

They Categorized Lower Order Thinking Skills but They Answer Incorrectly: How is the Opposite?

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Abstract. This study began with the discovery of writings in several journals about the difficulties of students in learning physics, as well as the importance of the role of using representation in the teaching and learning process to help students to solve problems. The purpose of this research is to identify the consistency of student responses of the test based on representation diagrams in the category of Low Order Category Thinking Skills (LOTS) and High Order Thinking Skills (HOTS). The test is designed only requires answers in the form of drawings or diagrams of the physics topic about dynamics. Participants in this research were 22 teacher-candidate students who had passed the course of Evaluation of Physics Learning. The results of the study found that those they categorized LOTS are 63.6% answered incorrectly and 19% did not answer, and those they categorized HOTS are 73.6% answered incorrectly and 26.4% did not answer. The implication of the results of this research is that for basic sciences such as physics requires mastery for all levels of thinking ability, not only for mastering mathematics as a tool but also for a good understanding of the use of representation diagrams.

Keywords: LOTS, HOTS, representation diagrams, incorrectly, not answer

INTRODUCTION

The industrial era 4.0 requires someone to have adequate high-level thinking skills. High school is not enough, undergraduate education is not enough, a master's degree is not enough, and a Ph.D. is not enough. Everyone is now responsible for lifelong learning and upskilling (Gleason, 2018:7). The ability to think logically and creatively becomes a demand in self-development. Sharpening your mind to be smarter and logical can be guided by sciences and mathematics knowledge. According to the head of the Indonesian Science Institute, the 4.0 Industrial Revolution (4IR) which is often discussed is based largely on mathematics and natural sciences because these two things are actually the basis of human logical thinking (Handoko, 2018:12). Substantial changes to the science and technology curriculum will be required to allow students to develop capacity in the rapidly emerging areas of genomics, data science, artificial intelligence (AI), robotics and nano-materials. Such a 4IR STEM (Science, Technology, Engineering, and Mathematics) curriculum would reconsider the curriculum within the traditional "primary" sciences - biology, chemistry, and physics - and place a higher premium for training in computer science subjects as a form of 4IR literacy (Penprase,

2018:217). If so, the demand mastery of basic sciences such as physics and mathematics is becoming increasingly important at this time. Vijaya Bhaskara by quoting the opinion of Ogunleye (2009) said that, in recent studies have been found that most of the students perform mathematical calculations, algorithms by rote memorization of formulas without having a basic understanding of specific concepts. The rationale of the difficulty in problem-solving in physics has been identified numerous researchers as physics students fail to construct meanings of the problem statement, unable to interlink the meaning of the statement. Most of the students are lack of the appropriate knowledge of structural construction in a specific content area (Vijaya Bhaskara Redy, 2017:59). Until the last few decades, research involving science students' outcomes-focused primarily on educational objectives in behavioral theory, but in more recent times, attention has been given to process of the cognitive and affective domain, and in this context, constructivism and similar cognitive theories also represent a paradigm shift from behavioral to cognitive theory (Keser, 2010:2). Today's society and students are faced with conditions of abundant information. This has an impact on the behavior of each person. Elena Tikhonova said that the twenty-first century has

brought about a new type of society, the information-based society. Although this type doubtless provides a lot of opportunities for development and self-realization, which are the top needs, according to Maslow hierarchy, we cannot but notice the existing downside as well. What is being promoted as a life motto worldwide is the combination of pragmatism and hedonism, which especially appeals to the youth. Such a combination presupposes that young people faced with the overload of available information prove to be unwilling to memorize this information or make sure that they understand it since they can gain access to it whenever and wherever they want or need. On the other hand, the information-based society requires a change in the existing educational paradigm, which means that the main focus of educators is shifting towards the development of higher order thinking skills – HOTS, while ignoring lower order thinking skills - LOTS (Tikhonova, E., Kudinova, N. 2015:1). Because it was found that physics knowledge was difficult for students, so it needed to do a deepening of cognitive processes in learning physics. Nguyen (2011), stated in his research that we have found that students have significant difficulties in transferring their problem-solving skills across representations. Our comparison of sequences of problems in different representations appears to indicate that no one in particular sequence is better than the other; rather it depends upon the context of the problem. However, we have also found evidence that students improve in their ability to transfer across representations as they solve more problems in different representations, as well as over a longer period of time. This study underscores the importance of learning experiences that would facilitate students' transfer of problem-solving skills across representations. It also calls for further research in investigating these issues across other problem contexts and other domains (Nguyen, 2011:565). As disclosed in the following example, “in order to help students to learn optics concepts better, it is necessary to assess the students' capability in using ray diagrams and other representations and devise a better way to encourage the integration of multiple representations in their learning” (Kuo YR, 2017:125). Based on some of the background of thought above, this research was conducted to identify the consistency of student responses of the test based on representation diagrams in the category of Low Order Category Thinking Skills (LOTS) and High Order Thinking Skills (HOTS). This research was conducted to explore students' cognitive abilities related to the use of representation diagrams in physics learning, specifically drawing force vectors on free body diagrams.

CONCEPTUAL FRAMEWORK

Physics is a basic science that studies matter and energy through observation of natural phenomena and experimentation and develops science in a strict manner. Physics was developed using mathematics as a tool (Kneubill, Robilotta, 2015:645), and use principle, law, and postulate, as well as processing and analyzing data to produce undoubted scientific truths. The use of mathematics in the development of physics and in the process of physics learning raises problems in physics education (Tzanakis, 2016). Furna Ornek, quoting Redish (1994), explains that physics as a discipline requires learners to employ a variety of methods of understanding and to translate from one to the other words, tables of numbers, graphs, equations, diagrams (Ainsworth, 2006), maps. Physics requires the ability to use algebra and geometry (Kanderakis, 2016:837), and to go from specific to the general back. This makes learning physics particularly difficult for many students (Ornek, 2007:165). The use of representation diagrams in physics learning has helped students to learn more systematically, compactly, and comprehensively so that they are able to solve problems better. Even so, didactic physics require serious attention from textbook writers, compilers of teaching materials, and especially from instructors or physics teachers. Specifically in physics learning about free body diagrams, studies of force concepts have been carried out by many experts, as reported by Kurnaz (2015) that many studies have investigated force and related concepts, and this practice can be classified into the following four types: (a) students' conceptions related to force concepts (Brown, 1989; Helm, 1980; Trumper & Gorsky, 1996, 1997); (b) students' conception levels of force concepts (Dekkers & ijs, 1998; Halloun, 1998; Heywood & Parker, 2001; Jimenez-Valladares & Perales-Palacios, 2001); (c) alternative approaches to teaching and learning force (Besson, Borghi, De Ambrosis, & Mascheretti, 2007; Kurt & Akdeniz, 2004; Sahin, 2010); and (d) studies focusing on teaching specific types of force (Besson & Viennot, 2004) (Kurnaz, 2015:788). Physics teachers must develop a physical didactic process with the correct assessment process specifically related to abstract concepts such as force. For examples as stated by Etkina, regarding a scoring rubric to assess a free-body diagram (FBD) about scientific ability to construct a (FBD): 0 (missing) – no FBD is constructed; 1 (inadequate) – FBD is constructed but contains major errors such as incorrect force vectors such as length of vectors, wrong direction, extra incorrect force vector, or missing vector; 2 (needs improvement) - FBD contains no errors in vectors but lacks a key feature such as labels of forces with two subscripts, vectors are not drawn

from single point, or axes are missing; 3 (adequate) – The diagrams contains no errors and each force is labeled so that it is clear what each force represents (Etkina, 2006). A good assessment starts with making the right test and implementing a good measurement. Bloom’s taxonomy provides guidance in the process of measuring education. Bloom saw the original Taxonomy as more than a measurement tool. He believed it could serve as a (a) common language about learning goals to facilitate communication across persons, subject matter, and grade levels; (b) basis for determining for a particular course or curriculum the specific meaning of broad educational goals, such as those found in the currently prevalent national, state, and local standards; (c) means for determining the congruence of educational objectives, activities, and assessments in a unit, course, or curriculum; and (d) panorama of the range of educational possibilities against which the limited breadth and depth of any particular educational course or curriculum could be contrasted (Krathwohl, 2002:212). David R. Krathwohl in a paper published in 2002 suggested a revision of Bloom’s taxonomy as follows: The original Taxonomy - the final draft was published in 1956 under the title, *Taxonomy of Educational Objectives: The Classification of Educational Goals. Handbook I: Cognitive Domain* (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956) - provided carefully developed definitions for each of the six major categories in the cognitive domain. The categories were *Knowledge, Comprehension, Application, Analysis, Synthesis, and Evaluation*. Then, Krathwohl explained that in the original Taxonomy, the *Knowledge* category embodied both noun and verb aspects. The noun or subject matter aspect was specified in *Knowledge’s* extensive subcategories. The verb aspect was included in the definition given to *Knowledge* where student was expected to be able to recall or recognize knowledge. This brought uni-dimensionality to the framework at the cost of a *Knowledge* category that was dual in nature and thus different from the other Taxonomic categories. This anomaly was eliminated in the revised Taxonomy by allowing these two aspects, the noun, and verb, to form separate dimensions, the noun providing the basis for the Knowledge dimension (see Table 1) and the verb forming the basis for the Cognitive Process dimension (see Table 2).

Table 1. Structure of the Knowledge Dimension of the Revised Taxonomy

1. <i>Factual Knowledge</i> The basic elements that students must know to be acquainted with a discipline or solve problems in it
a. Knowledge of terminology
b. Knowledge of specific details and elements

2. <i>Conceptual Knowledge</i> The interrelationships among the basic elements within a larger structure that enable them to function together
a. Knowledge of classifications and categories
b. Knowledge of principles and generalizations
c. Knowledge of theories, models, and structures
3. <i>Procedural Knowledge</i> How to do something; methods of inquiry, and criteria for using skills, algorithms, techniques, and methods
a. Knowledge of subject-specific skills and algorithms
b. Knowledge of subject-specific techniques and methods
c. Knowledge of criteria for determining when to use appropriate procedures
4. <i>Metacognitive Knowledge</i> Knowledge of cognition in general as well as awareness and knowledge of one’s own cognition.
a. Strategic knowledge
b. Knowledge of cognitive tasks, including appropriate contextual and conditional knowledge
c. Self-knowledge

(Krathwohl, 2002:214)

Table 2. Structure of the Cognitive Process Dimension of the Revised Taxonomy

1. <i>Remember</i> Retrieving relevant knowledge from long-term memory
1.1 Recognizing
1.2 Recalling
2. <i>Understand</i> Determining the meaning of instructional messages, including oral, written, and graphic communication
2.1 Interpreting
2.2 Exemplifying
2.3 Classifying
2.4 Summarizing
2.5 Inferring
2.6 Comparing
2.7 Explaining
3. <i>Apply</i> Carrying out or using a procedure in a given situation
3.1 Executing
3.2 Implementing
4. <i>Analyze</i> Breaking material into its constituent parts and detecting how the parts relate to one another and to an overall structure or purpose
4.1 Differentiating
4.2 Organizing
4.3 Attributing
5. <i>Evaluate</i> Making judgments based on criteria and standards
5.1 Checking
5.2 Critiquing
6. <i>Create</i>

Putting elements together to form a novel, coherent whole or make an original product
6.1 Generating _{STP}
6.2 Planning
6.3 Producing

(Krathwohl, 2002:215)

According to Krathwohl (2002), the categories of structure cognitive dimension were ordered from simple to complex and from concrete to abstract. If so, then the thinking skills start from the lowest dimension namely remember to the highest dimension, namely create. The order of thinking skills from the lowest to the highest is remembering, understanding, applying, analyzing, evaluating, and creating. If grouped into two broad categories, the LOTS (Low Ordered Thinking Skills) remembering, understanding and applying, and HOTS (High Ordered Thinking Skills) is analyzing, evaluating, and creating.

METHODS

This research starts from the study of physics literature especially in mechanics for several cases of the free-body system in order to make test instruments related to representation diagrams. The questions asked are questions that are often found in university physics reference handbooks written by Alonso-Finn, Sears-Zemansky, Giancoli, Halliday-Resnick, Young-Freedman and Schaum's Series. The questions given require special answers only in the form of drawings or diagrams. Test in the form of essay tests with a total of 10 questions. Test time for 30 minutes. The instrument is tested for the validity of content and construct. Content validity based on the test content. Construct validity based on the internal structure, response processes and consequences of testing. Participants in this research were 22 students the pre-service teacher who had passed the course of evaluation of physics learning. To check the consistency of students related to LOTS and HOTS categories, then after the test is complete, students give opinions about the test in accordance with the category of cognitive domain of Bloom's revised. Students respond by writing C1, C2, C3, C4, C5, and C6 according to the sequence of cognitive dimensions from low to high on the test material. The test material is shown in Table 3.

Table 3. Material of tests

Items	Material of test
1	Free-fall
2	Block static on the horizontal plane
3	Block move on the inclined plane no friction
4	Block move on the rough inclined plane
5	Ladder resting against a frictionless wall on the rough horizontal floor

6	Pulley with two blocks is hung free
7	Three of stacked block static on the horizontal plane
8	Two blocks are arranged on a horizontal plane and one block is hung free
9	Two blocks are connected by a rope, one above a rough inclined plane and one block is hung free
10	The block is released freely in the quarter circle's no friction curved plane and then glides over a rough horizontal plane

RESULT AND DISCUSSION

Based on the students' responses to the test material according to the cognitive dimension of Bloom's revised, the category of test material was compiled according to the criteria of LOTS and HOTS. For this purpose, the worksheets of participants were examined one by one. LOTS if students give respond C1, C2, and C3; then HOTS if they respond C4, C5, and C6, Data responses of participant is processed and analyzed, and the results are shown in Table 4.

Table 4. Student responses and categories of LOTS and HOTS test items

Items	Students' responses			LOTS	HOTS
	C	IC	NA		
1	11	11	0	100%	-
2	0	19	3	100%	-
3	2	17	3	95%	5%
4	1	13	8	82%	18%
5	0	1	21	27%	73%
6	5	10	7	82%	18%
7	0	22	0	31%	69%
8	0	19	3	5%	95%
9	0	22	0	-	100%
10	0	17	5	-	100%

C-correct; IC-incorrect; NA-not answer

The items are categorized as LOTS or HOTS if the percentage is greater 70%. Based on table 2, the test items categorized as LOTS are items 1,2,3,4, and 6 and those categorized as HOTS are 5,7,8,9, and 10.

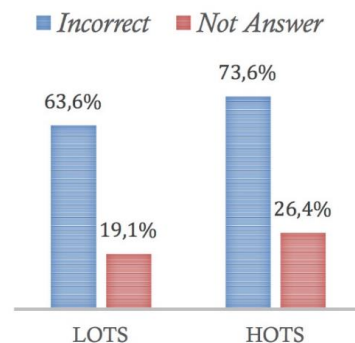


Figure 1. The identification of LOTS and HOTS related to students' responses incorrect and not answer

From Figure 1, it can be seen that between LOTS and HOTS, there is not much difference between students who answer incorrectly. Also from Figure 1 shows that between LOTS and HOTS there was no big difference between students who did not answer. According to Krathwohl (2002), the categories cognitive dimensions were ordered from simple to complex and from concrete to abstract (Krathwohl, 2002:212), then in the LOTS category, almost all of them could do the problem, only few of them chose wrong answer. Why research findings like this? The results of the study confirm the research conducted by Vijaya Bhaskara (2017) in the article: *Students Problem-Solving Difficulties and Implications in Physics: An Empirical Study on Influencing Factor*, found lack of ability in remembering related equations in physics subject, lack of understanding the fundamental basic of the physics problem, lack of motivation from the physics teachers and inexperience of the teacher, poor comprehensive skills on definitions, laws, and basic principles of physics (Vijaya Bhaskara, 2017:61). As stated by Amante, that learners have difficulties in analyzing what a problem requires and it leaves them confused about what to do next in completing the tasks (Amante, 2010:170). Physics can be understood well if the concepts of physics are fully understood and if not well understood there will be misconceptions. Selahattin Gonen (2008) presents the results of his research as follows a result of the analysis undertaken, it was found that teachers had serious misconceptions about inertia, gravity, gravitational acceleration, gravitational force and weight concepts (Selahattin, 2008:70), as stated by Sirat (2017) that the most difficult task for the students in terms was identifying the force diagram representing forces exerted on an object on in an inclined plane, and the students' difficulty is they are not aware of friction force, weight force, and normal force (Sirait, 2017:3). Current research in the field of physics learning shows the use of interaction diagrams in teaching can improve understanding of the concept of physics, example, the concept of Newton third law (Savinainen, 2015:). On the other-hand other research findings suggest, many scientific concepts including physics, processes and their relationships can be understood more quickly when they are given with various kinds of picture or diagrams, as well as the use of various sources of information (multiple sources), which then can make learners able to select sources as a reference and their way of learning (Opfermann, 2017:). Research in the field of physics education indicates the use of multiple representations in the teaching and learning process helps students become excellent problem-solvers (Nguyen, 2011). The use of multiple sources and multiple representation, according to *The Cognitive*

Theory of Multimedia Learning (CTML), as confirming by multimedia principles: *Students learn better from words and pictures than from words alone* (Mayer, 2009), and related to CTML, then *using multiple representations can foster learning* (Opfermann, 2017:). The interactions that occur in the teaching and learning process are actually information absorption and deposition, which according to The Theory of Mental Models suggests that "... learning is a form of information processing" (Hanke, 2008:). This is confirmed clearly according to Behavioral Psychology which states, "*successful learning involved the mental acquisition of a 'copy' of the information being*" (Gilbert, 2010:). Some of the views above give message of the importance of using representation diagrams in physics learning. The reason that underlies all the main theories of learning is the assumption that thinking proceeds by the brain acting on data being received as if that consisted of a stream of 'entities'-that is as if it had object-like properties. These entities convey specific information about what is being studied by depicting ideas, objects, systems, events, processes, as what may be broadly termed 'representations' (Gilbert, 2010). Thus, it is necessary to consider the views of Peter Huber (2014) as he wrote in his paper *Teacher Change in Implementing a Research Developed Representation Construction Pedagogy* that is the representations in learning science has successfully demonstrated enhanced student learning through sustained engagement with ideas, and enhancement of teachers' pedagogical knowledge and understandings of how knowledge in science is developed and communicated. This approach involves challenging students to generate and negotiate the representations (text, graphs, models, diagrams) that constitute the discursive practices of science, rather than focusing on the text-based, definitional versions of concepts. The representation construction approach is based on sequences of representational challenges which involve students constructing representations to actively explore and make claims about phenomena. It thus represents a more active view of knowledge than traditional structural approaches and encourages visual as well as the traditional text-based literacies (Hubber, 2014:1049). However, this research needs to reflect on the question of why tests that only require answers to draw or diagrams, and they categorize LOTS, but many students answer incorrectly and in fact, there are students who do not answer? Or a test that requires answers to diagrams or drawings is a test that requires the ability to think that is not dominated by remembering and understand, but tests that are more classified apply, analyze, evaluate and create (HOTS)? According to Mehmet Kurnaz (2015) that physics courses include many abstract concepts,

such as force and energy, and students' difficulties in fully grasping these concepts are frequently discussed in related literature, and by quoting from Clement (1982) who stated that it is hard for students who have incorrect or missing information about physics to correctly form new ideas (Kurnaz, 2015:788). The above opinion clarifies the idea that even though the test only requires answers to drawings, but if it is related to abstract concepts such as force vectors, this kind of test can be classified as HOTS. Because of that in a didactic manner, the problem of learning physics using diagrams representation requires in-depth research.

CONCLUSION

Krathwohl (2002) mentioned that the categories of cognitive dimensions were ordered from simple to complex and from concrete to abstract, and it was assumed that the original taxonomy represented a cumulative hierarchy; that is, mastery of each simpler category was prerequisite to mastery of the next more complex one (Krathwohl, 2002:212). Krathwohl's statement above emphasizes the role of cognitive domain mastery in all categories. Although cognitive domain such as remembering and understanding are categorized as LOTS this cognitive level must be mastered with the ability to think properly and correctly. Examples of remembering categories are defined as retrieving relevant knowledge from long-term memory, in the forms of verbs recognizing, recalling. At the lowest level of thinking ability is the tendency of rote thinking skills. As stated by Elby (1999) that most students who are substantially distort their study habits believe that failure to do so would lead to lower grades. Another large set of students believes that a deep understanding can lead to good grades, but that a more rote understanding can also lead to good grades (Elby, 1999:53). Those studies show that some students learn by rote partly because they have a naive conception of what it means to understand physics (Elby, 1999:56). Regarding the importance of using representation in physics learning, physics didactically need to make drawing or representation diagrams an important part of the teaching and learning process. Huber (2014) described his views were as follows, representation construction approach is broadly described as (a) *teaching sequences are based on sequences of representational challenges*: Students construct representations to actively explore and make claims about phenomena, (b) *representations are explicitly discussed*: The teacher plays multiple roles, build the discussion to critique and support student representation construction in a shared classroom process. Students build their meta-representational competency through these discussions, (c)

meaningful learning involves representational/ perceptual mapping: Students experience strong perceptual/experiential contexts, encouraging constant two-way mapping/reasoning between observable features of objects, potential inferences, and representations, (d) *formative and summative assessment is ongoing*: Students and teachers are involved in a continuous, embedded process of assessing the adequacy, and their coordination, in explanatory accounts (Hubber, 2014:1050). Specific research related to the measurement and assessment of the use of representation diagrams in both formative and summative forms is less reported in educational research journals. Considering the very important use of representation in physics learning it is necessary to conduct more in-depth research both related to taxonomy and measurement methods or techniques and assessment. As explained in the discussion section, if further studies support the importance of using representation diagrams in physics learning because they tend to be categorized as HOTS, then it needs to be accommodated as test material, questions that only need answers to drawings in the middle school national exams and college entrance test.

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