem is an integral part of most classes of physics (Tuminaro & Redish, 2007). Students' difficulties in dealing with problems can be overcome if the workload of problem solving is shared (Kuhn & Pease, 2008). In addition the findings of Mason & Singh (2016) showed that by categorizing concepts of physics in the tasks assigned to help students in solving problems. Categorizing and structuring the discussion allows students to categorize problems based on the physical concepts that underlie the problem.

Problem-based learning (PBL) is widely follow through as small group tutorials where students learn through the instruction scenario. The scenario involves a problem that becomes more complex over time (Jaffe et al., 2015), pull, open, and real to motivate students (Sahin, 2010). Through this learning, educators act as guides for students in solving problems by giving guide questions, motivating, going around the classroom to facilitate discussion, and so on, students are required to solve the problems presented. So through problem solving in learning physics, it is hoped that later it can develop problem-solving abilities (Syahbrudin, 2019). PBL can enhance academic accomplishment, cognitive abilities and procedural skills (Baran & Sozbilir, 2018) and scientific argumentation abilities (Pritasari et al., 2016).

There are four main components of structured problem solving section, the representation of the problem, develop a solution, the justification of the solution, and evaluate solutions. Representation of the problem is formed by two sub-passage; identify the cause problem and identify apropos information. Developing a solution made up of two subcomponents; propose or develop settlement and quality settlement. Finally, justification of the solution is also formed with two sub-components; building case, and dispense proof (Demiraslan Çevik, 2015).

The results of research from Mustofa & Rusdiana (2016) show that students' problem solving abilities are still in the sufficient category. Findings of Sujarwanto & Hidayat (2014) showed that the students were still difficulties in understanding and identifying the problem, planning a strategy, implement strategies and solutions in the evaluation. In the step of identifying and understanding the problem students only classify the problem based on what is known and asked on the problem. At the phase of devise a strategy, students create charts freely without making physical meaning and there are students who are not able to determine the equation correctly. At the stage of implementing the strategy most students fail due to carelessness during calculations (Alias & Ibrahim, 2015). At the stage of evaluating solutions students only evaluate based on facts that are known and are asked in the problem and there are still students who incorrectly write the unit (Sujarwanto & Hidayat, 2014).

Tytler & Peterson (2005) identified three levels of scientific reasoning abilities. Level one, does not involve systematic observations or comparisons but explanations are driven by a single data point. Level two, bound in making conclusions on the relationship between variables or pure ideas that are driven by data with some conceptual interpretations. Level three, involves the relationship between variables using theory. Brown et al. (2010) divide three levels of scientific reasoning abilities. Level one, don't know about trying. Level two, knowing the purpose of the experimental activity, that the attempt has the aim of verify the idea to see whether it is true. Level three, not only has the difference between level one and level two but also values the relationship between experimental results and the ideas tested (Wu & Tsai, 2011).

One of the instruments used to measure scientific reasoning is the Classroom Test Scientific Reasoning (CTSR). CTSR measures proportional reasoning, probabilistic reasoning, controlling variables, correlational reasoning, and the ability of hypodeductive reasoning (Lawson, 2000). Lee & She (2010) divides students' scientific reasoning abilities into four levels. A score of 0-2 is classified at Piaget's pre-concrete operational level. Scores of 3-4 are classified at Piaget's post-concrete operational level. Transitional levels are classified at a score of 5–8 and a formal operational level of Piaget which has a score of 9–12.

The findings of Jensen et al. (2017) indicate that there is a correlation between scientific reasoning ability and achievement in learning. Alshamali & Daher (2016) research results show that a high level of scientific reasoning results in high problem solving abilities in science teachers. Specifically, students who understand theoretical concepts exhibit scientific reasoning level lofty than they were just a hypothetical concept master. Uniformly, those who only have descriptive concepts show the uncouth reasoning skills (Ding et al., 2016).

PBL can be reflect on as a constructivist approach (Askell-Williams et al., 2007; Hung, 2016; Ulger, 2018) for education (Yew & Schmidt, 2012). PBL is a teaching and instruction strategy that is used to take part students in problem solving. PBL is defined as student-focused pedagogy (Raine & Symons, 2012; Senocak et al., 2007; Tosun & Senocak, 2013) where students develop intellectual independence when working through problems with little direction from the teacher (Vandenhouten et al., 2017).

PBL can improve academic achievement (Perdana et al., 2017), cognitive abilities, procedural skills (Baran & Sozbilir, 2018) scientific argumentation abilities (Pritasari et al., 2016) and enable students to work in groups cooperatively and build knowledge through social negotiation compared to traditional teaching methods (Akçay, 2009; Cross et al., 2008). Yew & Schmidt (2012) show that three PBL phases: problem analysis, independent learning, and reporting phases, play a special role in influencing students' natural reasoning abilities. Martin & Hand (2009) reports progress in understanding concepts when students are given the opportunity to work collaboratively fathom problems and discuss replacement views. Findings from Loyens et al. (2015) that PBL can enhance conceptual change because students seriously and critically consider contrasting information between scientific explanations and previous misconceptions.

Teachers as instructor need to consider various learning methods to overcome student difficulties in solving problems, problem-based learning methods are one of the learning methods that can be used. On the other hand, scientific reasoning ability can influence student achievement, even science teachers who have high scientific reasoning ability also have high solving abilities. Research on the effect of 7-step PBL and scientific reasoning on the ability to solve problems has been done but, previous research was conducted separately. In this study, researchers wanted to see the effect of 7-step PBL and the ability to reason scientifically on the ability to solve problems together and how scientific reasoning abilities play a role in learning.

METHOD

The method used in this study is a quantitative research method with a 2 x 2 factorial research design. Problem solving abilities data were analyzed using two-way ANOVA statistical tests. The population in this study were all grade X students of SMA Negeri 4 Malang. The sample selection technique used is convenience sampling. The sample in this study used 4 class X of SMA Negeri 4 Malang, totaling 125 students. The procedure in this study can be seen in Figure 1.

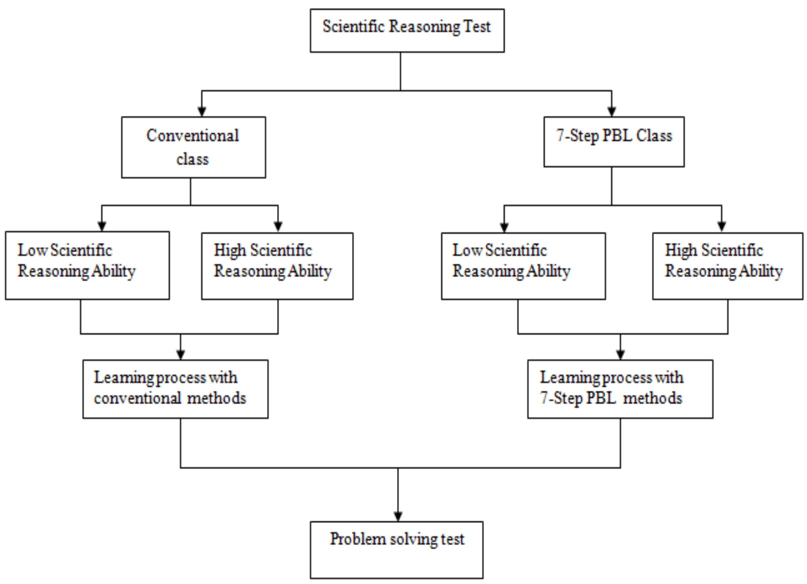

Figure 1. Flow chart data obtained

The problem solving ability of students is measured using 4 item description questions that have been tested for validity and reliability. Problem solving skills are given after learning is done both in class with PBL 7-step method and conventional methods. The 7-Step PBL used in this study are based on Maurer and Neuhold (2012) which consists of Clarification of terms and concepts, Formulation of Problem Statement, Brainstorm, Categorising and Structuring of Brainstorm, Formulation of Learning objectives, Self-Study, Post-discussion & Reflection on Learning Process. The four steps of problem solving according to Polya (1973) consisting of steps and problem solving, drawing up plans to solve problems, implementing plans and improving solutions used to measure problem solving. Problem solving rubrics based on Polya's problem solving steps (Hostos Rubrics, 2017) are presented in Table 1.

Tabel 1. Problem Solving Ability Rubric

Level	Problem Solving Steps			
	Define and solve problems	**Develop a plan or strategy to solve the problem**	**Carry out the plan**	**Reflect (evaluate) the solution**
1	Shows limited understanding of the problem and the wider context.	Students do not have the ability to consider new strategies even though the strategies used are clearly inappropriate	Declare at most one, often. Students do not recognize a lot of ways to carry out the plan even though the solution seems wrong	Students do not analyze or synthesize results
2	Demonstrate an understanding developed in part from the matter and decide certain factors that influence the approach to the problem before solving it	Students rarely recognize the need for several solutions, but sometimes can do it when asked or when removing an incorrect solution.	Sometimes students realize the need for several steps to carry out the plan especially if the first attempt fails but students do it with limited abilities.	Students sometimes apply background knowledge or problem context when considering solutions.
3	Demonstrate a clear awareness of the matter and recognize many determined factors that influence the approach to the problem before solving it	Students will be able to coordinate two processes into strategies and articulate important components of Student strategies.	Students can implement the plan with the number of processes or steps that a limited and express one or more potential solutions that accurately	Students often apply background knowledge or problem context when considering solutions. The wrong solution leads to reflection and adjustment in planning.
4	Demonstrate a clear understanding of the problem and identify specific factors that influence the problem approach before solving it	Students will demonstrate the ability to reverse a process to form a plan and clearly articulate the decision making process (in words or algebraic formulas)	Students can implement plans with several processes or steps (including reverse processes) and accurately identify at least one right or applicable solution (often creative)	Students can always apply background knowledge or problem context when considering solutions. Students can reflect on solutions to make adjustments and provide insight into student plans

The level of students' scientific reasoning ability in the learning class using the 7-step PBL method and the learning class using the conventional method were measured using Lawson's scientific reasoning ability questions. From 12 questions about the ability of scientific reasoning owned by Lawson only 11 items were used because 11 questions used included all the indicators contained in the matter of scientific reasoning ability. Criteria for students who have high scientific reasoning ability if they are at the formal and traditional operational and operational levels Piaget. While the criteria for students who have low scientific reasoning ability are students who are at the pre-concrete and post-concrete operational levels of Piaget.Tests to measure scientific reasoning abilities are conducted before learning.

RESULT AND DISCUSSION

Data on scientific reasoning ability Obtained from test results using Lawson's CTSR. The test given consisted of a double test in the form of a reasonable choice of 11 questions. This test is used to classify students who have high and low scientific reasoning abilities in conventional and 7-step PBL classes. This scientific reasoning ability test is carried out before studying physics on work and energy.

After studying physics on work and energy after the two classes were finished, they were given problem solving tests. The test is given in the form of an essay test as much as 4 matter which includes work, kinetic energy, potential energy and work and energy ties. This test is used to measure the ability of students who have high and low scientific reasoning abilities in conventional and 7-Step PBL classes

Statistical test results showed that there were no differences between the problem solving ability of students who have high scientific reasoning ability and low. While learning methods show differences in problem-solving abilities between classes using PBL and conventional 7-step methods. Taken together, scientific reasoning abilities and learning methods do not make a difference in problem solving abilities.

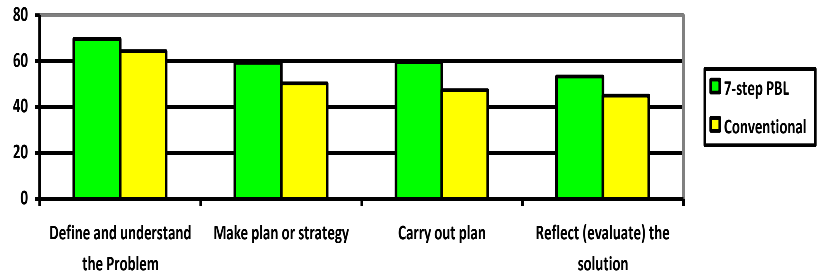

Figure 2. Mean value of problem solving ability at each step of class problem solving viewed from the learning method.

The results of the problem solving seen from the problem solving steps between the conventional 7-step PBL classes are presented in Figure 2. In the component defining and understanding the problem, the average value of students on problem solving is 69.76 for the class with PBL 7-step learning method while in conventional class the average value of problem solving is 64.38. In the component of making a plan or strategy, the mean value of students 'problem solving aptness is 59.17 in the class using the PBL 7-step method while in conventional class the mean worth of students' 'problem solving aptness is 50.30. In the component of implementing the plan, the average value of students' problem solving ability was 59.78 in the 7-step PBL class while in conventional class the average problem solving ability of students was 47.32. In the component reflecting (evaluating) the average solution value of students 'problem solving abilities in the class using the PBL 7-step method by 53.33 while in conventional classes the mean value of students 'problem solving aptness is 45.14.

The results of the problem solving ability seen from the learning method are presented in Figure 3. The average value of problem solving ability in the stages of defining and understanding problems in students with low scientific reasoning abilities is 64.65, while in students with high scientific reasoning abilities is 68.46. The average value of problem solving skills at the stage of preparing plans or strategies for students with low scientific reasoning abilities was 51.84, while for students with high scientific reasoning abilities was 56.05. The average value of problem solving skills at the stage of implementing plans for students with low scientific reasoning abilities was 51.95, while students with high scientific reasoning abilities were 54.69. The average problem solving ability at the stage of reflecting (evaluating) solutions to students with low scientific reasoning ability was 48.05, while students with high scientific reasoning ability were 50.20.

Average students' problem-solving skills after following study with 7-step method PBL is presented in Figure 4. As many as 30.56% of students are at level 1. As many as 40.32% of students are at level 2. As many as 29.03% of students are at level 3. The average problem solving ability of students after attending learning in class with conventional methods is presented in Figure 5. As many as 51.61% of students are at level 1. At level 2 there are as many as 40.32% of students. 9.67% of students are at level 3.

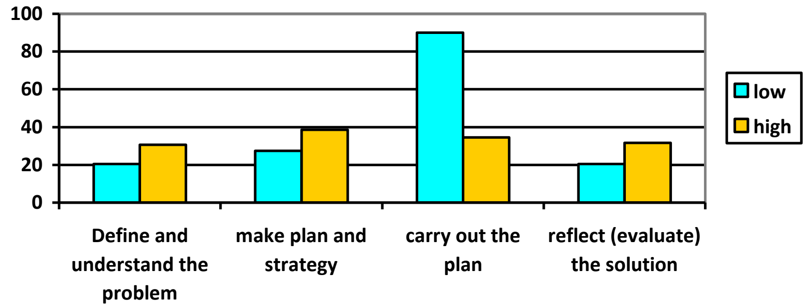

Figure 3. Average value of problem solving ability in each component of problem solving seen from the ability to reason scientifically.

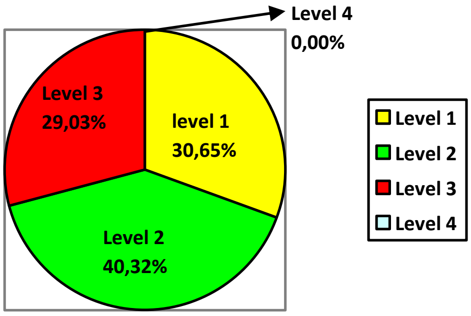

Figure 4. Average problem solving abilities in PBL 7-step classes

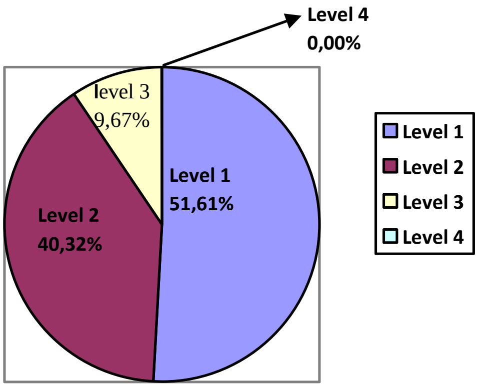

Figure 5. Average problem solving abilities in conventional classes

From Figure 3 the average value of problem solving ability of students who have high scientific reasoning ability is higher than students who have low scientific reasoning ability in the four steps of problem solving. This is caused by several things, at the stage of defining and understanding the problem of students who have low scientific reasoning abilities have a limited understanding of the problem in line with the findings of Rimadani et al. (2017) most students answer the question only passing on information that is accepted without delving deeper into the problem given, other than that at the stage of planning solutions students fail to consider new strategies when the strategies used are not appropriate this is in accordance with the findings of Sambada (2012) students do not consider alternative answers so that the problem solving strategies are not detailed, besides the ability in the previous stage will affect the next stage this is in line with the findings of Mustofa & Rusdiana (2016) when students have difficulty in understanding problems students will also have difficulty at the stage of planning a solution can be seen in Figure 6. At the stage of implementing the plan a student does not recognize many paths to carry out the plan even though the solution seems wrong this is in accordance with the findings of Fathiah et al. (2015) students have not been able to apply the equation to solve physics problems associated with dynamic fluid material. In the stage of evaluating solutions students identify partially correct solutions for a number of reasons with limited ability to examine a given solution can be seen in Figure 7.

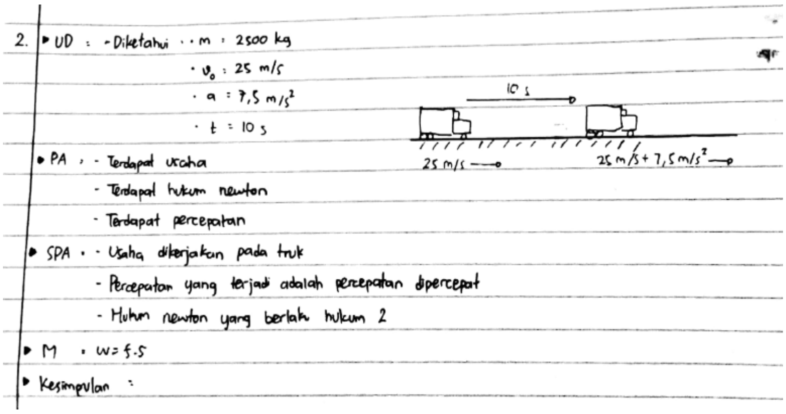

Figure 6. Answers of students who have a limited grasp in understanding and defining the problem

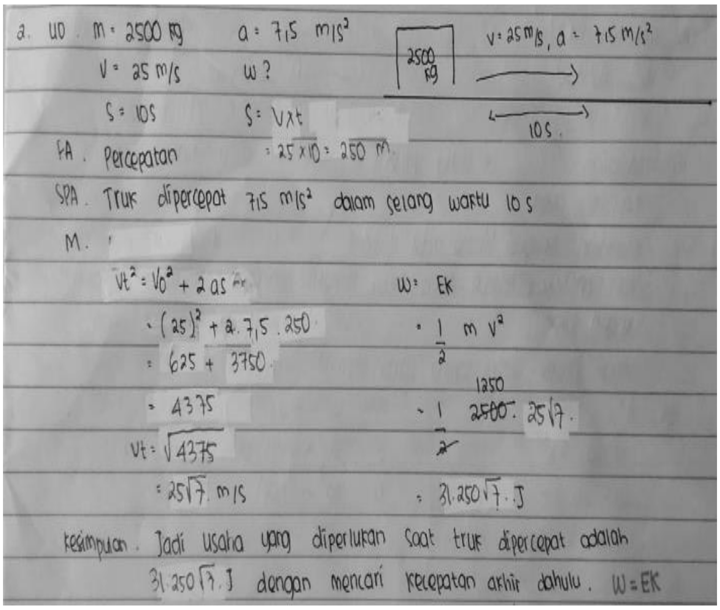

Figure 7. Student answer does not recognize many paths to carry out the plan even though the solution seems wrong

From the results of the two-way ANOVA statistical test there are differences in the ability of problem solving between students who take part in learning by using the 7-step PBL and conventional methods. This is caused by several things, first 7-step PBL learning in terms of clarifying terms and concepts provides an opportunity for the teacher to intervene if students provide incorrect explanations for the words/concepts of the problem given so students in the learning class using the 7-step method PBL shows superior explanation and understanding compared to students in conventional classes. The results are in line with the findings Yew & Schmidt (2012) one of the upper hand of PBL compared to common lecture-based teaching lies in its aptitude to help students fuse new concepts with at hand knowledge.

Students' misconceptions in integrating prior knowledge and given problems can be resolved at the learning step of formulating statements of problems, students are given the opportunity to set agreed problems not only to mention them but to discuss problem formulations and also examine broader relevance, this is in line with findings

Loyens et al. (2015) the use of problem solving assignments provides an opportunity for students to modify or replace their previous knowledge with a scientific perspective in order to successfully answer the questions raised.

In the step of independent learning in PBL 7-step learning, students are command to choose learning fount to surmount instruction problems that are work out in their slight discussion cohort. This makes students play an active role in the learning process, not just accepting learning material as in conventional classes. This is in line with the results of the study Wijnia et al. (2015) that PBL bid students more authority during the instruction process by permit to students appoint literature to learn from some agreed literature that can improve their insight of becoming maverick students.

Another thing that results in differences in problem solving abilities between students who take learning with PBL and conventional 7-step methods is the ability to apply the knowledge gained during learning to new situations / problems. This is in line with the findings Yadav et al. (2011) PBL students remember more about the application of principles. Specifically, the yield of the watchfulness show that students are at least twice as good at topics taught through problem-based learning compared to students taught through traditional lecture methods, students are better able to solve problems and transfer learning to new situations.

CONCLUSION

From the results of the research and discussion several things can be concluded. First, there are statistical differences in the ability of problem solving statistically between students who take learning using the 7-step PBL and conventional methods. Secondly, there is no difference in statistical problem solving abilities between students who have high and low scientific reasoning ability. This means that differences in problem-solving abilities between conventional classes and 7-Step PBL are only caused by learning models not scientific reasoning abilities Third, there is no interaction between learning models and scientific reasoning abilities towards problem solving abilities.

In this study, researchers have not examined why scientific reasoning abilities do not have an effect during learning on problem solving skills. It is hoped that in future studies it will dig deeper into why this has happened.

REFERENCES

Akçay, B. (2009). Problem-Based Learning in Science Education. *Journal of Turkish Science Education*, *6*(1), 26–36.

Alias, S. N. B., & Ibrahim, F. B. (2015). *Problem Solving Strategy in Balanced Forces*. *6*(8), 5.

Alshamali, M. A., & Daher, W. M. (2016). Scientific Reasoning and Its Relationship with Problem Solving: The Case of Upper Primary Science Teachers. *International Journal of Science and Mathematics Education*, *14*(6), 1003–1019. https://doi.org/10.1007/s10763-015-9646-1

Askell-Williams, H., Murray-Harvey, R., & Lawson, M. J. (2007). Teacher education students' reflections on how problem-based learning has changed their mental models about teaching and learning. *The Teacher Educator*, *42*(4), 237–263. https://doi.org/10.1080/08878730709555406

Baran, M., & Sozbilir, M. (2018). An Application of Context- and Problem-Based Learning (C-PBL) into Teaching Thermodynamics. *Research in Science Education*, *48*(4), 663–689. https://doi.org/10.1007/s11165-016-9583-1

Brown, N. J. S., Furtak, E. M., Timms, M., Nagashima, S. O., & Wilson, M. (2010). The Evidence-Based Reasoning Framework: Assessing Scientific Reasoning. *Educational Assessment*, *15*(3–4), 123–141. https://doi.org/10.1080/10627197.2010.530551

Cross, D., Taasoobshirazi, G., Hendricks, S., & Hickey, D. T. (2008). Argumentation: A strategy for improving achievement and revealing scientific identities. *International Journal of Science Education*, *30*(6), 837–861. https://doi.org/10.1080/09500690701411567

Demiraslan Çevik, Y. (2015). Assessor or assessee? Investigating the differential effects of online peer assessment roles in the development of students' problem-solving skills. *Computers in Human Behavior*, *52*, 250–258. https://doi.org/10.1016/j.chb.2015.05.056

Ding, L., Wei, X., & Liu, X. (2016). Variations in University Students' Scientific Reasoning Skills Across Majors, Years, and Types of Institutions. *Research in Science Education*, *46*(5), 613–632. https://doi.org/10.1007/s11165-015-9473-y

Fathiah, F., Kaniawati, I., & Utari, S. (2015). Analisis Didaktik Pembelajaran yang Dapat Meningkatkan Korelasi antara Pemahaman Konsep dan Kemampuan Pemecahan Masalah Siswa SMA pada Materi Fluida Dinamis. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, *01*(1), 111–118. https://doi.org/10.21009/1.01116

Harks, B., Klieme, E., Hartig, J., & Leiss, D. (2014). Separating Cognitive and Content Domains in Mathematical Competence. *Educational Assessment*, *19*(4), 243–266. https://doi.org/10.1080/10627197.2014.964114

Harnett, J. (2012). Reducing discrepancies between teachers' espoused theories and theories-in-use: An action research model of reflective professional development. *Educational Action Research*, *20*(3), 367–384. https://doi.org/10.1080/09650792.2012.697397

Hostos Rubrics. (2017). *Center for Teaching and Learning (CTL): Hostos and Value Rubrics*. Www.Hostos.Cuny.Edu. http://www.hostos.cuny.edu/oaa/pdf/genedf09_problem%20solving%20rubric.pdf

Hung, W. (2016). All PBL Starts Here: The Problem. *Interdisciplinary Journal of Problem-Based Learning*, *10*(2). https://doi.org/10.7771/1541-5015.1604

Jaffe, L., Gibson, R., & D'Amico, M. (2015). Process-Oriented Guided-Inquiry Learning: A Natural Fit for Occupational Therapy Education. *Occupational Therapy In Health Care*, *29*(2), 115–125. https://doi.org/10.3109/07380577.2015.1010030

Jensen, J. L., Neeley, S., Hatch, J. B., & Piorczynski, T. (2017). Learning Scientific Reasoning Skills May Be Key to Retention in Science, Technology, Engineering, and Mathematics. *Journal of College Student Retention: Research, Theory & Practice*, *19*(2), 126–144. https://doi.org/10.1177/1521025115611616

Kuhn, D., & Pease, M. (2008). What Needs to Develop in the Development of Inquiry Skills? *Cognition and Instruction*, *26*(4), 512–559. https://doi.org/10.1080/07370000802391745

Lawson, A. E. (2000). Development and validation of the classroom test of formal reasoning. *Journal of Research in Science Teaching*, *15*(1), 11–24.

Lee, C.-Q., & She, H.-C. (2010). Facilitating Students' Conceptual Change and Scientific Reasoning Involving the Unit of Combustion. *Research in Science Education*, *40*(4), 479–504. https://doi.org/10.1007/s11165-009-9130-4

Loyens, S. M. M., Jones, S. H., Mikkers, J., & van Gog, T. (2015). Problem-based learning as a facilitator of conceptual change. *Learning and Instruction*, *38*, 34–42. https://doi.org/10.1016/j.learninstruc.2015.03.002

Magnani, L. (2002). Conjectures and manipulations: External representations in scientific reasoning. *Mind & Society*, *3*(1), 9–31. https://doi.org/10.1007/BF02511863

Martin, A. M., & Hand, B. (2009). Factors Affecting the Implementation of Argument in the Elementary Science Classroom. A Longitudinal Case Study. *Research in Science Education*, *39*(1), 17–38. https://doi.org/10.1007/s11165-007-9072-7

Mason, A., & Singh, C. (2016). Using categorization of problems as an instructional tool to help introductory students learn physics. *Physics Education*, *51*(2), 025009. https://doi.org/10.1088/0031-9120/51/2/025009

Maurer, H., Neuhold, C., 2012. Problems Everywhere? Strengths and Challenges of a Problem-Based Learning Approach in European Studies (SSRN Scholarly Paper No. ID 1997614). Social Science Research Network, Rochester, NY.

Mustofa, M. H., & Rusdiana, D. (2016). Profil Kemampuan Pemecahan Masalah Siswa pada Pembelajaran Gerak Lurus. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, *02*(2), 15–22. https://doi.org/10.21009/1.02203

Perdana, F. R., Ertikanto, C., & Wahyudi, I. (2017). Pengaruh Pembelajaran Menggunakan Lembar Kerja Siswa Berbasis Problem Based Learning Pada Materi Fluida Statis Terhadap Hasil Belajar Fisika. *Jurnal Pembelajaran Fisika*, 9.

Polya, G. (1973). *How To Solve It A New Aspect of Mathematical Method* (2nd ed.). Princeton University Press.

Pritasari, A. C., Dwiastuti, S., & Probosari, R. M. (2016). Peningkatan Kemampuan Argumentasi melalui Penerapan Model Problem Based Learning pada Siswa Kelas X MIA 1 SMA Batik 2 Surakarta Tahun Pelajaran 2014/2015. *Jurnal Pendidikan Biologi*, *8*(1), 1–7.

Raine, D., & Symons, S. (2012). Problem-based learning: Undergraduate physics by research. *Contemporary Physics*, *53*(1), 39–51. https://doi.org/10.1080/00107514.2011.615162

Rees, C., Pardo, R., & Parker, J. (2013). Steps to Opening Scientific Inquiry: Pre-Service Teachers' Practicum Experiences with a New Support Framework. *Journal of Science Teacher Education*, *24*(3), 475–496. https://doi.org/10.1007/s10972-012-9315-y

Rimadani, E., Diantoro, M., & Parno. (2017). IDENTIFIKASI KEMAMPUAN PENALARAN ILMIAH SISWA SMA PADA MATERI SUHU DAN KALOR. *Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan*, *2*(6), 833–839.

Sahin, M. (2010). Effects of Problem-Based Learning on University Students' Epistemological Beliefs About Physics and Physics Learning and Conceptual Understanding of Newtonian Mechanics. *Journal of Science Education and Technology*, *19*(3), 266–275. https://doi.org/10.1007/s10956-009-9198-7

Sambada, D. (2012). PERANAN KREATIVITAS SISWA TERHADAP KEMAMPUAN MEMECAHKAN MASALAH FISIKA DALAM PEMBELAJARAN KONTEKSTUAL. *Jurnal Penelitian Fisika dan Aplikasinya (JPFA)*, *2*(2), 37. https://doi.org/10.26740/jpfa.v2n2.p37-47

Senocak, E., Taskesenligil, Y., & Sozbilir, M. (2007). A Study on Teaching Gases to Prospective Primary Science Teachers Through Problem-Based Learning. *Research in Science Education*, *37*(3), 279–290. https://doi.org/10.1007/s11165-006-9026-5

Smart, J. B., & Marshall, J. C. (2013). Interactions Between Classroom Discourse, Teacher Questioning, and Student Cognitive Engagement in Middle School Science. *Journal of Science Teacher Education*, *24*(2), 249–267. https://doi.org/10.1007/s10972-012-9297-9

Sujarwanto, E., & Hidayat, A. (2014). *KEMAMPUAN PEMECAHAN MASALAH FISIKA PADA MODELING INSTRUCTION PADA SISWA SMA KELAS XI*. 14.

Syahbrudin, J. (2019). *Development of Assessment Instruments for Physics Problem Solving Skill Based on Polya's Stages*. *7*, 8.

Tosun, C., & Senocak, E. (2013). The Effects of Problem-Based Learning on Metacognitive Awareness and Attitudes toward Chemistry of Prospective Teachers with Different Academic Backgrounds. *Australian Journal of Teacher Education*, *38*(3). https://doi.org/10.14221/ajte.2013v38n3.2

Tuminaro, J., & Redish, E. F. (2007). Elements of a cognitive model of physics problem solving: Epistemic games. *Physical Review Special Topics - Physics Education Research*, *3*(2), 020101. https://doi.org/10.1103/PhysRevSTPER.3.020101

Tytler, R., & Peterson, S. (2005). A Longitudinal Study of Children's Developing Knowledge and Reasoning in Science. *Research in Science Education*, *35*(1), 63–98. https://doi.org/10.1007/s11165-004-3434-1

Ulger, K. (2018). The Effect of Problem-Based Learning on the Creative Thinking and Critical Thinking Disposition of Students in Visual Arts Education. *Interdisciplinary Journal of Problem-Based Learning*, *12*(1). https://doi.org/10.7771/1541-5015.1649

Vandenhouten, C., Groessl, J., & Levintova, E. (2017). How Do You Use Problem-Based Learning to Improve Interdisciplinary Thinking?: How Do You Use Problem-Based Learning. *New Directions for Teaching and Learning*, *2017*(151), 117–133. https://doi.org/10.1002/tl.20252

Wijnia, L., Loyens, S. M. M., Derous, E., & Schmidt, H. G. (2015). How important are student-selected versus instructor-selected literature resources for students' learning and motivation in problem-based learning? *Instructional Science*, *43*(1), 39–58. https://doi.org/10.1007/s11251-014-9325-6

Wu, Y., & Tsai, C. (2011). High School Students' Informal Reasoning Regarding a Socio-scientific Issue, with Relation to Scientific Epistemological Beliefs and Cognitive Structures. *International Journal of Science Education*, *33*(3), 371–400. https://doi.org/10.1080/09500690903505661

Wuriyudani, H. A., Wiyanto, W., & Darsono, T. (2018). Problem Solving Heuristic to Develop Scientific Reasoning. *Physics Communication*, *3*(1), 1–9. https://doi.org/10.15294/physcomm.v3i1.15022

Yadav, A., Subedi, D., Lundeberg, M. A., & Bunting, C. F. (2011). Problem-based Learning: Influence on Students' Learning in an Electrical Engineering Course. *Journal of Engineering Education*, *100*(2), 253–280. https://doi.org/10.1002/j.2168-9830.2011.tb00013.x

Yew, E. H. J., & Schmidt, H. G. (2012). What students learn in problem-based learning: A process analysis. *Instructional Science*, *40*(2), 371–395. https://doi.org/10.1007/s11251-011-9181-6