How are student’s cognitive patterns viewed from higher-order thinking skills in kinematics?

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Abstract. Higher-Order Thinking Skills (HOTS) is an ability that must be achieved by students today because this ability is the core of assessment in K13 and also as demand for 21st-century skills. Giving HOTS-based tests is an attempt to explore further the extent to which HOTS is mastered by students in kinematics and also describe cognitive patterns based on student's HOTS. The method used in this study is descriptive, with an in-depth analysis of student answers. The research subjects were 51 students. The test instrument used consisted of five HOTS questions, which were divided into two analyzing questions, 1 evaluating question and 2 creating questions, has a reliability coefficient of 0.85 with considered high. The results of the study show that the cognitive patterns of students with high HOTS tend to be stable increasing following cognitive levels, for cognitive patterns of students with medium HOTS are having an up and down pattern, while the cognitive patterns of students with low HOTS tend to decline at higher cognitive levels. The whole HOTS in this study is relatively low because only 3.92% of students can reach high HOTS. Thus, it is necessary to apply of learning model such as Problem Based Learning to train students for higher order thinking in solving physics problems.

1. Introduction

Thinking ability is one of the crucial factors that educators must consider because the benchmark of students with excellent thinking skills is achieving maximum learning outcomes. Of course, this is the role of educators in developing thinking skills in the hope that students can solve physics problems well. The thinking ability divided into two levels, namely lower and higher order thinking skills (HOTS) [1]. HOTS is a level that students must achieve at this time because this ability is the core of assessment in K13, and also as demand for 21st-century skills [2].

High-level thinking ability is cognitive skills processing[3], which occurs when someone gets new information, remembers and compiles, connects existing knowledge, and produces information to achieve goals or resolve complicated situations[4]. In the cognitive domain capability of higher-order thinking can be seen through students' abilities to analyze (C4), evaluate (C5) and create (C6) [5]. Besides these abilities, there is also creative thinking in HOTS[6]. So, higher-order thinking skills are decision-making activities that involve a process of creative thinking at the cognitive level of analyzing, evaluating, and creating as an effort to solve problems.

The problem-solving process itself is an attempt by students to represent their knowledge to find the best solution to the problem given. The responses given by students in solving problems can be a
reflection of the extent to which higher-order thinking skills and physics concept understanding. Many responses are given when students do problem-solving such as using graphs, plug and chug, and mathematical equations [7]. Responses among them are often different and have specific patterns depends on the extent to which they understand the concepts of physics. Patterns used by students as an effort to solve the problems can be identified through cognitive patterns. Kholodnaya revealed that individual differences form cognitive patterns relatively similar in a similar group and different from other groups [8].

Cognitive patterns are individual differences in describing their cognitive information processing patterns [9], composed of knowledge, skills, beliefs, and strategies, from how students experience learning situations [10]. Cognitive patterns can also be used as a tool to identify and describe the perspectives that reflect the activities of reasoning or problem-solving [11]. So, cognitive patterns are differences in the students' description in capturing existing information to solve problems. So far, some researchers have explained cognitive patterns in general [9, 12, 13], or in physics education [8, 10]. However, no one has explained cognitive patterns, more specifically in kinematics.

Kinematics is one physics branch that explains the cause of the motion of an object. Therefore, thinking skills and analytical skills are needed for understanding these phenomena. Besides, kinematics is one of the physics topics with a minimum achievement in the cognitive level of analyzing (C4), so that higher-order thinking skills are needed to be mastery in these topics. However, students experiencing difficulties in the kinematics, namely the low basic concept of motion that raises a confusing analogy when connecting between position and speed, speed, and acceleration [14]. Many students experience misconceptions in the concept of straight motion in daily life [15]. Also, several researchers revealed the students' difficulty in understanding the concept of kinematics [16-18], but no one has to uncover students' cognitive patterns on the kinematics. Therefore, the need for measuring HOTS on kinematics to express student's cognitive patterns based on HOTS on kinematics.

2. Methods
The research implemented the descriptive method to in-depth analyze the results of the students' answers. The study was conducted at SMAN 4 Malang. The research subjects were students of class XII, as many as 51 students. The measuring instrument consists of 5 essay items, with two items C4 adoption of the National Council of Educational Research and Training (NCERT), 1 item C5 was adopted from the physics challenge question by Boston University, and two items C6 adopted from the District Science Olympiad (OSK) for High School. This test has a reliability coefficient of 0.85, which is high. The steps of this research are; 1) HOTS test was implemented to the subject to identify to what extent their thinking ability, 2) students worked on the problems based on their ability, 3) results of the student's answers were analyzed. In-depth analysis was done to look at cognitive patterns and higher-order thinking skills based on the overall average score and grouped them into three categories using the following formula in Table 1 [19]. Furthermore, the analysis of the cognitive patterns of each HOTS category was done.

| Categories | Formula          |
|------------|------------------|
| Low        | $X < M - 1SD$    |
| Medium     | $M - 1SD \leq X < M + 1SD$ |
| High       | $M + 1SD \leq X$ |

3. Results And Discussion
The results of the analysis obtained information about the percentage of high-level thinking skills and cognitive patterns. These HOT skills were obtained from the average value of each cognitive level, that is, 18.6% of students were able to do the analyzing problems, 13.7% were able to work on evaluating problems, and 1.96% were able to do the creating problems. From the overall results, it is known that
higher thinking skills are deficient. Furthermore, the cognitive pattern of students translated into three categories based on HOTS Table 2.

Table 2. HOTS Categorization

| Categories | Score       |
|------------|-------------|
| Low        | X < 3       |
| Medium     | 3 ≤ X < 4.5 |
| High       | 4.5 ≤ X     |

Table 1 explains how to categorize HOTS based on the overall average score of each cognitive level. For the data of each cognitive level, the average score is 5 for C4, score 5 for C5, and score 15 for C6. So, the average score for HOTS is 9.

3.1 Cognitive pattern of students

The results of the study showed that students with one another had different cognitive patterns. It is also explained that everyone has unique functional brain connectivity patterns, which can be used to predict individual differences in cognitive function[20]. Thus, the cognitive patterns of certain groups based on HOTS category have different tendencies.

From the categorization results, there were two students of high HOTS, ten students for medium HOTS, and 39 students for low HOTS. Cognitive patterns of each HOTS category can be seen from the following graph:

![Figure 1](image1.png)

**Figure 1** Students’ cognitive pattern with high HOTS

Figure 1 shows the cognitive pattern of 2 students (3.92%) with high HOTS. Students' cognitive pattern tends to increase in line with the increase of cognitive level. This graph shows that students’ cognitive patterns tend to be linear with the cognitive level in solving kinematics problems even though it is not optimal.

![Figure 2](image2.png)

**Figure 2** Students’ cognitive pattern with moderate HOTS
Figure 2 is a cognitive pattern of 10 students (19.6%) with moderate HOTS. Students' cognitive pattern tends to fluctuate irregularly.

![Figure 2](image)

**Figure 3** Students’ cognitive pattern with low HOTS

Figure 3 shows a cognitive pattern of 39 students (76.45%) classified as a low HOTS. Students' cognitive patterns tend to decrease with increasing cognitive levels.

The three students' cognitive patterns have different tendencies that have an impact on the students' problem-solving process. This pattern is in line with previous research, which stated that cognitive patterns have a relationship with problem-solving skills [11]. Thus, the students' cognitive patterns can be used to identify the student’s problem-solving process [21].

3.2 Cognitive activity of the students

Differences in students' cognitive patterns also result from cognitive activities performed. Cognitive activity is a form of problem-solving efforts by digging information and organizing in the form of knowledge[22] Efforts to solve problems in each cognitive pattern are described below.

![Figure 4](image)

**Figure 4.** Student problem-solving process with high HOTS with the cognitive pattern of steady increases

Figure 4 the analysis shows that the problem-solving process is systematic and reflective. Systematics is seen from the stages that he did according to Polya’s opinion that is 1) understanding a problem, 2) planning a solution, 3) implementing a solution plan, and 4) checking and evaluating[23]. Whereas in making decisions tend to be reflective, namely testing the hypothesis more specifically and making decisions based on analysis first [8].
Figure 5. The result of the problem-solving process of students with moderate HOT and fluctuating cognitive patterns.

Figure 5 from the results of the analysis, it appears that the problem-solving process is quite systematic, but students make mistakes in the stage of providing a solution. The solution shows the wrong analysis, and of course, the answer given is not as expected.

Figure 6. The result of the problem-solving of students with a low HOTS and the declining cognitive pattern

Figure 6 from the analysis, it can be seen that the problem-solving process is done on the impulsive way that is likely to react quickly to put forward a hypothesis without analyzing the process [8]. Conclusions are given without going through the process of proof analysis.

Most students had the highest difficulty in solving the of creating problems (creating a speed equation as a function of time from a predetermined acceleration equation). In this problem, the students argue that the position function is the same as the distance (s) and tends to do "Plug and Chug." In this way, the student matches the equations that are remembered and known accordingly, as in the following figure.

Figure 7. The result of the answers of the majority of students at the C6 cognitive-level problem.

Figure 7 based on students' answers, students tend to give the wrong response in solving problems. Students immediately take ordinary acceleration equations without differentiating processes of the function of position. These reflect that the student's ability to solve problems reaches just as far as remember, understand, and apply. This finding is consistent with previous studies, which explain that the highest false responses are found at higher cognitive levels[24].

At the C6 cognitive-level problems, students with moderate HOTS and low HOTS tend to have decreased cognitive patterns, which means that success in solving problems tends to be low. The low resolution of this problem is because the cognitive patterns of students are in the field-dependent category. In this category students use less analytical skills and have difficulty in focusing on a situation, choosing important details, analyzing a pattern into different parts, or using strategies in problem-solving [11].

4. Conclusion
The high-level thinking skills of high school students tend to be low. Only 18.6% of students were able to do analyzing problems, 13.7% of students were able to work on evaluating problems, and 1.96% of students were able to do the creating problems.
Three students' cognitive patterns have an impact on the process of solving different problems. The increasing cognitive pattern tends to a systematic and reflective problem-solving process. The fluctuating cognitive pattern tends to solve problems systematically but not accurately, while the decreasing cognitive pattern tends to solve problems impulsively.

Thus, there needs to be learning models such as PBL that is more directed at each student's cognitive patterns. Furthermore, the learning model must be able to train students regularly and systematically to improve their ability in higher order thinking for solving physics problems.

References

[1] Tanujaya B 2016 J. Educ. Pract. 7 144
[2] Sutarto, Indrawati, Prihatin J and Dwi P A 2018 J. Pendidik. IPA Indones. 7 376
[3] Istiyono E 2017 AIP Conf. Proc. 1868 1
[4] Yee M H, Yunos J M, Othman W, Hassan R, Tee T K and Mohamad M M 2015 Proc. Soc. Behav. Sci. 204 143
[5] Heong Y M, Yunos J M, Othman W, Hassan R, Kiong T T and Mohamad M M 2012 Proc. Soc. Behav. Sci. 59 197
[6] Sutrisno F H, Handayanto S K, and Supriyana E 2018 Momentum: J. Phys. Educ. 2, 21
[7] Doctor J L and Mestre J P 2014 Phys. Rev. Special Topics-Phys. Educ. Research 10 1
[8] Grebenev I V, Lozovskaya L B and Morozova E O, SpringerPlus 449 1
[9] Yasuda T 2019 Asian-Pac. J. Second Foreign Lang. Educ. 4 1
[10] Bodin M 2012 Int. J. of Sci and mathematics Educ. 010115 1
[11] Gusau N M B, Mohamad M M and Jamali A R 2018 Herald NAMSCA 1 498
[12] Chujfi S and Meinel C 2015 J. Interact. Sci. 5 1
[13] Peterson E R, Deary I J and Austin E J 2018 Personality and Individual Differences: Elsevier Sci. 8869 881
[14] Srivastava H 2015 Conf. paper in Research Associate 1
[15] Narjaikaew P 2013 Procedia - Soc. Behav. Sci. 88 250
[16] Bollen L, Cock M D and Zuza K 2016 Phys. Rev. Phys. Educ. Research 12 1
[17] Lichtenberger A, Wagner C, Hofer S I, Stern E and Vaterlaus A 2017 Phys. Rev. phys. educ. research 13 1
[18] Hochberg K, Kuhn K and Müller A 2016 Perspect. Sci. 10 13
[19] Azwar S 2012 Penyusunan Skala Psikologi Edisi 2 (Yogyakarta: Pustaka Pelajar)
[20] Wen T, Liu D and Hsieh S 2018 Elsevier-Neuropsychologia 114 195
[21] Kiesewetter J, Ebersbach R, Gorlitz A, Holzer M, Fischer M R and Schidmaier R 2013 Plosone 8 1
[22] Sujarwanto E, Hidayat A and Wartono 2014 J. Pendidik. IPA Indones. 3 65
[23] Rusilowati A and Lasiani 2017 Phys. Comm 1 1
[24] Kocdar S, Karadag N and Sahin M D 2016 J. of Educ. Tech. 15 16