Evaluating students logical thinking ability: TPACK model as a physics learning strategy to improve students logical thinking ability

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Abstract. Physics has the character of logical thinking. The use of technology in physics learning encounters the problem. The purpose of this study is to evaluate students logical thinking ability and determine a physics learning strategy to improve students logical thinking ability. The subjects of this study were 81 Islamic boarding school students in Ponorogo. The research approach was used mix method. Instrument test research was used by giving Tests of Logical Thinking (TOLT) which developed by Tobin and Capie. Instrument test contains 10 questions that depict probabilistic reasoning, controlling variable, proportional reasoning, correlational reasoning, and combinatorial reasoning. The results show that the average students logical thinking ability occupies a level of concrete thinking with a score of 1.36. This finding describes the logical thinking ability was still being the lowest level. Therefore, alternative learning such as integrating with technology is necessary to improve the logical thinking ability of students. Integrating learning with technology can be done by TPACK model.

1. Introduction
Physics is a branch of natural science that is required to think logically. But in learning, the learning outcomes of student material in Physics subjects are still low. This is indicated by the results of the 2017 National Examination from Puspendik Kemendikbud which shows the average national score of 43.68.

The ability to think logically is the ability to think coherently and make sense based on facts and walk hierarchically. Hadi [1] defines that logical thinking is a coherent, reasonable way of thinking, and is based on certain objective facts. Fios [2] states that the congruence between objective facts obtained from literature studies and the topics studied shows that there is a logical way of thinking. Matlin [3] revealed that the logical way of thinking is seen from the hierarchy, which is a system that organizes information in a class, starting from the most general to the specific thing.

Logical thinking is considered a staple for complex mental reservation and problem-solving processes. [4]. In the ability to think logically several indicators become a reference in assessing these abilities. Based on Piaget's view, indicators of logical thinking ability are 1) probabilistic thinking, 2) controlling variables, 3) proportional reasoning, 4) correlational reasoning, and 5) combinatoric reasoning. The purpose of this study is to evaluate students' logical thinking abilities. After obtaining the evaluation results can be found a physics learning strategy to improve logical thinking skills of students.
2. Method
This research was carried out in an Islamic boarding school, Ponorogo district with 81 students as the research subjects using the lecture method. The instrument used was TOLT (Test of Logical Thinking) with 8 multiple-choice questions and 2 essays developed by Tobin and Capie [5]. It is covering aspects of 1) probabilistic reasoning, 2) controlling variables, 3) proportional reasoning, 4) correlational reasoning and 5) combinatoric reasoning. The grid of questions used can be seen in table 1.

| Evaluated Aspect         | Form of The Test     | Item Number |
|--------------------------|----------------------|-------------|
| Probabilistic Reasoning  | Multilevel multiple choice | 1, 2        |
| Controlling Variable     | Multilevel multiple choice | 3, 4        |
| Proportional Reasoning   | Multilevel multiple choice | 5, 6        |
| Correlational Reasoning  | Multilevel multiple choice | 7, 8        |
| Combinatorial Reasoning  | Essay                | 9, 10       |

In table 1 explained that aspects of probabilistic reasoning, controlling variable, proportional reasoning and correlational reasoning have the form of multilevel multiple-choice questions from numbers 1 to 8. In the combinatorial aspect of reasoning has the form of problem description in numbers 9 and 10. A useful instrument for measuring students’ logical thinking abilities.

The assessment in this instrument is that each item that has a correct answer is worth 1 point so that the maximum value that can be obtained is 10 points. Obtaining this test can be categorized into 3 categories of logical thinking ability using Valanides rule [6] as shown in table 2.

| Score | Category            |
|-------|---------------------|
| 0-1   | Concrete logical ability |
| 2-3   | Transition logical ability |
| 4-10  | Formal logical ability |

3. Result and Discussion

3.1. Result of logical thinking ability
Data on students’ logical thinking skills in this study were generated from the TOLT test to 81 students. The data is contained in the following table 3.

| Respondent | Logical Thinking Ability | Sum |
|------------|--------------------------|-----|
|            | Concrete | Transition | Formal | |
| Total students | 49   | 25         | 7       | 81  |
| Percentage  | 60     | 31         | 9       | 100 |

Based on table 3, it appears that 81 students took the TOLT test. There are 49 (60%) students who have logical abilities from concrete operations, and 25 (31%) students have logical abilities for transition operations, and the remaining 7 (9%) students have formal logical operations skills. The TOLT (Test of Logical Thinking) instrument is divided into 5 aspects, namely 1) probabilistic reasoning, 2) controlling variables, 3) proportional reasoning, 4) correlational reasoning and 5) combinatoric reasoning. Each aspect has different results. Detailed assessment results can be seen in figure 1.

Figure 1 shows the average acquisition in every aspect of logical thinking ability. The aspect that has the highest value lies in Correlational Reasoning of 0.51 and the lowest value of Proportional Reasoning of 0.05. The average value of each aspect is 0.27. These values when converted into the
category of logical thinking ability that is considered to be a stand-alone aspect based on table 2, produce as listed in table 4.

![Figure 1](image_url)

**Figure 1.** The average value of every aspect of logical thinking ability.

| Aspect                  | Score | Category                      |
|-------------------------|-------|-------------------------------|
| Probabilistic Reasoning | 2.53  | Transition logical ability    |
| Controlling Variable    | 0.56  | Concrete logical ability      |
| Proportional Reasoning  | 0.25  | Concrete logical ability      |
| Correlational Reasoning | 2.65  | Transition logical ability    |
| Combinatorial Reasoning | 0.80  | Concrete logical ability      |
| Average                 | 1.36  | Concrete logical ability      |

The acquisition of these values indicates an imbalance in several aspects. Probabilistic Acquisition Reasoning students is 2.53 meaning students are quite able to interpret the data obtained in the form of the likelihood of an event occurring. Controlling Variable students worth 0.56, which means students are less able to plan, implement, and interpret information. Proportional Student Reasoning Acquisition is 0.25 meaning students are less able to determine and compare ratios. Lawson states that students who achieve proportional reasoning can describe the problem proportionally and combine their proportions [7]. In Correlational Reasoning, it is obtained 2.65 which means that students are quite able to determine the presence or absence of a relationship between two variables or events. Combinatorial Reasoning students 0.80 means students are less able to determine the combination of an event. The average value of critical thinking skills is 1.36, which means students can order (seriation), construct numerical thinking, spatial and temporal operations (sequential), classification (categorization), and all basic class operations basic logic (basic and simple) as well as basic geometry, basic mathematical relationships, and even basic physics [8].

### 3.2. Discussion

The acquisition of assessment data can also be seen from the category of students' ability to score each aspect of logical thinking ability so that it is presented in the following figure 2.
Figure 2 shows the average score of each consistent reasoning capacity angle against the class of legitimate considering capacity understudies. In the Probabilistic Reasoning aspect, Concrete students got an average score of 0.18, Transition students 0.84 and Formal students 1.50. In this aspect the higher the category of students, the higher the score obtained. Aspect of Controlling Variable Concrete students obtain an average score of 0.08, Transition students 0.12 and Formal students 0.17. In this aspect the higher the category of students, the higher the score obtained. The Proportional Aspect of Reasoning Concrete students gained an average score of 0.04, Transition students 0.00 and Formal students 0.33. In this aspect fluctuating data occurs in each category of students. Aspects of Correlational Reasoning Concrete students get an average score of 0.14, Transition students 1.00 and Formal students 1.67. In this aspect the higher the category of students, the higher the score obtained. The Combinatorial Aspect of Reasoning Concrete students obtained an average score of 0.04, Transition students 0.28 and Formal students 0.50. In this aspect the higher the category of students, the higher the score obtained.

These results indicate learning the lecture method has not been able to develop students' logical thinking skills. Integrating technology with other learning components is needed to improve students' logical thinking abilities. That is because an understudy whose psychological advancement has arrived at the formal operational level will be simpler to take care of issues in the learning procedure [9]. The results of learning physics that can think logically above average are better than students who can think logically below average [10].

TPACK (Technological Pedagogical Content Knowledge) is a learning model that integrates several programs including technology, content and learning material [11]. TPACK is a slice of TCK (Technological Content Knowledge), TPK (Technological Pedagogical Knowledge) and PCK (Pedagogical Content Knowledge). Therefore TPACK is the basis of good teaching by 1) technology and requires an understanding of the representation of concepts using technology, 2) pedagogical techniques that constructively use technology to teach material, 3) knowledge of what makes concepts difficult or easy to learn and how technology can help correct some of the problems students face, 4) knowledge of previous student knowledge and epistemological theories, and 5) knowledge of how
technology can be used to build on existing knowledge and to develop new epistemologies or strengthen old ones. The motivation behind utilizing innovation in instructing and learning is to expand efficiency, the viability of current practices and realize academic changes that are gainful for improving training [12]. The utilization of innovations, for example, intuitive mixed media based activity is compelling for expanding the dominance of ideas [13]. Enthusiasm for adapting additionally affects learning results [14].

4. Conclusion
Because of the outcomes it low passable may be reasoned that the understudies' sensible reasoning capacity has a score of 1.36. This means that students' logical thinking abilities are still at a concrete level. Learning is needed that can improve logical thinking ability, one of which is the use of TPACK.

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