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The Causal Model in Physics Learning with a Causalitic-thinking Approach to Increase the Problem-solving Ability of Pre-service Teachers

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ABSTRACT

The causal model is a specific relational pattern for the cause and effect of a phenomenon in learning with a causalitic-thinking approach (CTA) (causalitic means a combination of causality and analytic). This approach is oriented to increasing the problem-solving ability (PSA) of pre-service teachers and has been implemented in two subjects: work and energy, and thermodynamics. PSA includes the ability to understand (IPSA-1), select (IPSA-2), differentiate (IPSA-3), determine (IPSA-4), apply (IPSA-5), and identify (IPSA-6). This research aimed to investigate causal models in learning Physics, which are possible to develop for increasing PSA. This research was conducted by using a mixed method of an embedded, experimental, two phase design and used a sample of 49 students, with 39 females and 10 males. The differences between pre-test and post-test, and between the PSA gain of the low (Lo) and high (Hi) groups were tested using the Wilcoxon signed-ranks test. Results of the test on the subjects, among all pairs (24 pairs) of $t_{counted}$ and t_{table}, showed that there are differences of 71% (for pre- and post-test) and 33% (for Lo and Hi groups) that indicated $t_{counted} < t_{table}$. However, from the investigation of the physics phenomena used, there are six causal models as a result of the first year of this series of research. The models are simple causal model (SCM), divergent causal model (DCM), convergent causal model (CCM), chain causal model (ChCM), simple composite causal model (SCoCM), and chain composite causal model (ChCoCM). These models are useful as references when constructing phenomena for conducting Physics learning or learning for another discipline using this approach.

Keywords: Causal-model, causalitic-thinking approach, physics-learning, problem-solving ability

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INTRODUCTION

Many researchers have investigated learning strategies to improve the quality of physics learning. Examples of these are the use of conflict-cognitive learning (Baser, 2006); the process of meta-conceptual awareness, meta-conceptual monitoring and meta-conceptual evaluation (Yürük, 2007); interactive engagement (Hake, 2007); theorem-in-action (Escudero, Moreira, & Caballero, 2009); and the use of demonstration of three accelerated movements (Dykstra & Sweet, 2009). Other examples are the use of technology-enabled-active-learning (TEAL) studio format (Dori & Belcher, 2004); Powerpoint presentation and experimental demonstration (Obaidat & Malkawi, 2009); causal reasoning (Hung & Jonassen, 2006), Physics lecturing programme (PLP), which was designed to increase the ability to analyse and create (Rasagama, 2011); and the use of causality and analytical-thinking approach to increase students' problem-solving ability (PSA) (Rokhmat, 2013).

Rokhmat (2013) investigated the impact of a causalitic learning approach on the PSA for seven subjects: kinematics, Newton's law of motion, work and energy, linear momentum, gravity, rigid body equilibrium, and thermodynamics. He defines 'causalitic' as causality and analytic. He finds that the PSA increased significantly. In principle, this approach was oriented to facilitating students to develop their abilities in causalitic thinking.

Gopnik and Schulz (2007), and Meder (2006) gave three basic causal models, which are the divergent, convergent and chain models. Next, Rokhmat (2015) added two other models to them, which are simple and composite. He divided the composite model into simple and chain composites. As a result, there are six models of causal, which are simple, divergent, convergent, chain, simple composite and chain composite causal models; these are abbreviated as SCM, DCM, CCM, ChCM, SCoCM and ChCoCM, respectively.

As described previously, this paper focuses on discussing the six causal models and examples of their use in physics-learning phenomena. The discussion includes the conceptual presentations of the related physics-learning phenomena; and identifying their elements (which are the causes and effects) and which kind of causal model is appropriate. In the first year (of three years) of research, the causalitic-thinking approach was actually implemented in the seven subjects; however, in this paper, we only present its implementation in two subjects, i.e. work and energy, and thermodynamics because, statistically they would have been too many pairs for $t_{counted}$ and t_{table} ($t_{counted}$, t_{table}). There are18 pairs per-subject, so for the seven subjects it would have been 128 pairs of $t_{counted}$ and t_{table}. Finally, with respect to the title above, this paper is oriented to answer two questions: 1) how is PSA increased in the two subjects as a result of the CTA implementation. and 2) how examples of the causal models in physics learning.

Relating to the previous questions, we focus this literature review on three topics; the CTA, PSA and the causal model in Physics learning.

Causalitic-thinking Approach (CTA)

An approach is defined as a way of doing something. This paper regards this from the point of view of a learning process. Based on which is more active in the learning between a student and teacher, the approach is divided into two: student- and teacher-oriented approaches. In the former, the teacher has the role to facilitate the students exploring information by themselves. While, in the latter, a teacher is a source of information that they actively transfer to students.

Causalitic thinking (CT) is an abbreviation of 'causality and analytic thinking'. Paul (2003) divides thinking into eight elements, i.e. generating objectives, proposing questions, applying information, creating a concept, making a conclusion, making assumptions, generating understanding and realising a point of view. However, Gopnik and Schulz (2007) states a philosophical approach to causation theory, which is that it is difference-making, i.e. every cause will create a different effect. The cause must result in, or at least modify, the possibility for an effect to occur. This principle states that some causes are independent from space and time when resulting in an effect. Another principle is that the same initial conditions result in the same phenomenon series. In addition, two principles, Hill (2011) describes one principle of causality, i.e., that one event (a cause) will produce another event (an effect), and if the events are separated by space, they have to be separated by time.

Marzano and Kendall (2008) agreed that analytical thinking is higher-order thinking, while Amer (2005) revealed that analytical thinking is closed to creative thinking. He proposes that analytical thinking is a tool that is useful for understanding a phenomenon. The basic idea of analytical thinking is make a handful of elements, comparing them, give a rank, and finally select the most valuable and discharge the remainder. With respect to CT, analytical thinking refers to how well students can identify the conditions of causes so they result in the determined effect. Kasser (2006) mentioned that to identify, it needs an explanation, and, when establishing the explanation, it has to be presented in terms of facts, concepts, principles, theories and/or laws of physics.

In CT, a student completes some activities that are in line with the causality and analytic thinking. These are activities that are closed to causality thinking such as understanding phenomenon, determining causes, predicting effect and differentiating the causes that are factors of each effect. However, activities that are closed to analytic thinking include identifying the causes that result in an effect, codifying an explanation to correlate cause and effect, and establishing an argument for why the effects happen. To codify the explanation, it has to be presented in terms of facts, concepts, principles, theories and/or laws of Physics, which is closed to the causes and/or effects. Therefore, analytic thinking means determining and applying facts, concepts, principles, theories and/or laws of physics, and, finally, they are used for identifying or compiling an explanation of why the effect happens.

The elements of the CT agree with some elements of thinking, especially the elements that are stated by Paul (2003), and Kasser (2006). Congenialities exist between the CT and eight elements from Paul (2003), such as understanding CT in line with generating objectives and generating understanding, determining causes and predicting effects that agree with the generated objective, proposing questions, applying information and creating a concept, and differentiating causes is appropriate to proposing questions and creating concept. Furthermore, there are congenialities between CT and the ideas of identification from Kasser (2006) for at least two elements, i.e. identifying causes and explaining the relation between the cause and effect. Therefore, the elements of CT are in agreement for at least nine among the eleven (81%) elements of thinking described by Paul (2003), and Kasser (2006).

Problem-solving Ability (PSA)

In this paper, the term problem-solving ability (PSA) is deductively derived from several opinions such as Marzano and Kendall (2008), and Marzano and Brown (2009). Marzano and Brown (2009) agreed that it is necessary for students to use their knowledge in problem solving to generate and staunch their opinion. While, Marzano and Kendall (2008) gave recommendation for seven questions to encourage problem solving. The questions include determining what the objectives are, what the obstacles are, the way to handle obstacles, the best solutions, the real event, the congeniality between the result and solution, and/or the way to change thinking.

Marquardt (2004) explained two approaches to problem solving. The analytic approach is the first and is the approach through which he maintains that a phenomenon has only one solution. However, integrative approach is the second and the approach through which he proposes there are many solutions to one phenomenon. This approach is recommended in order to develop a multi-effect phenomenon. It varies as to whether there are one or more elements of cause in the phenomenon. Through this latter phenomenon, a student is facilitated to identify conditions of all causes and determine all of the possible effects.

Based on the two previous paragraphs, PSA is defined as two things. First, the ability to use knowledge to select and/or predict all effects when solving a phenomenon, and second, the ability to identify how causes result in each effect.

In general, PSA is defined as having the ability to solve a problem. With respect to causalitic thinking, PSA includes six indicators, i.e. understanding, selecting, differentiating, determining, applying and identifying (Gopnik & Schulz, 2007; Meder, 2006; Paul, 2003). Understanding is defined as the ability to know what the idea behind a problem is; selecting is the ability to determine which elements (in a problem) are the causes and which are the effects. A cause, statistically, is an independent variable and an effect is a dependent variable. Next, differentiating is defined as the ability to differentiate which cause (or causes) are factors of the effect. Determining is defined as the ability to establish the concepts, principles, theories and/or laws of physics that are related to each effect. Applying is defined as the ability to apply the concepts, principles, theories and/or laws of physics that explains why each effect occurs. And, finally, identifying is the ability to identify the conditions of the cause (or causes) so that it (they) results in the effect.

There is conformity between CT and PSA; to analyse a phenomenon and categorise the causes and effects needs an understanding of the idea and objective of the phenomenon, as well as the consideration and ability to analyse the differences. The three aforementioned needs (understanding, consideration and ability) are included in analytic thinking. Thus, analytic thinking has a significant role in causality thinking. This fact is in line with the findings of Amer (2005), Cohen (2000), Hamilton (2001), Paul (2003) and Zschunke (2000).

The three indicators of PSA (understanding, selecting and differentiating) and the interpretation of problem solving are summarised in the indicators for analytic thinking from Amer (2005), Cohen (2000), Hamilton (2001) and Zschunke (2000). The fourth and fifth indicators (determining and applying) support the ability to identify causes.

From the previous descriptions, it can be concluded that the ability for causality and analytic thinking supports PSA. Causality thinking directly supports the ability to select and/or predict effects in a phenomenon. However, analytic thinking supports the ability to identify how causes have the possibility of resulting in the determined effect. Thus, causality and analytic thinking supports PSA.

Causal Models in Physics Learning

Causal-thinking model: the three ideas with respect to the causal model of thinking from Gopnik and Schulz (2007), and Meder (2006) can be developed into six models. The models include three basic models (the divergent, convergent and chain models) and three other models from the development of the basic models (simple, simple composite, and chain composite models) (Figures 1 and 2).

Figure 1 shows four basic causal models; the circles represent the variables of events, while the arrows express the direction of cause-effect. The models are: (a) the SCM, where one cause X influences one effect Y; (b) the DCM, where one cause X influences two or more effects Y_1, Y_2 and so on; (c) the CCM, where two or more causes X_1, X_2, and so on influence one effect, Y; (d) the ChCM, where one initial cause Xinfluences one in-between effect Y, which influences one final effect Z. In addition, Figure 2 shows the combination of the four models (SCM, DCM, CCM and ChCM) into two further models: (a) the SCoCM and (b) the ChCoCM. In the SCoCM, two or more causes X_1, X_2, and so on influence two or more effects Y_1, Y_2 and so on, and in the ChCoCM, two or more initial causes X_1, X_2 and so on influence two or more in-between effects Y_1, Y_2 and so on, which influence two or more final effects Z_1, Z_2 and so on.

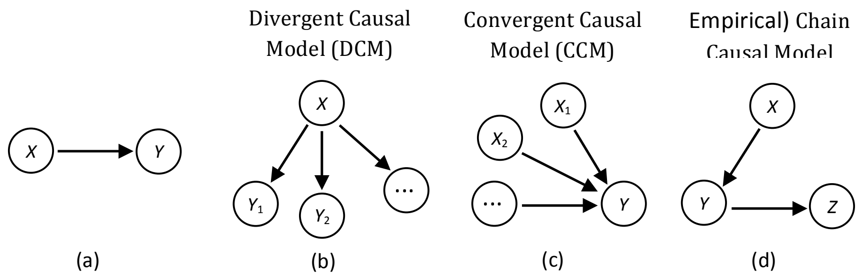

Figure 1. One Simple Causal Model (SCM) (Rokhmat, 2013; 2015; Rokhmat, Marzuki, Hikmawati, & Verawati, 2017) and three Basic Causal Models (Gopnik & Schulz, 2007; Meder, 2006)

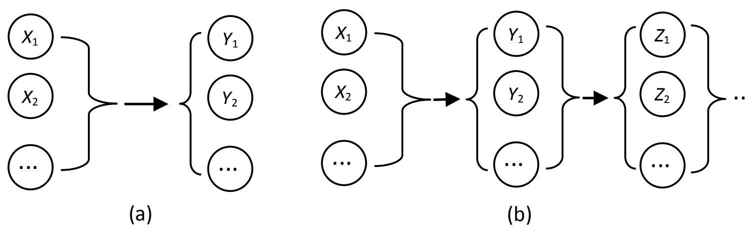

Figure 2. Composite Causal Models (CoCM) (Gopnik & Schulz, 2007; Rokhmat, 2015; Rokhmat, Marzuki, Hikmawati, & Verawati, 2017) (a) Simple (SCoCM) and (b) Chain (ChCoCM)

METHODS

This research (for the first of the three years) used a mixed methods of embedded, experimental design with a two-phase approach. This method uses a qualitative method as the main approach with a quantitative method embedded in it. The process for this research included four main activities; first, analysing the subject matter; second, designing the instruments; third, validating the instruments (expert and empiric); and forth, analysing and interpreting the instruments (Creswell & Clark, 2007) (Figure 3).

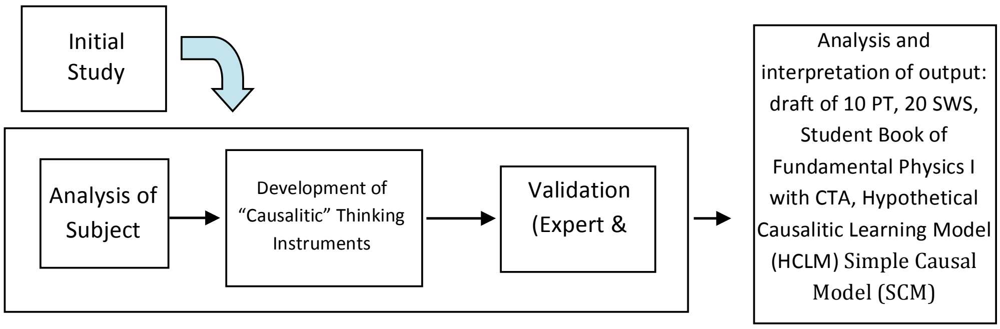

Figure 3. Two-Phase Embedded Experimental Design

Figure 3 is for the first year's (of three years) research design for one group pre-test–post-test (Suharsaputra, 2012) as a modification of Creswell and Clark (2007). In this design, the quantitative data are embedded in the qualitative data. The qualitative data were observed in analysing the subject, developing the instruments, validating the instruments, as well as in analysing and interpreting the results of this research. However, the quantitative data were collected during pre-test and post-test. The tests were conducted in the process of empirical instrument validation. A qualitative approach was needed to analyse the data including from filling in the attitude scale, observation and interviews. These data are related to the causal models and their characteristics. Furthermore, a quantitative approach was needed to analyse the results (increase) in PSA. Finally, information about the superiority and restrictiveness of the causal models, and about the PSA increase were useful to make recommendations to develop better instruments and for its implementation.

The subjects of this research were the students of the Physics Educational Programme at one university in Mataram in the 2015/2016 semester year. The sample included 49 students (ten among them males). In the empirical validation, we agglomerated the students into ten groups based on the results of the initial test; nine groups possessed five members, while the other one possessed four members. In the analysis, the subjects were agglomerated into three (approximately homogeneous) groups. Students with ranks 1 to 9 became group one, ranks 10 to 40 became group two, and, finally, ranks 41 to 49 become group three. We informed the first agglomeration but we did not announce the second one. Next, we named the first and the third groups, respectively, as the high (Hi) and low (Lo) groups. The aim of using these two groups was to analyse the increase in PSA while qualitatively validating the instruments. We gathered information on all students. Non-parametric statistic (test of location for two dependent groups), the Wilcoxon signed-ranks test (Minium, King, & Bear, 1993) was used to analyse the PSA increase and its N-gain difference between the Lo and Hi groups.

RESULTS

Increase of Problem-solving Ability (PSA)

The increase of PSA was obtained from calculating post-test minus pre-test. Its significance was determined using the values of $t_{counted}$ (value of t calculated from Wilcoxon signed rank test) and t_{table} (value of t from the table with a significance level 5%). We rejected the null hypothesis if the $t_{counted}$ equals or is less than t_{table} (Minium et al., 1993).

Table 1
Problem-solving ability (PSA) (%) from Pre-test (Pe) & Post-test (Po) for the Low (Lo) group

Subject	Indicators of Problem-solving Ability (IPSA)											
	IPSA-1		IPSA-2		IPSA-3		IPSA-4		IPSA-5		IPSA-6	
	Pe	Po	Pe	Po	Pe	Po	Pe	Po	Pe	Po	Pe	Po
Work and energy	11	28	6	28	0	17	11	33	0	17	0	19
Thermodynamics	22	96	33	63	0	30	11	74	0	30	0	26

Tables 1 and 2 show the percentage of PSA from the pre-test and post-test, respectively, for the Lo and Hi groups for the subjects of work and energy, and thermodynamics; visually, all indicators of the PSA (IPSA-1 to IPSA-6) increased. Table 3 indicates that all of the normal gains (Lo and Hi groups, and for the subjects) are positive.

Table 2
Problem-solving ability (PSA) (%) from Pre-test (Pe) & Post-Test (Po) of High (Hi) group

Subject	Indicators of Problem Solving Ability (IPSA)											
	IPSA-1		IPSA-2		IPSA-3		IPSA-4		IPSA-5		IPSA-6	
	Pe	Po	Pe	Po	Pe	Po	Pe	Po	Pe	Po	Pe	Po
Work and energy	39	100	11	56	0	56	33	100	0	67	0	43
Thermodynamics	30	89	26	63	4	33	26	82	7	41	4	30

Table 3
Normal gain of PSA for Low (Lo) group and High (Hi) group

Subject	Indicators of Problem Solving Ability (IPSA)											
	IPSA-1		IPSA-2		IPSA-3		IPSA-4		IPSA-5		IPSA-6	
	Lo	Hi	Lo	Hi	Lo	Hi	Lo	Hi	Lo	Hi	Lo	Hi
Work and energy	.19	1	.24	.50	.17	.56	.25	1	.17	.67	.19	.43
Thermodynamics	.95	.84	.45	.50	.30	.31	.71	.75	.30	.36	.26	.27

Table 4
List of $t_{counted}$ (t_c), number of effective data pairs (n) and t_{table} (t_t) resulting from the Wilcoxon signed rank test of each PSA indicator for work and energy

Attribute	Indicators of Problem Solving Ability (IPSA)																	
	IPSA-1			IPSA-2			IPSA-3			IPSA-4			IPSA-5			IPSA-6		
	t_c	n	t_t	t_c	n	t_t	t_c	n	t_t	t_c	n	t_t	t_c	n	t_t	t_c	n	t_t
Low group	0	3	-	0	4	-	0	3	-	0	3	-	0	3	-	0	7	2
High group	0	9	5	0	7	2	0	7	2	0	8	3	0	8	3	0	8	3
N-gain diff.	0	9	5	4	9	5	3	7	2	0	8	3	3	8	3	4.5	8	3

Next, Tables 4 and 5 reveal the list of tcounted (t_c), the number of effective pairs (n) and t_{table} (t_t) (for the PSA increase and its gain difference) for each subject. Pairs of $t_{counted}$ and t_{table} (t_{count}, t_{table}) for IPSA-1 to IPSA-6 for the Lo group are (0,-), (0,-), (0,-), (0,-), (0,-), (0,2) for work and energy, and (0, 5), (0, -), (0, 2), (0, 3), (0, 2), (0, 0) for thermodynamics. While, for the Hi group, the pairs are (0,5), (0,2), (0,2), (0,3), (0,3), (0,2) for work and energy, and (0,3), (0,3), (0,0), (0,5), (0,0), (0,-) at thermodynamics. Finally, the pairs of $t_{counted}$ and t_{table} ($t_{counted}$, t_{table}) for the PSA gain differences are (0,5), (4,5), (3,2), (0,3), (3,5), (4.5,5) at work and energy, and (3,-), (9.5,3), (12,2), (12,5), (12,3), (9,0) for thermodynamics. The value of t_{table} is related to the number of effective data pairs (for six, seven, eight and nine pairs, the t_{table}respectively are 0, 2, 3 and 5). It is clear that, there are 17 pairs (for the pre-and post-test difference) and nine pairs (for the N-gain difference) of $t_{counted}$ and t_{table}, with $t_{counted} < t_{table}$ for all groups and subjects, and so the null hypothesis was rejected.

Table 5
List of $t_{counted}$ (t_c), number of effective data pairs (n) and t_{table} (t_t) resulting from the Wilcoxon signed rank test of each PSA indicator for thermodynamics

Attribute	Indicators of Problem Solving Ability (IPSA)																	
	IPSA-1			IPSA-2			IPSA-3			IPSA-4			IPSA-5			IPSA-6		
	t_c	n	t_t	t_c	n	t_t	t_c	n	t_t	t_c	n	t_t	t_c	n	t_t	t_c	n	t_t
Low group	0	8	3	0	5	-	0	7	2	0	8	3	0	7	2	0	6	0
High group	0	8	3	2.5	8	3	0	6	0	0	9	5	0	6	0	0	5	-
N-gain diff.	0	2	-	9.5	8	3	12	7	2	12	9	5	12	8	3	9	6	0

Examples of the Causal Models in Physics Learning

Examples of causal models revealed the causes and effects in Physics that have the same relation as for one of the six models. The number of causes and effects for each physics phenomenon is basically indefinite. However, we could restrict them with a specific question, such as we can ask what will be a free body's experience with respect to its movement when a constant force acts to it. For this phenomenon, a constant force acts on a free body as the cause, while movement with constant acceleration is its effect.

The previous example is the pair of one cause and one effect, so is an SCM. For the DCM, we restrict it to ask for all possible happenings, both constant or change with respect to velocity, speed and acceleration of an object that is moving circling uniformly around a point, *P*. This phenomenon has one cause (the object moves uniformly in a circle around a point *P*) and three effects (its velocity changes uniformly, its speed is constant and its acceleration changes uniformly). For example, *f* the CCM, we can confine this to only ask for all possible directions of each velocity change when a ball moving, circling uniformly around point *P* with a constant speed *v* and where its velocity at four different positions (1, 2, 3 and 4) is always on a tangent to its orbit at that point. This phenomenon has five causes (moving uniformly in a circle around point *P*, and four vector velocities at points 1, 2, 3, and 4) and one effect (each velocity change is always towards point *P*).

Next, for the physics phenomenon in the ChCM, we can ask for all possible interaction forces (in series) between the block and the table when we put a block, which has weight *W*, on the table. In this example, there is one cause (the weight of block *W*), one in-between effect (the block presses the surface of the table downward with force $F_{downward}$) and one final effect (the surface of table holds back the block with normal force upward, *N*). In the SCoCM, for example, we may restrict this to asking for all possibilities where vehicles *P* and *Q* are in a side-by-side position when vehicle *P* is at rest athwart line *L* then moves to the right with constant acceleration a and, after few minutes, another vehicle *Q*, which is moving, also to the right, with constant velocity *v* crosses line *L*, and the trajectory of *P* and *Q* is side-by-side, straight and quite long. This physics phenomenon has three causes (vehicle *P* at rest athwart line *L* moves to the right with constant acceleration *a*, vehicle *Q* also moves to the right with constant velocity v across line *L*, and *P* crosses line *L* a few minutes before *Q*) and also three effects (*P* and *Q* will never be in a side-by-side position, will be in a side-by-side position one time, and will be in a side-by-side position two times).

Finally, in the ChCoCM, we can confine this to asking for all possible happenings that a block will experience with respect to the type of friction force, the shifting of its normal force, and whether the block remains at rest or moves (translational or rotational) when a homogeneous block *M*, with weight *W*, width a and height*2a*, is at rest on a table and a force *F* (its force line at a height of *h*) pulls it to the right, and it is known that the surfaces of both block and table are coarse (with static and kinetic coefficients of μ_s and μ_k, respectively, and $\mu_s > \mu_k$). In this example, there are eight causes, three in-between effects and three final effects. The eight causes are (1) weight of block M of *W*; (2) the size of the block, width *a* and height *2a*; (3) horizontal force *F* to the right; (4) the work line of *F* at height h above the surface of the table; (5) the static coefficient μ_s; (6) the kinetic coefficient μ_k; (7) value μ_s is greater than μ_k; and (8) the surface of the table holds the block with normal force upward, *N*, through the vertical symmetry line of the block. Next, the three in-between effects are (1) the block experiences a static friction force f_s (to the left), (2) the block experiences a kinetic friction force f_k (to the left), and (3) the normal force *N* shifts (to the right) so it ends up on the right side of the vertical symmetry line of the block. Finally, the three final effects are (1) the block *M* remains at rest, (2) the block *M* shifts to the right, and (3) the block *M* rolls in a clockwise direction.

It should be noted that the number of causes for a phenomenon is basically not absolute. For example, we may assume that causes 5, 6, and 7 are only one cause, i.e. the static and kinetic coefficients are μ_s and μ_k, with μ_s being greater than μ_k.

DISCUSSION

Modus of the Causal Model in Physics

What we commonly find in physics problems are CCMs (with multi-cause and mono-effect) due to there being only one answer to the problem. To increase creative thinking ability, problems with more than one correct answer (multi-effects) need to be developed. This agrees with causal models DCM, SCoCM or ChCoCM, but, among them, the SCoCM is the easiest to develop. In the SCoCM, we may arrange one or more of its causes as a variable and it is suggested to restrict them so that number of its effects is adjusted to the level of difficulty to make it possible for a learner to answer the problem. In addition to the number of effects, we can also direct the depth of its arguments by controlling on which concept, principle, theory and/or law they are based.

Relation of this Research to Some Previous Research

The three aforementioned models (DCM, SCoCM and ChCoCM) lineally encourage creative thinking which indicates that fluency, flexibility and/or originality will result from an open-ended task (Meyer & Lederman, 2015). However, Anwar, Aness, Khizatr and Muhammad (2012) stated that in addition to the three effects, the models also encourage elaboration. Fluency shows how many answers a learner has predicted, flexibility is related to how high a level of difficulty has been designed, originality is indicated from the additional answers written by a learner and, finally, elaboration is shown from how learners build their ideas. In addition, the models also have a similarity to the strategy used by Escudero et al. (2009). They facilitated undergraduate students investigating all possible knowledge (concepts and theories) about the phenomena (solid and hollow body, ball and cylinder, rolling on inclined coarse surface) through writing as many answers as possible about the knowledge they have gained).

While, Baser (2006) through conflict cognitive instruction (CCI) facilitated students to discuss contradictory facts (resulting from experiments) in relation to their previous conceptions. This instruction is in line with learning through CTA. Both foster the development of critical thinking, which needs analytical and causality thinking. Another conformity is that this CT develops a meta-concept, which also Yürük (2007) found in his research.

Effectiveness of the Causal Model in Physics Learning with a Causalitic-Thinking Approach (CTA).

The effectiveness of the causal model in physics learning with a CTA is indicated by an increase in PSA. Among the 24 pairs of $t_{counted}$ and t_{table} for each IPSA in the Lo and Hi groups, and for two subjects, 17 pairs (71%) indicate $t_{counted}<t_{table}$, which means that the PSA of students increased significantly. Furthermore, among 12 pairs of $t_{counted}$ and t_{table} for the N-gain difference between Lo and Hi groups, four pairs indicate $t_{counted}<t_{table}$, which means that the PSA increase for the Lo and Hi students was only 33%.

This fact means that using a causal model in the learning with CTA was effective in increasing the PSA of students, and the increases were not different between the Lo and Hi groups (it gives the same advantage for the Lo and Hi students). However, its final attainment was high, being only 8% in the Lo group and 33% in the Hi group. This means that the instrument still needs perfecting.

The positive impact of using the causal model in learning with CTA on the PSA agrees with the relation between the CTA and PSA, which was summarised from the statements of some experts. The experts include Amer (2005), Cohen (2000),Hamilton (2001), Paul and Elder (2003), and Zschunke (2000).

Restrictiveness of the Causal Model with CTA in Physics Learning.

There are some restrictions on the implementation of learning by using causal model with CTA. One of which is that it needs quite a long time to implement, so the lecturer had less time to discuss students' work, and it was difficult for students to solve the phenomenon. In addition, regarding the preparation of instruments and their implementation strategy, in general, each phenomenon needs a long description and we did not prepare a hand-out that is suitable for this type of learning. The restrictions did not foster the development of the CTA of students. This is caused by the fact that the process to select and/or deductively predict all possible effects needs initial knowledge.

To reduce the Restrictions of the Causal Model with CTA in learning.

It is advisable to include some stages for perfecting the instruments. Those are preparing a hand-out, using a shorter description of the phenomenon and, for 100 minutes of learning, it may need only one phenomenon to be studied. In addition, based on the final attainment of PSA (on average, this is moderate), it is advisable to design a causal model with the CTA in scaffolding form, i.e. with assistance to facilitate the students solving the phenomenon. Examples of the assistance are such as, for the causal model that has more than one cause and/or effect, we inform the students about some of them. In addition, we could also give an example of the explanation of the conditions for each cause so that they would result in the determined effect.

CONCLUSION

A causal model for Physics learning with CTA has been developed, which is significantly effective in increasing the PSA of students for the subsubjects of work and energy, and thermodynamics. The models are simple, divergent, convergent and chain causal, plus the composites of these four models, i.e. simple and chain composite causal models.

The PSA consists of six abilities, i.e. the ability to understand a problem; select causes and effects; differentiate which causes are the variables of the determined effect; determine the concepts, principles, theories and/or laws of physics; apply the concepts, principles, theories and/or laws of physics to identify the causes; and finally, identify how the conditions of all causes result in the determined effect. In addition, to increase the effectiveness of its instrument, it needs some actions for perfecting the instruments, which includes perfecting the design and strategy for implementation.

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REFERENCES

Amer, A., (2005). *Analytical thinking* (pp. 1-14). Cairo: Centre of Advancement of Postgraduate Studies and Research in Engineering Sciences, Cairo University (CAPSCU).

Anwar, M., N., Aness, M., Kizar, A., Naseer, M., & Muhammad, G. (2012). Relationship of creative thinking with the academic achievements of secondary school students. *International Interdisciplinary Journal of Education, 1*(3), 44.

Baser, M. (2006). Fostering conceptual change by cognitive conflict based instruction on students' understanding of heat and temperature concepts. *Eurasia Journal of Mathematics, Science and Technology Education, 2*(2), 96-108.

Cohen, G., A. (2000). *Karl Marx's theory of history*. US: Princeton University Press; OK: Oxford University Press, vii.

Creswell, J. W. & Clark, V. L. P. (2007). *Mixed methods research.* Thousand Oaks, CA: Sage Publications Inc.

Dori, Y. J. & Belcher, J. (2004). Improving students' understanding of electromagnetism through visualizations-a large scale study. The National Association for Research in Science Teaching Conference (NARST).

Dykstra, D. I., & Sweet, D. R. (2009). Conceptual development about motion and force in elementary and middle school students. *American Association of Physics Teachers, Am. J. Phys., 77*(5), 468-476.

Escudero, C., Moreira, A. M., & Caballero, C. (2009). A research on undergraduate students' conceptualizations of physics notions related to non-sliding rotational motion. *Lat. Am. I Phys. Educ., 3*(1), 1-7.

Gopnik, A. & Schulz, L. (2007). *Causal learning; Psychology, philosophy, and computation* (pp. 86-94). New York: Oxford University Press Inc.

Hake, R. (2007). Six lessons from the physics education reform effort. *Latin American Journal of Physics Education, 1*(1), 24-27.

Hamilton, A. (2001). *Managing subjects for success*. London: Albert Hamilton and Thomas Telford Limited.

Hill, S. E. (2011). Reanalysing the Ampere-Maxwell law. Retrieved from http://bulldog2.redlands.edu/fac/eric_hill/Research/Reanalyzing%20the%20Ampere-Maxwell%20Law.pdf

Hung, W. & Jonassen, D. H. (2006). Conceptual understanding & causal reasoning in physics. *International Journal of Science Education, 28*(13), October, 1601-1621.

Kasser J. L., (2006). *Philosophy of Science, part 2 of 3.* USA: The teaching company.

Marquardt, M. J. (2004). *Optimizing the power of action learning: Solving problems and building leaders in real time*. Mountain View, CA: Davies-Black Publishing.

Marzano, R. J. & Brown, J. L. (2009). *A handbook for the art and science of teaching.* Alexandria, VA: ASCD.

Marzano, R. J. & Kendall, J. S. (2008). *Designing and assessing educational objectives: Applying the new taxonomy.* Thousand, CA: Corwin Press.

Meder, B. (2006). *Seeing versus doing: Causal bayes nets as psychological models of causal reasoning,* (Dissertation, zur Erlangung des Doktorgrades der Mathematisch-Naturwisshensclaftlichen Fakultaten- Universitat zur Gottingen).

Meyer, A. A., & Lederman, N. G. (2015). Creative cognition on secondary science: An exploration of divergent thinking in science among adolescents. *International Journal of Science Education.* Retrieved from http://dx.doi.org/10.1080/09500693.2015.1043599.

Minium, E. W., King, B. M., & Bear, G. (1993). *Statistical reasoning in psychology and education*. New York, NY: John Wiley & Sons, Inc., 488-489, 579.

Obaidat, I. & Malkawi, E. (2009). The grasp of physics concepts of motion: Identifying particular patterns in students' thinking. *International Journal for the Scholarship of Teaching and Learning, 3*(1), January, 11-12.

Paul, R. & Elder, L. (2003). *The foundations of analytic thinking: The elements of thinking and the standards they must meet* (2nd ed.). Retrieved from www.criticalthinking.org

Rasagama, I. G. (2011). *Pengembangan program perkuliahan fisika untuk meningkatkan kemampuan menganalisis dan mengkreasi mahasiswa teknik konversi energi politeknik [The development of physics lecturing programme to increase ability to analise and create for students of energy conversion technical of polytechnic]* (Unpublished doctoral dissertation, Universitas Pendidikan Indonesia).

Rokhmat, J. (2013). *Peningkatan kemampuan pemecahan masalah mahasiswa calon guru fisika melalui berpikir kausalitas dan analitik [The increase of problem-solving ability of physics pre-service student through causality and analytic thinking]* (Unpublished doctoral dissertation), Universitas Pendidikan Indonesia.

Rokhmat, J. (2015). *Pengembangan model pembelajaran berbasis proses berpikir kausalitas dan analisik untuk meningkatkan kemampuan pemecahan masalah mahasiswa calon guru [The development of learning-model based on causality and analytic thinking to increase problem-solving ability of pre-service teacher]*. Penelitian Strategis Nasional: Universitas Mataram.

Rokhmat, J., Marzuki, Hikmawati, & Verawati, N. N. S. P. (2017). Instrument development of causalitic thinking approach in physics learning to increase problem solving ability of pre-service teacher. *American Institute of Physics Conference Proceeding, 03000-3 - 03000-5*.

Suharsaputra, U. (2012). *Metode penelitian, kuantitatif, kualitatif, dan tindakan [The method of quantitative, qualitative, and action research]*. Bandung: PT Refika Aditama.

Yürük, N. (2007). A case study of one student's metaconceptual processes and the changes in her alternative conceptions of force and motion. *Eurasia Journal of Mathematics, Science and Technology Education, 3*(4), 305-325.

Zschunke, A. (2000). *Reference materials in analytical chemistry.* Berlin, Germany: Springer Verlag Berlin Heidelberg.