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Kinematics of “Traffic Light”: A Socio Scientific Issue Performed by Undergraduate Physics Students

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Abstract. This research proposes an approach, especially on the socio-scientific issue in relating to the kinematics of traffic light (TL). The research utilised the one-shot case study that, an experimental treatment - modelling of SSI of the kinematics of TL is administered and then a post test is conducted to measure the effects of the treatment. Through the course of Physics for School, twenty-five junior physics students (3 males and 22 females) participated in the study. The results showed three main themes of the SSI item developed by students including: what should the driver do in the road for safety regarding the TL?; how much do the constant velocity for certain light of TL?; and which one the car across the TL?. Students' understanding of SSI issues on the kinematics of TL ranging from 48 to 92 point of 24 items. All items categorised as reasoning items and belong to HOTS; these questions are also contextual. It teaches us an orderly culture of traffic and road safety. Moreover, it also gives a lesson about science for all and science communication.

1. Introduction

Many socio-scientific issues (SSIs) relate to physics. Socio-scientific is an issue used in strengthening the process of students' argumentation *vis-à-vis* in discussing, debating, and solving problems [1]. Most of the physics taught in school can be described as well-established or consensus science. It is essential for teachers in providing broader images of science [2]. In this article, the author proposes 'the physics around traffic light (TL)'. This theme deals with road safety that can be described logically as an example of SSI. In a simple explanation, the relationship between physics and road safety can be seen from the side of the driver and the vehicle used. In the process of braking, visibility at high-speed and the speed of responding from sudden events on the highway are some of the physics events that are on the highway.

The following is a more detail illustration. Naturally, in a pedestrian creature, people are only able to anticipate something that suddenly appears in front of him if he moves below 10 km/h. If it moves above that, it cannot escape. This ability is related to people speed in reacting. Generally, people need 0.8 to 1 second to react. If someone drove a vehicle with a speed of 50 km/h, then the time of 1 second to react is equal to 14 meters (estimation) because 50 km/h is equal to 14 m/s. Meanwhile, a car going 50 km/h requires 14 m to fully stop. So, the total distance needed to stop fully is 28 m. At speeds of 90 km/h, the total distance required is 70 m, whereas, at a speed of 130 km/h, the total distance required is 129 m.

The next illustration is in TL settings. In general, the green-yellow-red flame at a crossroads has a certain duration of time. The duration setting of the TL at the intersection is needed to overcome the congestion. It can occur if the calculation of the duration of the TL used is incorrect. As an example of the results of research related to the analysis at a crossroads so that congestion does not occur as follows. The results obtained at Crossing 'X' are the duration of the green light from the north which



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is 60 seconds, the duration of the red light from the north 100 seconds, from the east 60 seconds, from the south 90 seconds, and from the west direction 75 seconds.

In the case of Indonesia, ATCS or Area Traffic Control System is a form of a centralized TL control system (TLCS), where all TLCS elements are connected with communication links between the controller in the field and the computer in the central control system or Central Control System Room [3]. ATCS in Indonesia began in the 1990s, from 3 Big Cities: Surabaya with SAINCO-Spanish Vendors; Jakarta, with vendors SAINCO, Telnic (SCATS), and Siemens (SCOOT); Bandung with AWA-Plessey - Telnic Vendors as local partners (SCATS). SCATS and SCOOT are the most widely applied ATCS throughout the world. The term ITS or Intelligent Traffic System is now popular. This ITS combines ATCS with other information systems, so that data obtained from ATCS can be processed for wider purposes, such as information on VMS (Variable Message Sign), incident and traffic jam information for road users, and provision of CCTV streaming [3].

The third illustration is related to traffic signs. Specifically, there are traffic signs in Indonesia that read $E = mc^2$ contained in the Minister of Transportation Regulation No. 13 of 2014 concerning 'Traffic Signs'. These signs are in the category of 'Instructions for Location of Educational Facilities'. There are two that fall into the category of educational facilities, namely School Location Guidelines and Library Location Guidelines. It is clear that SSI is present in physics.

The three illustrations above show socio scientific issues in the kinematics of motion that need to be analysed especially for undergraduate physics students. However, there are not many trying to present the above illustrations in physics class from junior school to university. If it is done, it is only limited to the general problems presented in class. The following are examples of common problems.

Car P moves from the TL with a fixed speed of 15 m/s. 10 s then car Q moves from the TL with a limited speed of 20 m/s following the P car, determine the distance travelled by the P car when the two cars meet!

This problem can be solved by the concept of straight motion. To determine the distance of the two cars when they meet, pay attention to the graph so that the two meet then the two marks must be the same, on the $v-t$ graph, the distance is the area under the graph, then the vertical shading area must be equal to the horizontal shading area so

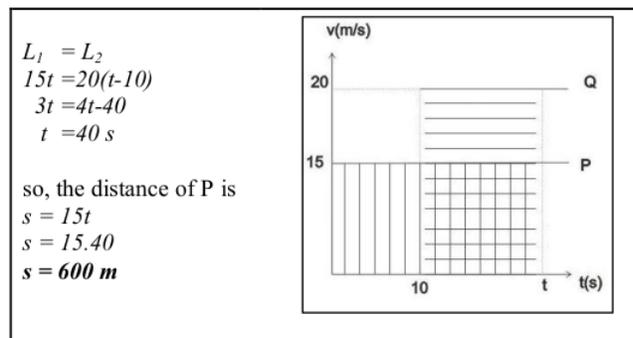


Figure 1. The graph of velocity versus time of common problem in the TL.

Previous researchers have also considered the issue of kinematics, such as research on vehicle-pedestrian collisions that are focusing on aspects regarding pedestrian kinematics, dynamics and biomechanics [4], a methodology for assessing the risk of road accidents during the transportation of schoolchildren [5]. However, those researches emphasised on the aspects of collision and safety as part of SSI. No previous research that specifically considers to traffic light. This research proposes another approach, especially on the socio-scientific issue in relating to the kinematics of traffic light. Figure 2 gives a brief illustration of the context of this research.



Figure 2. The illustration of the context of SSI: ‘the physics around traffic light (TL)’ [6,7].

In order to make the research more focused, then the following are the research questions:

- a) To what extent the variation of item test created by undergraduate physics students?
- b) To what extent do the undergraduate physics understanding of the concept of kinematics of traffic light?

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2. Research Method

2.1. Research Design

The research utilised the one-shot case study as part of single-group designs [8]. In this design, an experimental treatment (T), a modelling of SSI of kinematics of TL is administered and then a post test (O) is conducted to measure the effects of the treatment.

$$T \rightarrow O$$

2.2. Research Procedure and Participants

The steps in the treatment process are illustrated in Figure 3. Through the course of Physics for School, twenty-five junior physics students (3 males and 22 females) participated in the study. The step is initiated by the modelling from the lecturer and developing of items problem relating to the kinematics of TL. The next step is expert validating and it followed by cross-examination among undergraduate physics students. Each student did a cross-examination of 24 items because they would not do their work. The checking, correcting, and scoring are the last of the stage.

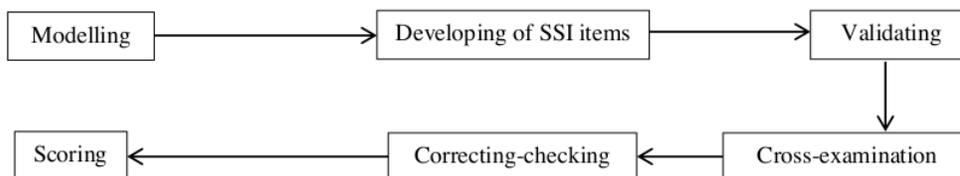


Figure 3. The illustration of the SSI treatment: ‘the physics around traffic light (TL)’.

2.3. Data Analysis

Data based on RQ 1 was analysed by a qualitatively descriptive [9]. Meanwhile, data of RQ 2 was analysed by a statistical descriptive and performed by the bar graph [10,11].

3. Results and Discussion

3.1. The variation of item test created by undergraduate physics students

After carefully checking the SSI item developed by students, then it categorised into three main themes: What should the driver do in the road for safety regarding the TL?; How much the constant velocity for certain light of TL?; and Which one the car across the TL?.

All the categories fulfil the criteria of reasoning model. The reasoning model is also called the Higher Order Thinking Skills (HOTS) model, which is a matter that requires thinking ability that is not just recall, restate, or refer without doing processing (recite). There are several principles of problem-solving that lead to HOTS, namely (1) measuring the ability to think at a higher level, minimising aspects of remembering and understanding; (2) contextually based problems; and (3) having an attractive stimulus [12]. The HOTS model measures the ability of students in terms of (1) transferring one concept to another; (2) process and apply information; (3) looking for links from various details; (4) using the information to solve problems; and (5) critically examines ideas and knowledge [12]. The following are the example of each theme of the kinematics of TL.

3.1.1. What should the driver do in the road for safety regarding the TL?

The following is an example of an item created by students that focused on the question, what should the driver do in the road for safety regarding the TL? (Item number 4).

At a distance of 500 m from the traffic lights, a truck driver slows down the speed of the vehicle by slowing down 10 m/s^2 . At that time, the TL lights up green for the first second and the speed of the truck is 100 km/h. If the order of the lights is green-yellow-red-yellow-green and the green time is 30 seconds, yellow is 10 seconds, and red is 60 seconds. What should the driver do right before the TL lights?

Based on the illustration of item number 4, the SSI could be capture is an orderly culture of traffic and road safety especially for the truck driver.

3.1.2. How much does the constant velocity for the particular light of TL?

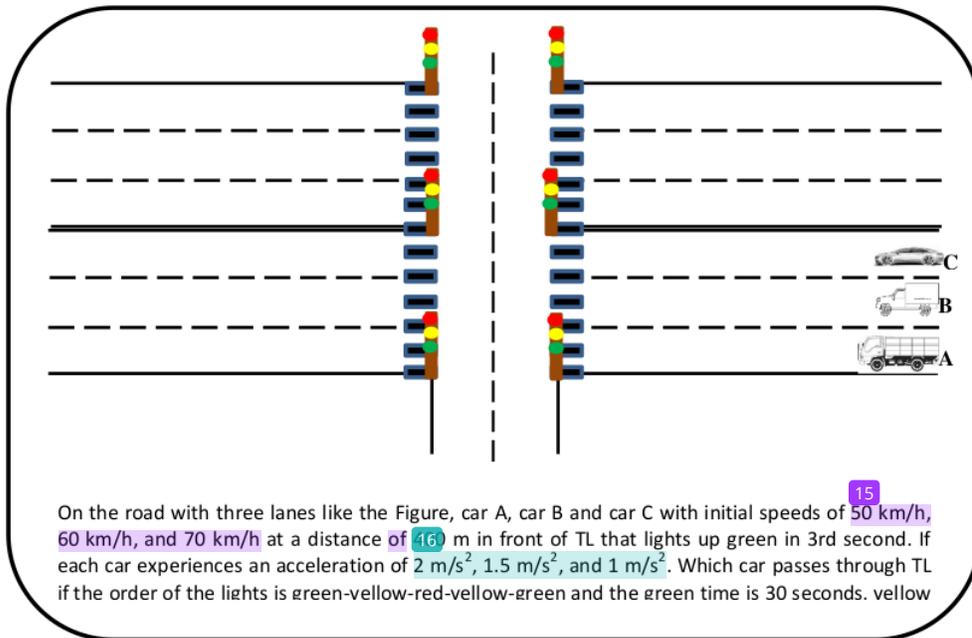
The following box is an example of an item created by students that focused on the question, how much does the constant velocity for certain light of TL? (Item number 9).

A boxcar driver sees a yellow light at a distance of 300 m from a traffic light. If the order of the lights is yellow-green-yellow-red-yellow-green and the length of time it lights green is 30 seconds, yellow is 10 seconds, and red is 60 seconds, what is the constant speed of the car must be arranged by the driver so that when passing TL he finds the lights turns green in the 10th second?

Item number 9 allows us to make a relation between the kinematics of TL and the SSI issues: how to regulate the speed of the car in the road. Therefore, it teaches us an orderly culture of traffic and road safety, especially for the boxcar driver. The item also gives a lesson about science for all and science communication. It important for every generation understands the basic concept of science; in this case, kinematics of TL teaches citizen how SSI is essential issues.

3.1.3. Which one the car across the TL?

The third box is an example of an item created by students that focused on the question, which one the car across the TL? (Item number 19).



On the road with three lanes like the Figure, car A, car B and car C with initial speeds of 50 km/h, 60 km/h, and 70 km/h at a distance of 16 m in front of TL that lights up green in 3rd second. If each car experiences an acceleration of 2 m/s², 1.5 m/s², and 1 m/s². Which car passes through TL if the order of the lights is green-yellow-red-yellow-green and the green time is 30 seconds. yellow

3.2. Undergraduate physics students' understanding of the concept of kinematics of traffic light

After undergraduate physics students did cross-examination of 24 items then as a lecturer did a checking, correcting, and scoring. Table 1 shows the distribution of correct answer of all items.

Table 1. Profile of undergraduate physics students' understanding on kinematics of traffic light.

Item	Number of correct answer (point)	Theme	Item	Number of correct answer (point)	Theme
1	20 (80)	1	13	20 (80)	2
2	22 (88)	1	14	15 (60)	2
3	15 (60)	1	15	12 (48)	2
*4	22 (88)	1	16	22 (88)	2
5	20 (80)	1	17	15 (60)	3
6	15 (60)	1	18	12 (48)	3
7	15 (60)	1	*19	23 (92)	3
8	20 (80)	2	20	21 (84)	3
*9	23 (92)	2	21	20 (80)	3
10	12 (48)	2	22	12 (48)	3
11	22 (88)	2	23	22 (88)	3
12	15 (60)	2	24	15 (60)	3

It is clear that students' understanding of SSI issues of the kinematics of TL ranging from 48 to 92 point of each item. The asterisk indicates the maximum point achieved by the students of each item. Overall, the results are quite good. This can be discussed besides all the questions categorized as reasoning items and HOTS. These questions are also contextual. Contextual means that the problem must use a real-world context. Presentation of real cases allow students to process the review of information. While, an interesting stimulus can be in the form of some information can be in the form

of pictures, graphs, tables, discourse, etc. that have a relationship in a case. The stimulus should demand the ability to interpret, search for relationships, analyse, conclude, or create [12].

The purpose of introducing the problem reasoning model or HOTS in the assessment is to encourage students to do high-level reasoning so that it is not fixated on a pattern of answers that results from the memorisation process, without knowing scientific concepts. Meanwhile, National Examination (UN) questions consist of 3 levels, namely level 1 (understanding) as much as 25-30%, level 2 (application) as much as 50-60%, and level 3 (reasoning) 10-15% [12]. When compared between UN and PISA questions, the percentage of reasoning questions on PISA questions is more than 25%. Percentage level 1, 2, 3, at PISA respectively 25%, 50%, and 25% [12]. The assessment of the reasoning model or HOTS was conducted to pursue the backwardness of the Indonesian nation at the international level, particularly the results of the Program for International Student Assessment (PISA).

4. Conclusion

The purpose of the research is introducing the model of reasoning or HOTS to encourage students to do high-level reasoning and performing socio-scientific issues. The research utilised the one-shot case study via modelling of SSI of the kinematics of TL. Through the course 'Physics for School', the research showed three main themes of the SSI including: what should the driver do in the road for safety regarding the TL?; how much do the constant velocity for certain light of TL?; and which one the car across the TL?. Meanwhile, students' understanding of SSI issues on the kinematics of TL, ranging from 48 to 92 point of 24 items. All items categorised as contextual items. It teaches us an orderly culture of traffic, road safety, science for all, and science communication. It important for every generation understands the basic concept of science; in this case, kinematics of TL teaches citizen how SSI is important.

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