

## Assessing Students' Critical Thinking and Physics Problem-Solving Skills in Secondary Schools

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### ABSTRACT

Critical thinking and problem-solving skills are some of the most crucial elements of 21st Century Skills. Very few studies have been conducted to specifically assess critical thinking and physics problem-solving skills among secondary school students. Therefore, a survey research was conducted on 66 Form Four science stream students from secondary schools in the Federal Territory of Labuan, Malaysia. Critical Thinking Assessment and Physics Problem Solving Ability Test instruments were used to measure critical thinking and problem-solving skill in Physics respectively. Overall, the level of critical thinking and physics problem-solving skills were moderate. The finding also indicated that there was a significant difference in critical thinking and Physics problem-solving skill based on achievement of the students. Meanwhile, the relationship between critical thinking and problem-solving skill in Physics was found to be positive and strongly significant. The findings from this study implied that more actions need to be taken to improve students' critical thinking and problem-solving skill in Physics.

**Contribution/Originality:** This article contributes to the relevant existing literature about the critical thinking and physics problem-solving skills of secondary school students.

## 1. Introduction

Critical thinking and problem-solving skills are some of the most crucial elements of 21st Century Skills. The globalization era around the world put more emphasis on the educational fields that can foster critical thinking and problem-solving skills in individuals. Additionally, the development of advanced technology requires human capital to be equipped with critical thinking and problem-solving skill. Furthermore, these two skills are also found to be important in developing human capital which is essential to produce graduates that can meet the needs of the country as well as can compete in the job market (Sahbullah, 2012). Ariffin et al. (2008) stated that critical

thinking and problem-solving skills are very important skills in all professions. Meanwhile, [Wan Mamat \(2013\)](#) stressed that critical thinking is part of the thinking skills that help solve problems effectively.

Problem-solving has been identified as the most important cognitive action in daily life ([Abdullah et al., 2017](#)). Meanwhile, [Butler and Coleoni \(2016\)](#) stated that problem-solving is an activity that teachers select to assist students to study the concept. However, according to [Abdul Hamid \(2008\)](#), problem-solving is an aspect that is considered to be difficult to learn and understand for most students. This is also true for students who are taking Physics subjects in secondary schools. In the context of Physics learning, problem-solving is one of the main components that was included in the lesson. Physics problem solving is not just about finding the final answer, but it also involves understanding and mastering more complex strategies such as understanding the meaning of the question, relating the information to the equation, working on the equation that has been identified, and obtaining the desired solution ([Sulaiman & Maskuri, 2010](#)). Problem-solving is considered as an important cognitive skill because the ability to process, organize, and use information in the context of problem-solving is a necessity for today's society. Recognizing this fact, the goals of Malaysian secondary school education especially *Secondary Schools Standard Curriculum (KSSM)* places problem-solving as the highest objective in Physics education ([Sulaiman et al., 2007](#)).

According to [Snetinova and Koupilova \(2012\)](#), students often have difficulty in understanding and solving Physics problems at the secondary level. Students also fail to master the Physics contents which require them to solve problems as well as the contents that require the ability to think, plan, and choose strategies to the solution. Moreover, there was evidence in a previous study conducted by [Sulaiman and Maskuri \(2010\)](#) which discovered that critical thinking affects the ability to solve Physics problems among Malaysian secondary school students. Physics problems presented nowadays include high-level thinking skills ([Gunawan et al. 2018](#)), so the students should be equipped with a high level of critical thinking skills. After all, individuals with good critical thinking skills also will be good at problem-solving ([Verawati et al., 2010](#)).

Teaching and learning methods in Physics lessons can be improved if the level of students' ability to think critically in solving problems could be measured as early as possible. Very few studies have been conducted to specifically examine the students' critical thinking and Physics problem-solving skills. Therefore, this study is expected to fill gaps in the literature. This study offered the opportunity to investigate the level of critical thinking and Physics problem-solving skills as well as the relationship between these two skills using the sample from secondary school students. Additionally, the differences in the level of students' critical thinking and Physics problems solving skills based on achievement was also investigated in this study, which can be a useful reference for future researches.

## 2. Literature Review

### 2.1. Critical Thinking

Generally, critical thinking can be linked to the process of using the mind to make decisions and solve problems. This means that critical thinking is an intellectual process that involves conceptualizing, applying, analysing, synthesising, and evaluating information that was collected or produced through observation, experience, reflection,

reasoning, or communication as a basis for belief and action. According to [Che Md Ghaazali et al. \(2010\)](#), critical thinking skills are divided into 4 main aspects, namely *Reasoning*, *Analytical and Logical*, *Disposition*, and *Assumption*. *Reasoning* is a skill of students in focusing on making decisions related to something that should be believed or should be done, then building and evaluating the reasons to support the decision, as mentioned by [Reichenbach \(2002\)](#). Meanwhile, *Analytical and Logical* is a skill to identify the ability of students to make assumptions or conclusions based on the facts and analysis made. *Dispositional* is a skill related to a person's rational thinking, having an open mind, focusing on accuracy, and always looking for alternatives in solving a problem. Whereas *Assumption* is a skill to identify the individual's ability to control self-inclination clearly in a given problem. According to [Che Md Ghaazali et al. \(2010\)](#), not everyone uses critical thinking when solving problems due to a lack of self-awareness and other characteristics that allow them to interpret and evaluate material.

## 2.2. Physics Problem Solving Skill

Individuals who possess high ability in problem-solving skills can have a far better life than others because they're more successful in seeking the simplest solution and knowing the way to act during a difficult condition ([Coşkun et al., 2014](#)). In Physics education, students are encouraged to use existing knowledge and skills to find answers to Physics problems, for example, the relationship between surface area and pressure. Effective problem solving depends on the imagination, creativity, logical thinking and seriousness of the students. [Heller and Heller \(1995\)](#) in their study proposed a model for problem-solving in Physics, and this model consisted of five main strategies which were *Focus on the Problem*, *Describe the Physics*, *Plan the Solution*, *Execute the Plan*, and *Evaluate the Answer*.

In the *Focus on the Problem*, the first thing to do is to visualize the events described in the problem statement using an initial framework. Then, write a short statement on what to find, as well as the Physics concepts and ideas that may be involved in the problem. Meanwhile in *Describe the Physics*, students need to create a figure or picture of the problem with physical diagrams and physical quantities of Physics, where the problem statements that need to be found should be written along with the figure, and make sure that all of the symbols and equation related to Physics problem are also stated. In *Plan the Solution*, all the descriptions about the related Physics need to be represented by equations that solve the Physics problem including the unit of the quantities, and then, students have to include all known quantities with the right units into the algebraic solution or the physical equation obtained in the *Execute the Plan*. Lastly, in the *Evaluate the Answer*, all of the written solutions need to be rechecked so that the solutions are answered to the stated problem.

[Heller and Heller's \(1995\)](#) model was used by the researchers in this study to assess students' problem-solving skills in Physics. This is because the subject of Physics is mechanical where the process of Physics can be explained through the statement of Physics. It is also used because this model has met some criteria in implementing Physics problem-solving. Thus, the [Heller and Heller \(1995\)](#) model provides more accurate guidelines in solving Physics problems for this study.

## 2.3. Purpose of Study

Generally, this study aimed to assess critical thinking and Physics problem-solving skills among secondary school students. The operational definition of terms for critical thinking was based on [Che Md Ghaazali et al. \(2010\)](#)'s scales which were *Reasoning, Analytical and Logical, Disposition* and *Assumption*. Meanwhile, the Physics problem-solving skills were based on the four strategies in [Heller and Heller \(1995\)](#) model namely *Focus on the Problem, Describe the Physics, Plan the Solution*, and *Execute the Plan* under the topic of Linear Motion. This study was guided by the following five main research questions:

- i. What is the level of students' critical thinking?
- ii. What is the level of students' Physics problems solving skills?
- iii. Is there a difference in the level of students' critical thinking based on achievement?
- iv. Is there a difference in the level of students' Physics problems solving skills based on achievement?
- v. Is there a relationship between critical thinking and Physics problems solving skills?

### 3. Research Methodology

#### 3.1. Research Procedure

This study employed a survey research method and was carried out in three secondary schools in the Federal Territory of Labuan, Malaysia. In this study, the researchers had taken a sample of 66 students from a total population of 80 students which was selected by using [Krejcie and Morgan's \(1970\)](#) method. The students in the sample were Form Four students aged 16 years old who enrolled in science stream class. The administration of the instruments was done by the researchers with the help of Physics teachers in the selected schools and the survey was carried out during the Physics lesson.

#### 3.2. Instrumentation

There were two main instruments used in this study, which were the Critical Thinking Assessment (CTA) and Physics Problem Solving Ability Test (PPSAT). These instruments were in the Malay language because the teaching and learning processes as well as the materials in Physics lessons were in Malay.

##### 3.2.1. Critical Thinking Assessment (CTA)

The CTA instrument was adapted from [Alolor \(2010\)](#) to assess students' critical thinking. It consisted of 20 multiple choice objectives questions which assessed students' critical thinking in these four scales, which were Reasoning (5 items), Analytical and Logical (5 items), Disposition (5 items) and Assumption (5 items). This instrument had an internal consistency of  $\alpha = 0.77$ , which indicated that this instrument had moderate-high reliability. Thirty minutes were given to the students to answer this instrument

##### 3.2.2. Physics Problem Solving Ability Test (PPSAT)

The PPSAT instrument was adopted by the researchers from [Sulaiman, Abdullah, and Ali \(2007\)](#) to assess students' skills in problem-solving in Physics subjects. The Physics problems covered in this instrument were from the topic of Linear Motion. Linear Motion was particularly chosen because the students in this study had already learnt about this

topic at the beginning of the year. There were four main items in the PPSAT instrument, and all of these items were in the form of the open-ended subjective test format. Students' problem-solving skill in Physics was tested by following the four strategies in [Heller and Heller \(1995\)](#) model namely *Focus on the Problem*, *Describe the Physics*, *Plan the Solution*, and *Execute the Plan*. To ensure the students get tested solely focused on the problem-solving skills, this instrument had provided the equations related to the problems in Linear Motion to get rid of the test on memorization of equations ([Sulaiman et al, 2007](#)). In addition to that, there was no time limit in answering the test.

In this study, the Physics problem-solving skill was tested with the assumption that the students were equipped with the same Mathematical skills but if there were Mathematical errors in the answers, it would not be taken into account to ensure that these external variables can be controlled. The full score for PPSAT was 40 marks, and the marking was done by following the marking scheme provided by [Sulaiman et al. \(2007\)](#) in line with the strategy in Physics problems solving in [Heller and Heller \(1995\)](#) model. This instrument had a high internal consistency with Cronbach's alpha value of 0.80. Additionally, [Sulaiman et al. \(2007\)](#) stated that this instrument had good inter-rater reliability.

### 3.3. Data Analysis

Mean and standard deviation was used to analyse the level of critical thinking and problem-solving skill in Physics. The level of critical thinking can be categorized into three levels: 0 to 7 was Low, 8 to 14 was Moderate, and 15 to 20 was High. Similarly, the level of Physics problem-solving skill also can be categorized into three levels: 0 to 17 was Poor, 18 to 32 was Moderate, and 33 to 40 was Excellent. The scores for both critical thinking and Physics problem-solving skills were determined by adding the correct response from each of the items in the respective instruments. Meanwhile, the determination for the differences in the level of critical thinking and Physics problem-solving skills based on the achievement was done by using one-way ANOVA. Pearson correlation analysis was used to determine the relationship between critical thinking and Physics problem-solving skills. Additionally, students' grades in Science subject in the Form 3 Assessment (PT3) which was carried out in the previous year was used as a form of students' achievement in this study. The Science grade was categorized into three grades, which were Grade A, Grade B, and Grade C.

### 4. Findings

Based on [Table 1](#), it was discovered that the level of critical thinking was Moderate (mean = 2.91, SD = 1.03). Meanwhile, the level of critical thinking for Reasoning and Analytical and Logical also was Moderate, while the level for Disposition and Assumption was High. The assumption scale had the highest mean score, followed by the Disposition, Analytical and Logical, and Reasoning scale.

Table 1: Mean and Standard Deviation for the Level of Critical Thinking

| Scale                  | Mean | SD   | Level    |
|------------------------|------|------|----------|
| Reasoning              | 2.48 | 0.86 | Moderate |
| Analytical and Logical | 2.92 | 1.10 | Moderate |
| Disposition            | 3.09 | 1.26 | High     |
| Assumption             | 3.14 | 0.89 | High     |
| Overall                | 2.91 | 1.03 | Moderate |

Table 2 showed that the level of problem-solving skill in Physics was Moderate (mean = 2.06, SD = 0.84).

Table 2: Mean and Standard Deviation for the Level of Physics Problem Solving Skill

|         | Mean | SD   | Level    |
|---------|------|------|----------|
| Overall | 2.06 | 0.84 | Moderate |

Based on Table 3, the finding showed that there was a significant difference in the Reasoning scale based on students' achievement as determined by one-way ANOVA [ $F(2, 63) = 56.902, p = 0.001$ ]. As for the Analytical and Logical scale, it was discovered that the students also can be differed significantly based on their achievement [ $F(2, 63) = 105.899, p = 0.001$ ]. Students' critical thinking related to Disposition also can be differed significantly based on their achievement [ $F(2, 63) = 101.411, p = 0.001$ ]. Similarly, it was found that there was also a significant difference in Assumption based on achievement [ $F(2, 63) = 119.829, p = 0.001$ ].

Table 3: One-way ANOVA for the Level of Critical Thinking based on Achievement

| Scale                  |                | Sum of Square | df | Mean Square | F       | Sig.  |
|------------------------|----------------|---------------|----|-------------|---------|-------|
| Reasoning              | Between Groups | 31.208        | 2  | 15.604      | 56.902  | 0.001 |
|                        | Within Groups  | 17.276        | 63 | 0.274       |         |       |
|                        | Total          | 48.485        | 65 |             |         |       |
|                        |                |               |    |             |         |       |
| Analytical and Logical | Between Groups | 39.903        | 2  | 19.952      | 105.899 | 0.001 |
|                        | Within Groups  | 11.869        | 63 | 0.188       |         |       |
|                        | Total          | 51.773        | 65 |             |         |       |
|                        |                |               |    |             |         |       |
| Disposition            | Between Groups | 78.936        | 2  | 39.468      | 101.411 | 0.001 |
|                        | Within Groups  | 24.519        | 63 | 0.389       |         |       |
|                        | Total          | 103.455       | 65 |             |         |       |
|                        |                |               |    |             |         |       |
| Assumption             | Between Groups | 62.256        | 2  | 31.128      | 119.829 | 0.001 |
|                        | Within Groups  | 16.365        | 63 | 0.260       |         |       |
|                        | Total          | 78.621        | 65 |             |         |       |
|                        |                |               |    |             |         |       |

One-way ANOVA in Table 4 revealed that the students' problem-solving skills in Physics can be differed significantly based on their achievement [ $F(2, 63) = 36.862, p = 0.001$ ].

Table 4: One-way ANOVA for the Level of Physics Problem Solving Skills based on Achievement

|                                |                | df | F      | Sig.  |
|--------------------------------|----------------|----|--------|-------|
| Physics Problem Solving Skills | Between Groups | 2  | 36.862 | 0.001 |
|                                | Within Groups  | 63 |        |       |
|                                | Total          | 65 |        |       |

The result of the correlation analysis in Table 5 showed that the level of critical thinking had a significant relationship with problem-solving skills in Physics. The magnitude of the relationship between these two variables was strong and in a positive direction ( $r = 0.861, p < 0.01$ ).

Table 5: Pearson Correlation Analysis between the Level of Critical Thinking and Physics Problem Solving Skills

|                          |                     | Physics Problem Solving Skills |
|--------------------------|---------------------|--------------------------------|
| <b>Critical Thinking</b> | Pearson Correlation | 0.861                          |
|                          | Sig. (2-tailed)     | 0.001                          |

## 5. Discussion

The finding from this study showed that the level of critical thinking of students was at a moderate level. This finding supported the findings from [Che Md Ghazali et al. \(2010\)](#) which also discovered that there was a moderate level of critical thinking among Tenth Grade science stream students at Selangor. The similar finding from both studies further highlights the need to improve the level of critical thinking among science stream students, especially for the critical thinking that was related to the Reasoning and Logical and Analytical aspect. This is because, in this context, students were seen to not completely build their knowledge, while in fact, they need to relate the newly received knowledge to the existing knowledge so that the teaching and learning process can be progressed effectively ([Md. din & Amir, 2016](#)). Critical thinking skill after all is seen as the most potential thinking skill that can help students to improve their learning.

The finding also revealed that students' Physics problem-solving skill was also at a moderate level, in line with the findings of the study conducted by [Sulaiman and Maskuri \(2010\)](#) which discovered that students performed moderately in Physics problem solving and have difficulties in learning and solving Physics problems. [Abdul Hamid \(2008\)](#) in her study stated that problem-solving was an aspect of Physics learning that is considered difficult for most students. This is because Physics problem solving is not just about finding the final answer but also involves understanding and mastering more complex strategies such as understanding the meaning of the question, connecting the information with the formula, applying the formula that has been identified and getting the desired solution, which leads to the difficulty in understanding the subject. Therefore, this is also might be one of the reasons why the students couldn't obtain a high level of performance related to the problem-solving in Physics.

Meanwhile, one-way ANOVA analysis showed that there was a significant difference in the mean of critical thinking (*Reasoning, Analytical and Logical, Disposition, and Assumptions*) as well as in the Physics problem-solving skill among students based on achievement. This indicates that there was a difference in the level of critical thinking and problem-solving skill in Physics of students between students who obtained Grade A, Grade B, and Grade C. This finding strengthened the claims made by [Ibrahim and Noordin \(2003\)](#) who stated there would be a difference in students' intellectual development and critical thinking due to the differences in their achievement. However, this study did not perform a multiple comparison test, causing the researchers to not have the information about which scales in the critical thinking and Physics problem solving differed significantly from each other based on the achievement.

Based on the Pearson correlation analysis, the findings showed that there was a strong positive relationship between students' level of critical thinking and Physics problem-solving skills, in line with the finding by [Sulaiman and Maskuri \(2010\)](#). This shows that the level of critical thinking of students is greatly related to the students' knowledge they have learned, analysing to determine the best answers, as well as making an

assessment by detailing the answers to the problem-solving questions in Physics. These findings supported the claim by Radzi et al. (2009) that applying critical thinking techniques such as weighing something thoroughly with an open mind and evaluating the accuracy of an argument can lead to more effective results based on concrete and clear evidence. Indirectly, students can produce meaningful learning as emphasized by Ausubel (1968) in cognitive learning theory. Here, students are not only trained to develop the ability to think at a higher level alone but they benefit from the knowledge or theory they have learned by applying it in new situations.

## 6. Conclusion

This study fills the gap of research related to critical thinking and Physics problem-solving skills in secondary school. Generally, students were discovered to have a moderate level of critical thinking and Physics problem-solving skills. However, since it only involved 66 science stream students, the findings may not be generalized to the other secondary school students. For future research, several aspects can be implemented such as increasing the number of samples in the study so that the results obtained can be representative of the whole population. In addition, the sample of the study also should be extended to the other sample such as by including the sample from different grades so that the difference between two different levels of ages could also be investigated.

It is believed that the findings from this study have implications for both students and educators. Therefore, the emphasis on critical thinking of students needs to be enhanced and fully developed at the school level to produce citizens who can think critically and can solve problems that will be faced in the future. To realize this, educators need to increase their efforts by diversifying teaching and learning methods that aim in improving critical thinking and problem-solving skill in Physics lessons.

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## Conflict of Interests

The authors have no conflict of interest.

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