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by Kosim Kosim

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The influence of causalitic-learning model on problem-solving ability in terms of students' mastery of physics concepts

J Rokhmat[1,2], Hikmawati[2], Kosim[1,2], Wahyudi[2] and Y Sari[2]

[1] Department of Natural Science Education, Postgraduate Program, Universitas Mataram, Indonesia
[2] Physics Education, Faculty of Teacher Training and Education, Universitas Mataram, Mataram, Indonesia

E-mail: joni.fkip@unram.ac.id

Abstract. This study aims to investigate the effects of (a) the causalitic-learning Model (CLM) on (a) Problem-solving Abilities (PSA), (b) mastery of physics-concepts on PSA, and (c) the interaction between CLM and mastery physics-concepts on PSA. This research is a quasi-experimental design with an untreated control group design with a pre-test and post-test. The population is all students of class X Public Senior High School (PSHS) 1 Narmada, amounting to 396 people. Samples were taken using cluster random sampling technique and obtained students class X-1 as the experimental class (14 men and 16 women) and X-2 as the control class (9 men and 21 women). The data were collected using a PSA test and analyzed using parametric statistics two-way ANOVA test. With a significance of 0.05 and the criteria if the sig value <0.05 then Ha is accepted, it found that: (a) CLM affects PSA (sig. score = 0.02), (b) mastery physics-concepts affect PSA (sig. score = 0.007), but (c) there is no interaction effect between CLM and mastery physics-concepts on PSA (sig. score = 0.740).

1. Introduction

Physics is part of natural science and also a collection of knowledge, ways of thinking, and investigation. One of the challenges in learning physics is creating experiences by involving students in comprehensively constructing conceptual-knowledge. In the classroom the teacher helps students find concepts, principles, or facts for themselves, not giving lectures or controlling the class. The active involvement of students in learning is in line with causalitic learning that students are oriented to be able to create meaning from the material studied conceptually [1].

To the author's knowledge, in fact, in practice, there are still many educational problems, namely low learning outcomes. These are shown in part by the low physics scores of students. One of the reasons is that there are still quite a lot of teachers who organize teacher-oriented physics learning. In this case, the teacher only conveys information to students in an imposition (pouring) manner. Students only object to learning activities and do not have the opportunity to discover the physics-concepts they are learning on their own. Students directly receive ready-made knowledge from the teacher. The low mastery of this concept has an impact on the inability to solve physics problems. Mastery concept as a whole is an absolute requirement in achieving the success of learning physics and in problem-solving ability [2]. Therefore, the mastery concept as a whole needs to be developed to support problem-solving abilities.

Problem-solving ability (PSA) is one of the high-level cognitive abilities that allow students to acquire knowledge and skills [3]. Meanwhile, Rokhmat, Marzuki, Kosim, & Verawati [1] revealed that PSA is the ability of students to express their ability to choose or deductively predict various possible consequences of a phenomenon, which contains one or more causes given, and is able to identify how one or more of these causes can produce a selected or predicted result. PSA consists of six problem-solving indicators (IPSA), namely as follows: IPSA-1 understanding, IPSA-2 selecting, IPSA-3 differentiating, IPSA-4 determining, IPSA-5 applying, and IPSA-6 identifying.

The results of several studies show that learning physics with causalitic-thinking has a positive effect on problem-solving abilities [4], [5], [6], [7], [8]). In addition, the implementation of physics learning based on causalitic-thinking processes also received a very positive response from physics education students [9].

With regard to the title of this article, the discussion in this paper is oriented to answer the following two questions: first, what are the characteristics of the learning instrument with a causalitic-model, second, how do the empirical test results influence the implementation of the causalitic-learning model on (a) problem-solving abilities, (b) physics-concepts mastery, and (c) the interaction between CLM and mastery physics-concept on PSA.

The causalitic-learning is a new model that was developed in 2013. This learning model facilitates students to have an ability to think causally and think analytically. In causality thinking, students analyze the causal factors and predict the potential consequences for each problem or phenomenon. In a statistical sense, the causal factor is the independent variable, while the effect is the dependent variable. The main orientation of the development of this learning model is the improvement of problem-solving abilities. However, this learning model is also very suitable for improving the ability of conceptual understanding of physics material because, in learning, the conceptual discussion has a very large portion compared to mathematical discussion [10]

2. Methods

This type of research is quasi-experimental with an untreated control group design with a pre-test and post-test. In this research design, two classes were selected as samples, one class as the experimental class and the other as the control class. At first, a preliminary test was carried out for students in these two classes to determine their initial problem-solving abilities. Furthermore, in the research process, students in the control class were given conventional learning while students in the experimental class were given learning using a causalitic-model. At the end of the research activity, a final test was carried out for students to determine the level of final ability of students' problem-solving. The description of this research can be seen in Table 1.

Table 1. Research Design with Untreated Control Group Design with Pretest and Posttest.

Class	Pre-test	Treatment	Post-test
Experiment	O_{11}	X_1	O_{12}
Control	O_{21}	X_2	O_{22}

(Adobted from Crewell, [11])

O_{11} = experimental class before being given treatment,
O_{12} = experimental class after being given treatment,
O_{21} = control class before being given treatment,
O_{22} = control class after being given treatment,
X_1 = learning using a causalitic-model, and
X_2 = conventional learning.

2.1. Population

The population was 396 students of class X Mathematical & Natural Science (MNS) of Public Senior High School 1 (PSHS 1) Narmada in the 2018/2019 academic year. The sample was taken using cluster random sampling technique and obtained MNS-1 class students as the experimental group (14 male and 16 female) and MNS-2 class students as the control group (9 male and 21 female). The research treatment using causalitic-learning model was carried out for five weeks on momentum and impulse materials. The data for the Problem-solving Abilities (PSA) were taken by mean four descriptive questions, while the data for the concept-mastery were the results of physics-tests from the teacher at the school. In learning with this causalitic-model, uses instruments of the syllabus, lesson plans, and student worksheets. This Causalitic-learning Model (CLM) has four phases, namely (1) the orientation phase, (2) the exploration phase, and the development of the concept of causality, (3) the argumentation phase, and (4) the evaluation [1].

2.2. Instruments

The instruments in this study included the syllabus, lesson plans, and student worksheets, as well as test kits. The first three instruments are used for learning with a causalitic-model while the last instrument, a test tool, is used to retrieve data on students' problem-solving abilities.

There are three main components in the student worksheets. Those are the physics phenomenon, the causality table, and the identification space. First, the physics phenomenon is in the form of a simple-composite causal model (SCoCM). With this model, in the phenomenon, there are two or more elements of cause as well as elements of effect [4], [6], [1]). The second component is the causality-table for writing down all elements causes and effects resulted from the exploration. Finally, the identification-space is a place for students to compile arguments to explain how the conditions of each causal element so all of them produce each predicted effect element.

The problem-solving ability test kit has four main parts. The first part, namely the phenomena, is equipped with statements regarding the potential consequences. The second part is a space to write down the choice statements that students think potentially occur. The third is a place for writing students' opinions of other consequences outside of the provided choices. Finally, the fourth is a space for writing an explanation of how the conditions of each causal element together result in the effect that has been selected in the second section or predicted in the third section.

2.3. Data analysis

Data were analyzed using two types of statistics, descriptive and inferential. Descriptive statistics to analyze the position of group data, such as the mean and mean. Furthermore, inferential statistics are used to analyze the effect of using the causalitic-learning model in learning on problem-solving abilities in terms of mastery of the concept. The statistical test used is the Anova-test.

3. Result and Discussion

3.1. Result

The study aims to test the effect of (a) the Causalitic-learning Model (CLM) on students' Problem-solving Ability (PSA), (b) mastery of physics-concepts on students' PSA, and (c) of the interaction between CLM and mastery concept on students' PSA. The mastery concept, which is a moderating variable, is for classifying students who have high and low concept mastery. The score of concept-mastery is sorted from highest to lowest then divided into two groups. The first group (with the high score) is named the high-group while the rest (with the low score) the low-group. Given that the number of samples in the experiment and control groups is the same, namely 30 students, the number of students in the high and low groups in the experimental and control class is 15 students each. The data from the grouping results are presented in Table 2.

Table 2. Experiment and Control Class Student Grouping based on Concept-mastery

Class	Concept-mastery	N	Max	Min	Mean
Experiment	Low	15	98	24	58
	High	15			
Control	Low	15	94	20	59
	High	15			

Table 2 shows that for students in the experimental class, the highest, lowest, and mean scores for mastery of physics concepts were 98, 24, and 58, respectively. For students in the control class, the highest, lowest, and mean scores of mastery of physics concepts are 94, 20, and 59, respectively. Furthermore, the results of the analysis of Problem-solving Ability (PSA) before and after the implementation of learning with a causalitic model for the experimental class and conventional learning for the control class obtained results as in Table 3.

Table 3. Recapitulation of Problem-solving Ability Score

Problem-solving Ability		N	Min	Max	Mean	Std. Deviation
Experiment Class	Pre-test	30	12	50	30	
	Post-test	30	33	88	61	
Control Class	Pre-test	30	8	50	27	
	Post-test	30	33	72	52	

Table 3 shows a recapitulation of the score of physics Problem-solving Ability (PSA) in the experimental and control classes. In both, the minimum, maximum, and mean scores have all increased. The lowest score increased from 12 to 33, the highest score increased from 50 to 88, and the mean value increased from 30 to 61 (experiment class). In the control class, the lowest score from 8 to 33, the highest score increased from 50 to 72, and the mean value increased increased from 27 to 52.

Tabel 4. Average & N-Gain of Problem-solving Ability Score

Class	Pre-Test	Post-Test	N-Gain
Control	25.70	52.40	0.36
Esperiment	29.90	60.00	0.44

Table 4 shows the mean and N-gain scores of the students' Problem-solving Abilities (PSA) in the experimental and control classes.

Table 5. Research Hypothesis Test with IBM SPSS 24 Assistance

Dependent Variable: Problem-solving Ability (PSA) Significance Level: 0.05

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	2504.183[a]	3	834.728	4.551	0.006
Intercept	190970.417	1	190970.417	1041.075	0.000
CLM	1033.350	1	1033.350	5.633	0.021
Mastery of Concept	1450.417	1	1450.417	7.907	0.007
CLM * Mastery of Concept	20.417	1	20.417	0.111	0.740
Error	10272.400	56	183.436		
Total	203747.000	60			
Corrected Total	12776.583	59			

The data on Problem-solving Ability (PSA) and concept mastery are then used as the basis for testing the effectiveness of the implementation of the Causalitic-learning Model (CLM) in improving PSA in terms of the students' mastery of physics concepts (Table 4).

Table 5 shows the results of the two-way ANOVA test using the SPSS 24 application. With a significance level of 0.05, the alternative hypothesis is accepted and the null hypothesis is rejected if the sig-score less than 0.05. In the table, it is found that the sig-score to test the effect of the implementation of the CLM on PSA is 0.021 (0.021 <0.05), to test the effect of mastery of physics concepts on PSA is 0.007 (0.007 <0.05). Meanwhile, to test the effect of the interaction between the implementation of the CLM and mastery of physics concepts on PSA, sig.-score is 0.740 (0.740> 0.05). With three sig.-scores, this means that the alternative hypothesis on the three tests is accepted, accepted, and rejected, respectively. Conversely, for the null hypothesis, respectively is rejected, rejected, and accepted. The effect of the interaction between the implementation of the learning model and the students' mastery of physics concepts on problem-solving abilities is presented in Figure 1.

Figure 1 shows no interaction effect between the Causalitic-learning Model (CLM) and mastery of physics concepts on Problem-solving Abilities (PSA). Graphically, the PSA for high group students is greater than that of the low group. These apply to students in the experimental class (doing learning with a causalitic-model) and students in the control class (doing conventional-learning). The two graphs (the top chart for students in the high group and bottom for students in the low group) appear roughly to be more likely to be parallel.

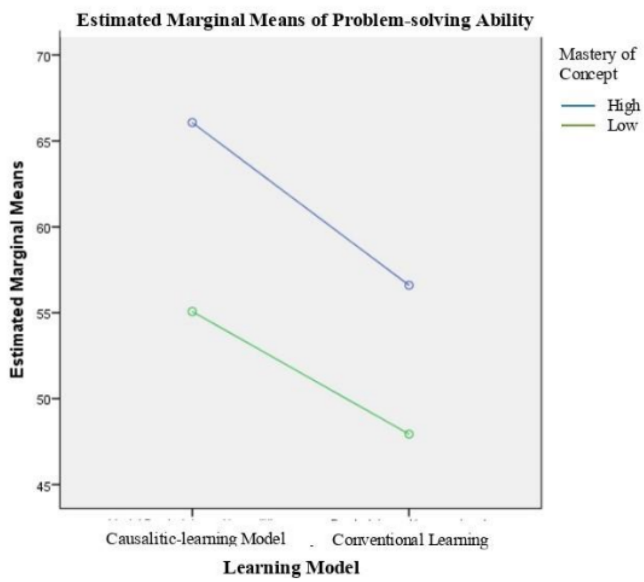

Figure 1. The Interaction Between the Causalitic-learning Model and the Students' Mastery of the Concept.

3.2. Discussion

Problem-solving Ability (PSA) must be explained as an estuary in every learning process. Practically, after completing the study, each student is expected to be able to solve problems related to everyday life. This underlies why in every lesson, PSA is placed as an essential orientation for every student.

As an estuary of all learning objectives, Problem-solving Ability (PSA) needs support by all higher-order thinking skills. In solving problems, it is necessary to carry out a critical analysis to obtain the key-problem. Next, it also needs to analyze the factors that cause the problem to occur. In this case, the problem is a result of these factors. Of course, PSA also needs the presence of knowledge related to these problems in students. The three sub-explanations above show that PSA is closely related to critical thinking skills, causality thinking, and conceptual mastery of knowledge. Of course, there are not only two thinking skills and the mastery of these concepts to optimize the PSA. These mean that other thinking skills are needed, such as synthesis thinking, systemic thinking, analytical thinking, and the other one.

The above paragraph can be interpreted that the process of developing PSA is complex. It is difficult to practice it in its entirety. Therefore, developing PSA needs to be done gradually and assistance at the early stage.

In developing critical thinking ability, one alternative way is to use multi-answer questions. This opinion is in line with Sarwanto, Fajari, & Chumdari [12] that stated the need to use open-ended questions for developing critical thinking. The use of these questions is relevant to the model of phenomena or problems used in causalitic-learning, namely phenomena or problems with a simple-composite causal model that have two or more elements of cause or effect [6], [10], [1].

Furthermore, the relationship of using knowledge as a support for developing PSA is also stated by Rudibyani, Perdana, & Elisanti [13]. They develop PSA based on knowledge assessment instruments. Meanwhile, related to the need for scaffolding in developing students' PSA in line with Rokhmat, et al ([6] & [1]), as well as Abugobar, Salheen, Yassin, Saed, & Yunus [14]. Rokhmat, et al [6] & [1] implement a scaffolding system in causalitic-learning, namely by providing information or exemplifying some of the work that must be done by students. Meanwhile, Abugobar, et al [14] uses scaffolding to help students learn English to be more fluent.

The word causalitic is an acronym for the words causality and analytic, so the term causalitic is related to the ability to think causality and analytics. Rokhmat [15] states that the process of causality and analytical thinking has five advantages, namely that with these two thinking, students are: 1) trained to analyze physical phenomena, 2) comprehend concepts comprehensively, 3) think critically and synthesize, 4) think comprehensively. divergent, and 5) solving problems based on the concept. Also, causal learning facilitates students to build their knowledge independently through group activities in solving physical phenomena and conducting classical discussions. This activity is by the principle of student-centered learning, that is, students are more active in learning. In line with this, Rokhmat [16] emphasizes that the causality thinking approach is centered on the activities of students. The student activity in question takes place when the student completes the tasks in the Student Worksheet and during discussion.

The results of hypothesis testing showed the influence of the causalitic-learning model on problem-solving abilities (sig. = 0.021 <0.05) (Table 5). Table 4 shows that the final achievement of students' PSA in the experimental class is higher than in the control class. The experimental class had an average score of 60.0 and an N-gain of 0.44, while the control class had an average score of 52.4 and an N-gain of 0.36. These two facts indicate that the implementation of physics learning with a causalitic model is more effective than conventional learning that is usually carried out by teachers in these schools. The results of this study are in line with research conducted by Tamami, Rokhmat, & Gunada [8], Nurmadiah, Rokhmat, & Ayub [17], Abdani, Rokhmat, & Rahayu [18], Anshori, Rokhmat, & Gunada [19], Faisal, et al [7], as well as by Nurjamilah, Rokhmat, Sahidu, & Harjono [20] all of which show that the causalitic-thinking approach and causalitic-learning have a positive effect on students' PSA.

Learning in the experimental class is focused on completing tasks and discussing them through causal thinking activities. This process is by the syntax of the Causalitic-learning Model (CLM), which consists of four phases, orientation, exploration, and development of the concept of causality, preparation of arguments, and the evaluation phase [1]. In learning, students are facilitated to be able to complete tasks in Student Worksheets (SWS) with the aim of training students in solving physics problems (momentum and impulse). Next, Nurjamilah, et al [20] stated that the implementation of causalitic learning improves students' reasoning abilities. Meanwhile, Anshori, et al [21] showed a positive effect of causalitic learning on creative thinking skills. The ability to reason does not stand alone but must be supported by other higher-order thinking skills, such as critical thinking and creative thinking. The ability to reason itself supports the development of Problem-solving Ability (PSA). Causalitic thinking can be divided into causality and analytic thinkings. The implementation of causality thinking requires other higher-order thinking skills, such as critical thinking, creative thinking, systems thinking [15]. Furthermore, analytic thinking in the context of causalitic learning requires the ability to reason. Some of these explanations show a strong relationship between causalitic-thinking ability and PSA. So through learning a causalitic model, the PSA of students can be improved.

Rokhmat, et al [4] stated that causality thinking includes understanding phenomena, determining causes, predicting effects, and distinguishing which causes as factors of every effect. Meanwhile, Rokhmat [15] stated when thinking analytically, students are required to be able to identify how the conditions of the causes that can result in each effect are based on the knowledge they already have which includes concepts, principles, theories, or physical laws.

The control class uses a conventional learning model. In this learning, students are still required to be active and given the opportunity to have discussions, presentations, and questions and answers. However, during the learning process, not all of the students were able to discuss well and understand the percentage that was delivered. During the question and answer process, students are less active and less enthusiastic. This is because most students only focus on how to solve the problems given, not on what concepts will be discussed. In addition, students cannot think openly in understanding a concept so that students' understanding of the concepts of momentum and impulse is not comprehensive and results in the problem-solving ability of the control class lower than the experimental class that uses the causalitic-learning model.

Comprehensive mastery of concepts is an absolute requirement in achieving the success of learning physics, and only by mastering the concept, all physics problems can be solved [2]. Therefore, by mastering concept as a whole, students have the potential to be able to develop problem-solving abilities more optimally.

The results of data analysis showed that the independent variable, namely the Causalitic-learning Model (CLM), had a positive impact on Problem-solving Ability (PSA). The average score of PSA in the experimental class is higher than the control class. The results also showed that the moderator variable, namely conceptual mastery, had a positive impact on students' PSA. This can be seen from the PSA of students who have high concept mastery, obtaining a better average score than students with low concept mastery both in CLM and conventional learning. In addition to mastery of physics concepts and problem-solving skills, the implementation of causalitic-learning has been shown to improve several other higher-order thinking skills, such as creative thinking skills, critical thinking, and reasoning abilities. Related to these three abilities, among others, as a result of research by Harwati & Rokhmat [22], Nurjamilah, Rokhmat, , Sahidu, Harjono, & Hikmawati [23], Rezeki, Rokhmat, Gunawan, Makhrus, & Wahyudi [24], and Warodiah, Rokhmat, Zuhdi, Kosim, & Ayub [25]

4. Conclusion

The results showed that the Problem-solving Ability (PSA) of students after learning with a causal learning model had increased. This means that there is an effect of the Causalitic-learning Model (CLM) on students' PSA. The CLM provides a better effect than conventional learning on the PSA of physics of students. Mastery of physics concepts also affects students' PSA. Students with high concept mastery have better PSA than students with low concept mastery. However, the interaction between the CLM and the mastery of physics concepts does not affect students' PSA.

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