

PAPER • OPEN ACCESS

## Analysis of Students' Causal Reasoning in Physics Problem Solving

Recent citations

- [Causal reasoning in understanding Newton's third law](#)  
Cheng Chen *et al*

To cite this article: M Mustakim *et al* 2020 *J. Phys.: Conf. Ser.* **1521** 022058

View the [article online](#) for updates and enhancements.



### 240th ECS Meeting

Digital Meeting, Oct 10-14, 2021

**We are going fully digital!**

Attendees register for free!

**REGISTER NOW**



# Analysis of Students' Causal Reasoning in Physics Problem Solving

M Mustakim<sup>1</sup>, J Mansyur<sup>1</sup>, A Hatibe<sup>1</sup>, M Rizal<sup>2</sup>, and S N Kaharu<sup>3</sup>

<sup>1</sup> Pendidikan Sains, Program Pascasarjana, Universitas Tadulako

<sup>2</sup> Pendidikan Matematika, Program Pascasarjana, Universitas Tadulako

<sup>3</sup> STMIK Bina Mulia

\*corresponding author's email: [jusman\\_mansyur@untad.ac.id](mailto:jusman_mansyur@untad.ac.id)

**Abstract.** This research was aimed to describe the causal reasoning of students in physics problem-solving. The research subjects were students of Physics Education Study Program of Universitas Tadulako. The research respondents consisted of two students obtained through a selection test of respondents representing the categories of high ability. Data collection through thinking-aloud activity and it was followed by an interview. The thinking-aloud data were analyzed according to Pearl which illustrates how students use students' causal reasoning in solving the problem. Based on data analysis it can be concluded that causal reasoning has an important role for students when solving the problem. The causal reasoning process conducted by the respondents through the collection of information from the problem; structural equalization of the problem elements with elements of events known by the respondents; reviewed information for the provision of intervention or manipulation in the appropriate decision-making; and made a conclusion by considering a paradox and conflicting of the data on the problem.

## 1. Introduction

Research on causal reasoning has been carried out by researchers in the field of education, especially in physics education. Causal framework is Proposed [1] and [2] claimed that the way to present a more plausible by elaborating Pearl's framework in the application for the case of cause and effect. A tendency among physicists to avoid discussion of circle causal involving intentional action because the deliberate action is the best way to make a mystery to be fortuitous [3]. A learner can be helped to achieve a better understanding of the causal model as what they learned in various concepts and topics in science [4]. Some physics concepts are indeed abstract [5], like astronomy as a mature science at the time and they noted that the science was less concerned about things that can not be observed as well as nature and explicit functional relationship [6]. The role of irregularities causal when used with assumed on a pattern of the dispersion relation is a testament to the fact that the idea of a causal asymmetrical [7]. For example, a way in which the theory of general relativity to understand the sound field paved the way for a causal conception of nature sounds [8]. In this context, causal claims to be objective and we do not need to make a postulate the existence of additional specific facts for regular physical facts as described by theoretical physics [9]. The number of research on causal reasoning especially in the field of physics can improve aspects in the field of education such as student's learning outcomes and understanding. The process of reasoning is a benchmark that can be used to see how a



person has a maturity in thinking that is usually associated with causation or the so-called causal reasoning process. Based on the results of the review journal research about causal reasoning may be a new thing that can be used as a reference, especially in science education and become something that can be considered by educators in assessing their learners.

Pearl [1] following a few propositions on the interference cause and effect. Although the relationship between cause and effect is essentially deterministic, it explicitly makes exceptions to the quantum mechanical phenomena of the concept of cause and effect. The cause and effect analysis includes probability languages. The language of probability helps convey uncertainty about cause and effect relationships but is not sufficient to fully address the relationship. In addition to conditional event probabilities, cause and effect analysis require graphs or diagrams and languages that distinguish the intervention or manipulation of observations. Cause and effect analysis also requires counterfactual reasoning and causal assumptions in addition to observations and statistical assumptions, including:

- a. Collect information on elements present in an event.
- b. Construct the previous elements into concluded causal theories.
- c. Focus on causal diagrams and identify causal influences.
- d. Examine the actual causal effects and examine the effect of intervention or manipulation.
- e. Taking into account the model of causality and structural equations.
- f. Discusses paradox and contradictory data.
- g. Approach to the placement of randomized imperfect experiments through counterfactual and binding effects.
- h. Analyze important and common causal ideas.
- i. Explain a single event causality concept.

The nature of books from various disciplines has a high percentage which sometimes makes it difficult to read because the concluded causal theory combines econometric and statistical languages, mathematical graphics theory, and Bayesian networks with the philosophical ideas of cause and effect. Even so, Pearl [1] facilitates early readers to understand by using fairly simple mathematics and examples that help connect the discourse of different disciplines. Thus, we will conduct research with the aim to describe the causal reasoning of students in physics problem-solving.

## 2. Methods

This research used a qualitative research method or often referred to as naturalistic research methods because the research is done under natural conditions. Sugiyono [10] stated that qualitative research method is a research method that is used to examine the condition of natural object, (as opposed to experimenting) where the researcher is a key instrument, data collection technique is done by triangulation (combination), data analysis is inductive, and the results of qualitative research more emphasize the meaning of the generalization.

The research was carried out in the Physics Education Study Program at the Teacher Training and Education Faculty of Universitas Tadulako.

Research Subjects in this research were Physics Education Study Program students FKIP-UNTAD. The respondents were obtained based on the respondent selection test. Based on the test results of the selection of respondents, we selected two respondents representing the category of high ability.

## 3. Results and Discussion

The first data were collected by giving the respondent selection test (TSR) in the class which has 33 students who have gone through the elementary physics course 2 and the school physics 2. The selection is done to see the causal reasoning of the respondents related to the mindset in connecting each science to solve problems.

The TA process performed by each respondent representing three categories of abilities is illustrated in a transcript of TA that describes a causal reasoning indicator. The causal reasoning indicator consisting of nine indicators only six indicators became the focus of the study. The causal reasoning indicators that are the focus of research are as follows:

- Collect information on existing elements in an event (PKa).

- Constructing the previous elements into a concluded causal theory (PKb).
- Focus on causal diagrams and identify causal influences (PKc).
- Examine the actual causal effects and examine the effect of intervention or manipulation (PKd).
- Pay attention to the model of causality and structural equations (PKe).
- Discusses paradox and contradictory data (PKf).

### 3.1. Causal reasoning high ability category (1)

#### 3.1.1. Respondents 1 to Category High Ability (RT-1).

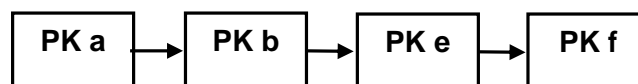
TA process performed RT-1 in solving a problem (Problem 1) due to the using of causal reasoning in four stages. The process of causal reasoning conducted by RT-1 was first to begin the process of causal reasoning is collecting information in an event such as the RT-1 said “... I know there are two cases mentioned that the first aircraft with the laws of Bernoulli and the second balloon gas to the law of Archimedes then asked whether the principles used in aircraft horizontally same air with the principles of the blimp to move horizontally in the air (?) ...” the process of gathering information in an event (PK a) that do will help RT -1 in problem-solving.

RT-1 said: “... for the A's ... (...) (+) is not the same principle (-) because if it's own aircraft he was able to move horizontally, e ... he is using the law of Bernoulli wherein (+) aircraft can move because the pressure (-)...” which describes the information collected previously by RT-1 helped in establishing the theory of causation and concluded (PK b); “... let's say the train was moving, velocity, means {we} will, because the pressure is large ( ) because in part (wiggle hands) great speed, because she bit so ( ) times so does the concept (?) ...” which describes the process of structural equation of an event which is known by RT-1 causal with the problems it faces (PK e) might be helpful RT-1 in problem-solving faced; “... so the answer is not the same as to move horizontally ( ) Aircraft that he has if he can horizontal he already {balance} she got a machine here but if the blimp as it is propelled by the wind ...” which describes the process of discussing the paradoxes and conflicting data (PK f) conducted by RT-1.

The causal reasoning of RT-1 to solve problems that the respondents are facing already successful but RT-1 encountered an error in understanding the concept of the Bernoulli law until the end of problem-solving. Excerpts of interviews of the researcher (P) of the RT-1 as follows:

- P : Are there any conflicting issues in the number one thing you read?  
 RT-1 : yes. contrary  
 P : Can you point out conflicting issues in number one you read and explain it?  
 RT-1 : if the case of airplanes and air balloons that it is different how it works that I know so if the plane to fly horizontally that if he can move that horizontal if it can balance the same above the same style that if the balloon air he can move horizontally because eyes blowing in the wind.

The causal reasoning process of RT-1 in resolving Problem 1 can be seen in Figure 1.



**Figure 1.** The Scheme of RT-1's Causal Reasoning Process for Problem 1

#### 3.1.2. Respondents 2 with High Ability category (RT-2).

TA process performed RT-2 in solving Problem 1 in the process of causal reasoning favoring structural equation and paid attention to cause and effect. RT-2 encountered an error in understanding the concept of the law of Archimedes until the end of problem-solving and how to move horizontally so that the RT-2 cannot complete the problem-solving process. The result of interview session can be seen in the following (Researcher = P):

- P : Are there any conflicting issues in the number one thing you read?  
 RT-2 : No

P : Is there any information or data that is not true on question number one?

RT-2 : I think no

The causal reasoning process of RT-2 in resolving Problem 1 is presented in Figure 2.



**Figure 2.** The Scheme of RT-2's Causal Reasoning Process for Problem 1

### 3.2. Causal reasoning about the high capability category (2)

#### 3.2.1. Respondent 1 with a high capability category (RT-1).

TA process performed RT-1 in solving Problems 2 consisted of four stages. In the early stage, the causal reasoning process performed by RT-1 was collecting information included in an event (PK a). The process can assist the respondent in solving the problem.

RT-1 said "...I know that when the object (drawing cube) ( ) all or any portion of that volume is above the surface of the water was still in the category of floating..." a portrait of the development process theory of causation and conclusions (PK b) that RT-1 will be used as the basis for the settlement of the problems and the equation structural between image cube made RT-1 with the problem and pay attention to causal (PK e) which will help the RT-1 in solving the problem. Then, RT-1 said "...floating means he's all over it is above the surface of the water or is he just some part (-) of the volume (+) present on the surface of the water was still in the category of floating..." which describes the process of assessment of the information that is to manipulate and intervene (PK d), RT-1 in taking the right decisions to resolve the problem. RT-1 said "... so to say whether the submarine almost floating in the category is already floating..." which describes not its impact on RT-1 with the information that is to manipulate and intervene in taking appropriate decisions to resolve the problem.

The process of causal reasoning by RT-1 in solving the problem was in a very good category. RT-1's reasoning capabilities are in the excellent category which greatly helped him in solving the problem. Excerpts of an interview of the researcher (P) of the RT-1 as in the following:

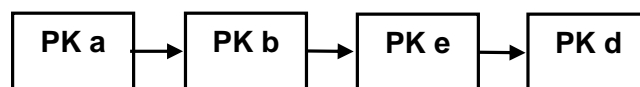
P : on the answer sheet for question number two you write "to part a) is not in the category of almost floating, but is said to have been afloat and to section b) can be said to be drowning or other terms drift" my question, whether there is information or data about the number one that affects your answer like this?

RT-1 : yes

P : Can you show information or data that affects your answer like this on number three?

RT-1 : It seems to me that this "appears 3/7 for type 1650 and for type 950 appears 4/5 for part a and almost sinks for part b" so equally there appear so I can categorize these two floating vessels

The causal reasoning process of RT-1 in solving Problem 1 can be seen in Figure 3.



**Figure 3.** The Scheme of Causal Reasoning Process RT-1 for Problem 1.

#### 3.2.2. Respondents 2 with the category of high ability (RT-2).

TA process performed RT-2 in solving Problem 2 consisted of the causal reasoning process in three stages. Overall causal reasoning process performed by RT-2 in solving the problem was in good category. The reasoning ability of RT-2 is very helpful to solve the problem. Excerpts of interviews of the researcher (P) of the RT-2 is presented in the following:

P : Is there a conflicting problem in the number two you read?

RT-2 : Yes

- RT-2 : I think you have this. Actually, I think the submarine, the submarine is using the principle Archimedes so I have ever read that submarine if he wants to float he's got air cavity so he can float if he wants to sink it, I think no
- P : Is there any information or data that is incorrect in question number two?
- RT-2 : Yes
- P : Can you indicate incorrect information or data on two?
- RT-2 : Submarine almost floating, right should I think it floats in here it appears and this is almost drowned because I think it is not nearly drowned but drowned.
- The causal reasoning process of RT-2 for Problem 2 can be seen in Figure 4.



**Figure 4.** The Scheme of Causal Reasoning Process of RT-2 for Problem 2.

### 3.3. Causal reasoning about the high capability category (3)

#### 3.3.1. Respondent 1 with a high capability category (RT-1).

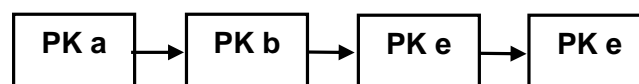
The process of TA conducted by RT-1 in solving the problem performed an issue of causal reasoning with three stages.

The causal reasoning process performed by RT-1 was first to start the process of reasoning the collection of information included in an event (PKa). The process assisted RT-1 in solving the problem. RT-1 and then performed the development process and the theory of causal inference (PKb) as a basis for the settlement of the problem.

In the thinking-aloud session, RT-1 said “...*F times A is equal to p (write formulas) so that the pressure is said to be twice the surface area, the surface area is big pressure small...*” and “...*A1v1 equal to A2v2 (write formulas) surface area is inversely proportional to k...*” which describes the process of structural equations among the equations are known to RT-1 with the problem and pay attention to causal (PKe), which will help RT-1 in solving the problem. The amount of knowledge possessed RT-1 on the applicability of the concept in everyday life making more frequent use of the equation structural an event with the problems it faces by considering causal (PKe). At the end of the TA process, RT-1 “...*broad cross-section of the inversely proportional to the fluid velocity. ( ) For example ... if I hit it faster...*”. The process of causal reasoning was in a good category. Excerpts of an interview with the researcher (P) to RT-1 as in the following:

- P : On the answer sheet for question number three you write “Fluid velocity flowing in pipes installed (which is a smaller cross-section) is greater than excl. fluid flowing in the pipe with a larger cross-section. Because this is the cross-sectional area is inversely proportional to fluid velocity”. Whether there is information or data on the number one problem that affects your answers like this?
- RT-1 : Yes
- P : Can you show the information or the data that affect your answer like this in problem number three?
- RT-1 : Sectional area and fluid flow velocity

The causal reasoning process of RT-1 for Problem 3 can be seen in Figure 5.



**Figure 5.** The Scheme of Causal Reasoning Process RT-1 for Problem 3.

#### 3.3.2. Respondent 2 with the category of high ability (RT-2).

TA process performed RT-2 in solving problems or answering question number three process stages causal reasoning by as much as two stages. Overall causal reasoning process performed RT-2 in solving

the problems faced can be said to be lacking. Reasoning ability RT-2 that can be said about this does not help in solving the problems faced. Excerpts of interviews researcher (P) of the RT-2 :

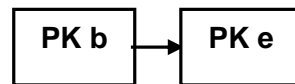
P : on the answer sheet for question number three you write “speed of fluid flowing in the pipe is installed has a fluid velocity equal to the main pipe even though the main pipeline even though the main pipe of a pressurized 2-fold greater” my question, Whether there is information or the data the number one problem that Affects your answers like this?

RT-2 : I think here (appoint while playing pipe picture) with here (appoint while pipes installed image)

P : Means the big pipes and small pipes at the same speed?

RT-2 : I do not understand but there is also that I have read the more he cross section was small Ir velocity was quickly intervening so but I was confused it's a cross-section A2 it's small compared to A1, for example like a hose that if he turned down that is velocity is greater...I also confused

The causal reasoning process of RT-2 for Problem 3 can be seen in Figure 6.



**Figure 6.** The Scheme of Causal Reasoning Process of RT-2 for Problem 3.

#### 4. Conclusion

These results indicate that the causal reasoning has an important role in students when solving problems. Causal reasoning process performed by the respondents, initially collecting information on the problems faced by structural equation then continued between events and problems faced by paying attention to the elements of the problems faced by elements of the unknown event. The next causal reasoning process undertaken by the respondents was by reviewing the information to intervene or manipulate the respondent in making the right decision. The respondents made a conclusion by discussing the paradoxes and conflicting data on the problem.

#### 5. References

- [1] Pearl J 2000 *Causality: Models, Reasoning, and Inference* (U.S.A.: Cambridge University Press)
- [2] Menzies P 2002 *Causal Models, Token-Causation, and Processes* (Sydney: Philosophy of Science)
- [3] Hanley R 2004 No End in Sight: Causal Loops in Philosophy, Physics, and Fiction *Synthese* **141** 1 123-152
- [4] Perkins D N, and Grotzer T A 2005 *Dimension of Causal Understanding: the Role of Complex Causal Models in Students' Understanding of Science* (U.S.A.: Harvard University)
- [5] Aminudin A H, Adimayuda R, Kaniawati I, Suhendi E, Samsudin A, and Coştu B 2019 Rasch Analysis of Multitier Open-ended Light-Wave Instrument (MOLWI): Developing and Assessing Second-Years Sundanese-Scholars Alternative Conceptions *Journal for the Education of Gifted Young Scientists* **7** 3 557-579
- [6] Hastjarjo D 2008 *Ringkasan Buku Cook and Campbell. Quasi-Experimentation: Design & Analysis Issues for Field Setting*
- [7] Frisch M 2008 *Causal Reasoning in Physics* (Cambridge: Cambridge University Press)
- [8] Esfeld M 2010 Physics and Causation *Foundations of Physics* **40** 9-10 1597-1610
- [9] Elgin M 2010 How Could There Be True Causal Claims Without There Being Special Causal Facts in the World? *Philosophia* **38** 4 755-771
- [10] Sugiono 2013 *Memahami Penelitian Kualitatif* (Bandung: Alfabeta)