IOP Conference Series: Earth and Environmental Science

PAPER • OPEN ACCESS

What can students show about higher order thinking skills in physics learning?

Supeno[1], S Astutik[1], S Bektiarso[1], A D Lesmono[1] and L Nuraini[1]

Published under licence by IOP Publishing Ltd
IOP Conference Series: Earth and Environmental Science, Volume 243, conference 1

Abstract

Higher order thinking skills are the ability to think not just recall, restate, or recite but it reaches several dimensions of knowledge, including metacognitive dimensions. Students who have higher order thinking skills will be have the ability of connect different concepts, interpret, problem solving, communication, reasoning, and make the right decisions. Identification of higher order thinking skills needs to be done through research and the results are expected to be used as a reference to design of instructional strategies that are appropriate to the characteristics of students. In this study, identification is done by measuring the ability of problem solving, communication, and reasoning skills. The results showed that students' ability to solve of well structured problem including satisfactory but the ability to solve of ill structured problem needs to be developed. For communication skill, students are still not used to expressing their ideas in scientific writing. For reasoning skill, although students are able to reason on some aspects, but in general still not satisfactory. Therefore, it is necessary to develop a proper physics instructional design and in accordance with the characteristics of students to teach higher order thinking skills.

References

[1] Anderson G L, Krathwohl D R, Airasian W P, Cruikshank K A, Mayer E R, Pintrich R P *et al* (ed) 2001 *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives* (Boston: Allyn & Bacon)
Google Scholar

[2] Ben-Chaim D, Ron S and Zoller U 2000 The disposition of eleventh-grade science students toward critical thinking *Journal of Science Education and Technology* **9** 149-159
Crossref Google Scholar

[3] Bjork R A, Dunlosky J and Kornell N 2013 Self-regulated learning: Beliefs, techniques, and illusions *Annual Review of Psychology* **64** 417-444
Crossref Google Scholar

[4] Dori Y J, Tal R T and Tsaushu M 2003 Teaching biotechnology through case studies—can we improve higher order thinking skills of nonscience majors? *Science Education* **87** 767-793
Crossref Google Scholar

[5] Facione P A 2013 *Critical Thinking; what it is and why it counts?*
Google Scholar

[6] Garcia L C 2015 Environmental science issues for higher-order thinking skills (hots) development: A case study in the Philippines *Biology Education and Research in a Changing Planet* ed Sarojini Daniel Esther Gnanamalar 45-54
Crossref Google Scholar

[7] Garrison D R, Anderson T and Archer W 2001 Critical thinking, cognitive presence, and computer conferencing in distance education *American Journal of Distance Education* **15** 7-23
Crossref Google Scholar

[8] Graesser A C, Person N and Hu X 2002 Improving comprehension through discourse processes *New Directions in Teaching and Learning* **89** 33-44
Crossref Google Scholar

[9] Harrigan A and Vincenti V 2004 Developing higher-order thinking through an intercultural assignment *College Teaching* **52** 113-120
Google Scholar

[10] Jensen J L, McDaniel M A, Woodard S M and Kummer T A 2014 Teaching to the test…or testing to teach: Exams requiring higher order thinking skills encourage greater conceptual understanding *Educational Psychology Review* **26** 307-329
Crossref Google Scholar

[11] Kuhn D 2005 *Education for thinking* (Cambridge, MA: Harvard University Press)
Google Scholar

[12] Madhuri GV, Kantamreddi VSSN and Goteti LNSP 2012 Promoting higher order thinking skills using inquiry-based learning *European Journal of Engineering Education* **37** 117-123
Crossref Google Scholar

[13] McQuiggan S, Kosturko L, McQuiggan J and Sabourin J 2015 *Mobile learning; A handbook for developers, educators, and learners* (New Jersey: John Wiley & Sons, Inc)
Google Scholar

[14] Milner-Bolotin M and Nashon S M 2012 The essence of student visual-spatial literacy and higher order thinking skills in undergraduate biology *Protoplasma* **249** S25-S30
Crossref Google Scholar

[15] Miri B and Dori Y J 2009 Enhancing higher order thinking skills among inservice science teachers via embedded assessment *Journal of Science Teacher Education* **20** 459-474
Crossref Google Scholar

[16] Miri B, David B-C and Uri Z 2007 Purposely teaching for the promotion of higher-order thinking skills: A case of critical thinking *Research in Science Education* **37** 353-369
Crossref Google Scholar

[17] OECD 2018 *PISA 2015 Results in Focus*
Google Scholar

[18] Peterson D, Kromrey J, Lewis A and Borg J 1992 Clinical pedagogy: defining and measuring the teaching of essential and higher order thinking skills *Journal of Personnel Evaluation in Education* **6** 57-70
Crossref Google Scholar

[19] Resnick L 1987 *Educational and learning to think* (Washington D.C.: National Academy Pres)
Google Scholar

[20] Roets L and Maritz J 2017 Facilitating the development of Higher-Order Thinking Skills (HOTS) of novice nursing postgraduates in Africa *Nurse Education Today* **49** 51-56
Crossref Google Scholar

[21] Scott K M, Barbarin O A and Brown J M 2013 From higher order thinking to higher order behavior: exploring the relationship between early cognitive skills and social competence in black boys *American Journal of Orthopsychiatry* **83** 185-193
Crossref Google Scholar

[22] Senk S L, Beckmann C E and Thompson D R 1997 Assessment and grading in high school mathematics classrooms *Journal for Research in Mathematics Education* **28** 187-215
Crossref Google Scholar

[23] Timmerman B E C, Strickland D C, Johnson R L and Payn J R 2011 Development of a 'universal' rubric for assessing undergraduates' scientific reasoning skills using scientific writing *Assessment & Evaluation in Higher Education* **36** 509-547
Crossref Google Scholar

[24] van den Berg G 2004 The use of assessment in the development of higher order thinking skills *Africa Education Review* **1** 279-294
Crossref Google Scholar

[25] Vidergor H E 2010 The multidimensional curriculum model *Gifted and Talented International* **25** 153-165
Crossref Google Scholar

[26] Whimbey A 1984 The key to higher order thinking is precise processin *Educational Leadership* **42** 66-70
Google Scholar

[27] Widana W I 2017 *Modul penyusunan soal Higher Order Thinking Skills (HOTS)* (Jakarta: Direktorat Pembinaan SMA Direktorat Jenderal Pendidikan Dasar dan Menengah Departemen Pendidikan dan Kebudayaan)
Google Scholar

[28] Yee MH, Yunos JM, Othman W, Hassan R, Tee TK and Mohaffyza M 2015 Disparity of learning styles and higher order thinking skills among technical students *Procedia - Social and Behavioral Sciences* **204** 143-152
Crossref Google Scholar

[29] Zohar A 2004 *Higher order thinking in science classrooms: students' learning and teachers' professional development* (Science+Business Media Dordrecht: Springer)
Crossref Google Scholar

[30] Zohar A and Dori Y J 2003 Higher order thinking skills and low-achieving students: Are they mutually exclusive? *The Journal of the Learning Sciences* **12** 145-181
Crossref Google Scholar

[31] Zohar A and Nemet F 2002 Fostering students' knowledge and argumentation skills through dilemmas in human genetics *Journal of Research in Science Teaching* **39** 35-62
Crossref Google Scholar

[32] Zoller U 1993 Lecture and learning: Are they compatible? Maybe for locs; unlikely for hocs *Journal of Chemical Education* **70** 195-197
Crossref Google Scholar

[33] Zoller U 1999 Teaching tomorrow's college science courses - Are we getting it right? *Journal of College Science Teaching* **29** 409-414
Google Scholar

[34] Zoller U 2001 Alternative assessment as (critical) means of facilitating HOCS-promoting teaching and learning in chemistry education *Chemical Education Research and Practice in Europe* **2** 9-17
Crossref Google Scholar

[35] Leou M., Abder P., Riordan M. and Zoller U. 2006 Using 'HOCS-centered learning' as a pathway to promote science teachers' metacognitive development *Research in Science Education* **36** 69-84
Crossref Google Scholar

PAPER • OPEN ACCESS

What can students show about higher order thinking skills in physics learning?

To cite this article: Supeno *et al* 2019 *IOP Conf. Ser.: Earth Environ. Sci.* **243** 012127

What can students show about higher order thinking skills in physics learning?

Supeno[1], S Astutik[1], S Bektiarso[1], A D Lesmono[1] and L Nuraini[1]

[1] Faculty of Teacher Training and Education, University of Jember

supeno.fkip@unej.ac.id

Abstract. Higher order thinking skills are the ability to think not just recall, restate, or recite but it reaches several dimensions of knowledge, including metacognitive dimensions. Students who have higher order thinking skills will be have the ability of connect different concepts, interpret, problem solving, communication, reasoning, and make the right decisions. Identification of higher order thinking skills needs to be done through research and the results are expected to be used as a reference to design of instructional strategies that are appropriate to the characteristics of students. In this study, identification is done by measuring the ability of problem solving, communication, and reasoning skills. The results showed that students' ability to solve of well structured problem including satisfactory but the ability to solve of ill structured problem needs to be developed. For communication skill, students are still not used to expressing their ideas in scientific writing. For reasoning skill, although students are able to reason on some aspects, but in general still not satisfactory. Therefore, it is necessary to develop a proper physics instructional design and in accordance with the characteristics of students to teach higher order thinking skills.

1. Introduction

The current curriculum in Indonesia is the 2013 curriculum. Ministerial regulation No. 59 of 2014 on the 2013 curriculum states that one of the reasons for the improvement of the curriculum is the existence of internal and external challenges. External challenges are linked to globalization and environmental issues, technological and information developments, the demands of creative industries, culture, and the development of education at the international level. One of the improvements of the curriculum is the demands on process standards and direct assessment to the achievement of high-order thinking skills or namely called HOTS.

HOTS is a high-level thinking ability, i.e the ability to think not just remember, restate, or recite. However, HOTS reaches several capabilities: 1) transfering one concept to another, 2) processesing and implementing information, 3) seeking links from different information, 4) processesing information to solve problems, and 5) analyzing ideas and information critically [27]. Based on the dimension of knowledge, HOTS is not merely knowledge in the factual, conceptual, or procedural dimension but to the metacognitive dimension [1]. The metacognitive dimension describes the learner's ability to connect several concepts, interpret, problem solving, discovery, reasoning, and decision making.

Higher order thinking skills may also be used to delineate cognitive activities that are beyond the stage of understanding. Cognitive activities that are classified as higher order include constructing arguments, asking research questions, making comparisons, solving non algorithmic complex problems, dealing with controversies, and identifying hidden assumptions [30]. Characteristics of mental activity derived from the high order of thinking process often involve complex thinking, non-algorithmic, independence in the thinking process and can result in applicative solutions [15, 19, 29]. Other examples of cognitive activities that can be classified as higher-order thinking activities are argumentation, comparison, problem solving, dealing with difference of opinion, decision making, and identification of hidden assumptions [31]. Senk et al. state that high order of thinking has a characteristic to solve special problems and the solutions are results of thinking and reasoning [22]. Futhermore, higher order thinking skills relate to skills of research, problem-solving, exploration and academic writing, critical thinking and reasoning, and creativity for other material [13, 20]. HOTS related with emotion regulation, behavior regulation, social communication skills, peer social skills, teacher relations [21]. Thus, recent trends in science education focus on higher-order thinking skills [6].

Learning oriented to the achievement of HOTS is the focus of education today because it provides many benefits for students. The development of higher-order thinking skills, or higher order cognitive skills by others [2, 33] is the prominent in order to facilitate the transition of students' knowledge and skills into responsible action, regardless of their particular future role in society [33, 34]. Students' higher order thinking skills were enhanced in terms of their ability to (a) pose complex questions, (b) present solid opinions, (c) introduce consistent arguments, and (d) demonstrate critical thinking [15]. Widana states that learning and assessment by involving HOTS provide several benefits to students [27], i.e. 1) preparing the competence of students to meet the 21st century, 2) fostering a sense of care about the progress of the region because HOTS assessment is generally based on the contextual close to the student environment, 3) improving student learning motivation, and 4) improving the quality of assessment. Students with good HOTS not only have conceptual mastery but also have good retention of knowledge [10]. HOTS enable students to overcome challenges in the current information age, where too much information but time is limited for processing [28]. Students who have high-level thinking skills will be able to analyze a complex condition and be able to initiate good ideas and arguments [11] so as to compete in today's modern world [5].

Assessment of HOTS plays an important role in assisting students in learning. The assessment level incorporated into the course had a significant impact on students' conceptual understanding and final achievement scores. Higher-order assessments may be a key factor in stimulating students to effectively acquire a deep understanding of the material, an understanding that support, not only application, analysis and evaluation, but also better retention of the core facts [10]. Diagnosis of higher-order thinking skills and the development of methods by which one of the most important is the ability to move from "one-shot thinking toward precise processing" [26]. A striking pattern emerged that requests higher than average scores on the basis of higher scores on the facts, as evidenced by higher scores on low-level questions. However, higher-order assessments may not be the most important, but also better retention of the core facts [10].

Several studies have been conducted to obtain information about students' HOTS abilities. The results of the International Study Program for International Student Assessment (PISA) indicate that Indonesian students' literacy is low categorized in: (1) understanding complex information; (2) theory, analysis, and problem solving; (3) use of tools, procedures, and problem solving; and (4) conduct investigations [17]. The results of several other studies also show that the achievement of HOTS students in the category is unsatisfactory [24, 14]. It was our impression that their frustration was not due to a lack of ability but rather to a lack of experience with exams requiring study strategies aimed at deep conceptual learning and critical thinking [10]. As was pointed out in a recent review, students often do not recognize how they learn and thus do not appreciate many beneficial learning tasks [3].

Science learning was directed at the accomplishment of high-order thinking skills that studied in several studies [4, 9, 12, 15]. A major component of the current reforms in science education worldwide is the shift from the dominant traditional teaching for algorithmic, lower-order cognitive skills, to higher-order cognitive or thinking skills [32, 33, 35]. In general, it can be said that higher order thinking skills become one of the main goals in science learning. HOTS can be trained in the learning process. Therefore, the learning process should give space to the students to discover the concept with activity-based knowledge. Activity in learning can encourage learners to build creativity and critical thinking. The learning strategy must be appropriate with the characteristics of the students. Learning should be designed by taking into account the HOTS capabilities possessed by students [4]. For this reason, researchers identify students' abilities towards higher-order thinking skills. The three higher order thinking skills studied included the ability to complete ill structured problems, reasoning, and writing skills.

The main problems in this study are:

1. How is the ability of students to complete ill structured problems about dynamics of harmonic motion and application of newtons' law on seat belt?
2. How is the student's ability to give reasoning accompanied by scientific evidence?
3. How is the ability of students in scientific writing while doing laboratory work?

The results of this study are expected to be used as a reference in designing appropriate learning strategies and lead to the achievement of high-level thinking skills and taking into consider the potential of students.

2. Method

2.1 Responden

The research was conducted in three senior high schools in Jember district of East Java, Indonesia. Each school is adjusted to the skills measured. In the first school, we have studied the problem solving ability of 164 students. In the second school, we have studie the reasoning ability of 138 respondents. In the third school, we have studied the scientific writing ability of 36 respondents.

2.2 Research Instrument

Data of high-level thinking skills is obtained through tests conducted after the students follow the instruction about oscilation, dynamic, and optic. Physics learning is done by applying scientific approach in accordance with the applicable curriculum demands. Test was designed to measure three skills, i.e. problem solving, reasoning, and writing skills. The test to measure problem solving ability is two questions with the topic of dynamics of harmonic motion and the problem of seat belt on the car. Problems include ill structured problem, i.e. type problem in the form of a description problem without any clear components. Ill structured problem is a difficult problem and requires higher-order thinking skills to solve the problem. In ill structured problem, students are given the opportunity to be creative in solving problems. The solution of ill structured problem varies, depending on the students' ability to solve the problem. Each individual has a different way of problem solving.

The test to measure the reasoning ability consists of two questions with the topic of the use of mirrors and lenses. In reasoning tests, students are assigned to answer questions by providing claims, evidence, and providing reasoning that relate evidence to claims. Students with good reasoning ability demonstrated true claims and accompanied by sufficient evidence. The link between claims and evidence should be supported with sufficient scientific explanation. The results of this test are used to measure students' ability in providing reasoning in the form of scientific explanations.

The scientific writing skills assessment instruments use a student worksheet containing investigative guidelines, systematic laboratory reports, and investigative steps. After conducting an investigation, students induce the results of their activities in a scientific paper in the form of laboratory reports. Scientific writing skills are measured through the assessment of laboratory reports using rubrics which include eleven components consist of context, accuracy, hypotheses, methods, data selection, data presentation, conclusions, design limitations, significance, and quality of writing [23].

2.3 Data Analysis
The data obtained are further processed and analyzed by assessing and scoring the test results. Furthermore, the results are used to describe the profile of students' achievement abilities in problem solving, reasoning, and writing skills. The problem solving problem profile is described based on the percentage of the number of students and the characteristics of the outcome of the problem in the answer sheet. The profile of reasoning ability is described based on scoring achievement for every aspect of reasoning. The profile of scientific writing ability is described based on the scoring achievement of students' scientific writing ability on eleven aspects of scientific writing.

3. Result and Discussion

3.1 Problem Solving Skills
The first problems posed to students is the application of Newton's law in harmonic motion. Problems are presented in incomplete information and objectives. The ability of students to solve ill structured problems in the dynamics of harmonic motion is determined based on the problem solving procedure consisting of four stages, that is, identifying the problem, planning the strategy, applying the strategy, and evaluating. The result of problem solving ability assessment for harmonic motion dynamics problem is shown in Table 1.

Table 1. Problem solving ability about dynamics of harmonic motion.

Component of Skills	Percentage number of students				
	Very Good	Good	Enough	Poor	Very Poor
Indentifying the Problem	32,31	48,78	16,46	1,21	2,43
Planning the Strategy	29,26	15,24	2,40	32,31	20,73
Applying the Strategy	0,60	15,84	13,41	25,00	48,17
Evaluating	33,53	0,00	23,17	0,00	48,17

Based on data in Table 1, it can be explained about the students' ability to identify problems, plan strategies, implement strategies, and evaluate strategies when solving ill structured problems about the dynamics of harmonic motion. Based on the data, it can be said that most students have the ability to recognize problems in the ill structured problem about the dynamics of harmonic motion. Students are able to identify problems based on the basic concepts of physics, make a list of known physics quantities, and determine the quantities being asked. When planning the strategy, about half of the respondents have the ability to plan the strategy and about half of the other respondents have the ability to plan the strategy of ill structured problem including the category of less and even less. Students who are able to plan a strategy can demonstrate the ability to create free-body diagrams or sketches that describe the problem and be able to determine the formula with the appropriate physical explanation to solve the problem.

For the ability of applying strategy and evaluation, most students have low ability. Students have not been able to apply the strategy, it means that students have not been able to substitute the value of known physics to mathematical formula, performing calculations using mathematical formula chosen. Most students also have not been able to do the evaluation, which means that students have not been able to give an explanation of the conformity of the answers with the concept of physics and the suitability of units for the amount of physics.

When completing the ill structured problem in harmonic motion dynamics, number of students who are able to recognize the problem is almost equivalent to the number of students who are able to evaluate. The number of students who are able to evaluate is greater than the number of students who are able to implement the strategy. There are some students who do not identify problems based on the

basic concepts of physics, do not list the known physical quantities, and do not write down the quantities that must be determined. In addition, there are also some students who do not make free object diagrams or sketches that illustrate the problem and do not write the formula with the right physical explanation to solve the problem. When students are able to evaluate, they are not able to apply the strategy very well. When applying the strategy, students should be able to explore the problem space so that students must know all possible alternative answers and choose the most correct strategy. The ability of evaluation can be seen from the ability of students choose the correct answer and able to answer the purpose of the problem. Generally, although several students are not able to explore the problem space but they are able to write and use the correct mathematical formula so that the answer is correct and able to perform the evaluation including very well category.
The second problem posed to the student is about the use of seat belts on the car, i.e. the application of Newton's law to a suddenly braked car seat belt. Problems are presented in incomplete information and objectives. The ability of students to solve ill structured problems in the application of Newtons' law on seat belt is assessed based on the problem solving procedure consisting of four stages, that is, identifying the problem, planning the strategy, applying the strategy, and evaluating. The ability of students in solving ill structured problems on the application of car seat belts is shown in Table 2.

Table 2. The ability of problem solving about application of newtons' law on seat belt.

Component of Skills	Percentage number of students				
	Very Good	Good	Enough	Poor	Very Poor
Indentifying the Problem	29,87	34,75	17,68	12,19	5,48
Planning the Strategy	51,21	27,43	0,00	5,48	15,85
Applying the Strategy	46,34	39,02	0,60	0,00	9,75
Evaluating	55,48	0,00	7,31	0,00	37,19

Based on the data in Table 2, it can be said that half of the respondents were able to recognize problems when solving ill structured problems about applying Newton's law to the car seat belt. Students were able to identify problems based on the basic concepts of physics, make a list of known physics quantities, and determine the quantities being asked. When planning the strategy, more than half of the respondents were able to plan the strategy. This shows that most students are able to make free object diagrams or sketches that describe the problem and determine the formula with the proper physical explanation to solve the problem. Likewise, when implementing the strategy, more than half of the respondents were able to implement the strategy. This is mean that most students were able to substitute the value of physical quantities known to mathematical formulas, doing calculations using mathematical formulas. When evaluating, more than half of the respondents were able to evaluate the results of problem solving. Most students are able to give an explanation of the conformity of the answers with the concepts of physics as well as the suitability of units for the quantities of physics.
When students solve the ill structured problem in applying Newton's law on a car seat belt, the number of students who are able to recognize the problem is very well smaller than in the number of students who are able to implement the strategy and evaluate. Students generally immediately apply the strategy to use quantities and values without writing down the known physical quantities. Some students write strategies that are not coherent and incomplete and the strategies used are not appropriate. In addition, there are several students who write strategies by using the formula that will be used. Students immediately write the formula used in the indicator to implement the strategy. According to students' information during the interview, students were not used to writing strategies so that they had difficulty in planning strategies. In addition, students are accustomed to memorizing formulas so that they are difficult in terms of the physical meaning of the formula. Students have

difficulty solving problems that have never been met before even though the core problem uses the same concept.
Based on the analysis conducted by researchers, there are some students who are not complete in writing components to recognize the problem. The percentage of students who are able to apply strategy is smaller than the percentage of students who are able to evaluate because some students do not depict free-body diagrams. The student immediately writes a mathematical formula and the answer given is correct. From the data in Table 2, the percentage of students who are able to recognize the problem is smaller than the percentage of students who were able to evaluate because some students were not able to recognize the problem but they were implement the strategy and evaluate immediately.

3.2 Reasoning

The reasoning ability is based on the reasoning assessment result which consists of two questions about the application of concave mirrors and the application of convex lenses. The assessment results for both problems are shown in Table 3.

Table 3. Students' achievement of each reasoning indicator.

Indicator	Score	Number of Students on Each Topic			
		Concave Mirrors	Percentage	Convex Lenses	Percentage
Claim	0	3	2,20%	6	4,40%
	1	13	9,40%	95	68,80%
	2	122	88,40%	37	26,80%
Evidence	0	0	0,00%	1	0,70%
	1	12	8,70%	4	2,90%
	2	29	21,00%	40	29,00%
	3	97	70,30%	93	67,40%
Reasoning	0	0	0,00%	2	1,45%
	1	116	84,10%	130	94,20%
	2	15	10,80%	4	2,90%
	3	7	5,10%	2	1,45%

Based on Table 3, it can be seen that most of the respondents are able to provide the right claim and a few others are still unable to provide appropriate evidence. Likewise for the ability to provide evidence, most students are able to provide evidence that can support the claim given. Nevertheless, some students can't give the reason clearly. Some students are also unable to explain the link between claims and evidence. Based on these data, it can be said that students are able to provide claims and evidence but they are less able in providing reasoning about the application of concave mirrors in everyday life. Slightly different for data on reasoning abilities about the application of convex lenses, several students are able to provide claims and evidence correctly and others are unable to properly provide claims and evidence. Most students are not able to reason correctly. Students are also unable to provide an explanation of the relationship between claims and evidence. In this case, students tend to be able to provide claims and evidence but are less able to provide reasoning about the application of convex lenses in everyday life. Many students make claims about concave lenses but provide evidence by showing examples of tools in everyday life that use convex lenses. This shows that the reasoning given by students cannot link claims with evidence. Overall, it appears that students tend to provide appropriate claims and evidence, but can't give the right reasoning. Students master satisfactory ability in providing claims and evidence is categorized as satisfying, whereas the ability to provide reasoning tends to be in the unsatisfactory category.

3.3 Writing Skills

Scientific writing skills are skills in scientific writing activities that students do to express ideas or ideas into written form. In this study, scientific writing skills were measured based on reports of laboratory activities made by students after investigation. Assessment is done using a rubric with components of context, accuracy, hypothesis, method, data selection, data presentation, conclusion, design limitations, significance, and quality of writing. The results of the assessment of the laboratory activity report are shown in Table 4.

Table 4. Students' achievement of scientific writing skills.

Components of Skills	Scores Reached	Percentage of Achievement
Context	38	35%
Accuracy	38	35%
Hypotheses Testable	32	30%
Hypotheses Scientific merit	8	7%
Methods	38	35%
Data selection	54	50%
Data presentation	108	100%
Conclusions	22	20%
Limitations of design	0	0%
Significance of research	10	9%
Writing quality	43	40%

Based on the data in Table 4, it can be seen that the achievement of scores for each component of scientific writing skills is still in the unsatisfactory category, except the ability to present data. Students still have difficulties in writing the background why the problem being studied is interesting to investigate. When writing a background, students have not been able to demonstrate the accuracy and relevance of the background of the investigation. Students also have difficulties in writing hypotheses, investigative methods, writing data acquisition procedures, and interpreting the results of investigations in the form of tables or graphs. When writing conclusions, students find it difficult to explain the relationship between the proposed hypothesis and the data obtained. Although the students were able to present the data, they still had difficulty in writing an explanation of the weaknesses of data presentation and errors in data retrieval during the investigation. Students also still have difficulty explaining the importance of the results of the investigation for subsequent activities. In the use of grammar, students need to learn a lot using the grammar and spelling used in writing reports.

The results show that high-order thinking skills are still in the less satisfactory category. Based on the results of this study, the teacher must redesign the learning process. Various strategies can be integrated into scientific approaches, including dealing in classes with encouraging open-ended class discussions, and fostering inquiry-oriented experiments [16]. Scaffolding, by others who are more expert, both peers and teachers also become an alternative in teaching high-order thinking skills because the reasoning skills associated with thinking are generally agreed upon by many experts [9]. Open-ended class discussions can enhance higher-order thinking skills because good discussion involves posing questions, expressing critical views, and providing arguments to support one's views [8]. Kuhn argues that teaching to increase higher order thinking skills is essential for equipping students to participate in and contribute to modern democratic societies [11]. With inquiry-oriented experiments, students learn how to engage in higher order thinking activity; identifying problems, formulating possible solutions in the form of generalizations or hypotheses, and evaluating consequences of possible solutions [18].

4. Conclusion

Higher-order thinking skills reach several dimensions of knowledge and describe cognitive creativity. Cognitive activities that can be classified as high order include problem solving, reasoning, and communication skills in the form of scientific writing skills. In this study, it was conducted an assessment of these skills. The results of the assessment show that some students are capable of some aspects of ill structured problem solving and others are still not satisfying. For reasoning abilities, the results of the study showed that most students were able to provide claims and evidence appropriately. However, many students cannot provide reasoning correctly and rarely provide an explanation of the relationship between claims and evidence that has been given. For scientific writing skills, research results indicate that most students have difficulty writing reports of investigative activities in accordance with appropriate systematics. Based on the results of these studies, it is necessary to create and innovate of various learning activities that lead to the improvement of higher-order thinking skills.

Acknowledgement

The authors thank to the University of Jember for financial support of this project under scheme of Hibah Keris 2018 with Contract Number: 2863/UN25.3.1/LT/2018.

References

[1] Anderson G L, Krathwohl, D R, Airasian, P W, Cruikshank, K A, Mayer, R E, Pintrich, P R, et al. (Eds.) 2001 *A taxonomy for learning, teaching, and assessing: A revision of Bloom's taxonomy of educational objectives* (Boston: Allyn & Bacon)

[2] Ben-Chaim D, Ron S, and Zoller U 2000The disposition of eleventh-grade science students toward critical thinking *Journal of Science Education and Technology* **9(2)** p 149–159

[3] Bjork R A, Dunlosky J, and Kornell N 2013 Self-regulated learning: Beliefs, techniques, and illusions *Annual Review of Psychology* **64** p 417–444

[4] Dori Y J, Tal R T, and Tsaushu M (2003), Teaching biotechnology through case studies—can we improve higher order thinking skills of nonscience majors? *Science Education* **87(6)** p 767-793

[5] Facione P A 2013 *Critical Thinking*; *what it is and why it counts*?

[6] Garcia L C 2015 Environmental science issues for higher-order thinking skills (hots) development: A case study in the Philippines, in Biology Education and Research in a Changing Planet. edited by Esther Gnanamalar Sarojini Daniel p 45-54

[7] Garrison D R, Anderson T, and Archer W 2001 Critical thinking, cognitive presence, and computer conferencing in distance education *American Journal of Distance Education* **15(1)** p 7–23

[8] Graesser A C, Person N, and Hu X 2002 Improving comprehension through discourse processes *New Directions in Teaching and Learning* **89** p 33–44

[9] Harrigan A and Vincenti V 2004 Developing higher-order thinking through an intercultural assignment *College Teaching* **52(3)** p 113-120

[10] Jensen J L, McDaniel M A, Woodard S M, and Kummer T A (2014), Teaching to the test…or testing to teach: Exams requiring higher order thinking skills encourage greater conceptual understanding *Educational Psychology Review* **26(2)** p 307-329

[11] Kuhn D 2005 *Education for thinking* (Cambridge, MA: Harvard University Press).
[12] Madhuri GV, Kantamreddi VSSN and Goteti LNSP 2012 Promoting higher order thinking skills using inquiry-based learning *European Journal of Engineering Education* **37(2)** p 117-123
[13] McQuiggan S, Kosturko L, McQuiggan J and Sabourin J 2015 *Mobile learning*; *A handbook for developers, educators, and learners* (New Jersey: John Wiley & Sons, Inc)
[14] Milner-Bolotin M and Nashon S M 2012 The essence of student visual–spatial literacy and higher order thinking skills in undergraduate biology. *Protoplasma*, 249(Suppl 1) S25–S30
[15] Miri B & Dori Y J 2009 Enhancing higher order thinking skills among inservice science teachers via embedded assessment *Journal of Science Teacher Education* **20(5)** p 459-474
[16] Miri B, David B-C and Uri Z 2007 Purposely teaching for the promotion of higher-order thinking skills: A case of critical thinking *Research in Science Education* **37(4)** p 353–369
[17] OECD 2018 PISA 2015 Results in Focus
[18] Peterson D, Kromrey J, Lewis A and Borg J 1992 Clinical pedagogy: defining and measuring the teaching of essential and higher order thinking skills *Journal of Personnel Evaluation in Education* **6(1)** p 57-70
[19] Resnick L 1987 *Educational and learning to think* (Washington D.C.: National Academy Pres).
[20] Roets L and Maritz J 2017 Facilitating the development of Higher-Order Thinking Skills (HOTS) of novice nursing postgraduates in Africa *Nurse Education Today* **49** p 51-56
[21] Scott K M, Barbarin O A and Brown J M 2013 From higher order thinking to higher order behavior: exploring the relationship between early cognitive skills and social competence in black boys *American Journal of Orthopsychiatry* **83(2)** p 185–193
[22] Senk S L, Beckmann C E, and Thompson D R 1997 Assessment and grading in high school mathematics classrooms *Journal for Research in Mathematics Education* **28(2)** p 187-215
[23] Timmerman B E C, Strickland D C, Johnson R L, and Payn J R (2011), Development of a 'universal' rubric for assessing undergraduates' scientific reasoning skills using scientific writing *Assessment & Evaluation in Higher Education* **36(5)** p 509-547
[24] van den Berg G 2004 The use of assessment in the development of higher order thinking skills.*Africa Education Review* **1(2)** p 279-294
[25] Vidergor H E 2010 The multidimensional curriculum model *Gifted and Talented International* **25(2)** p 153–165
[26] Whimbey A 1984 The key to higher order thinking is precise processin*Educational Leadership* **42** p 66-70
[27] Widana W I 2017 *Modul penyusunan soal Higher Order Thinking Skills* (*HOTS*) (Jakarta: Direktorat Pembinaan SMA Direktorat Jenderal Pendidikan Dasar dan Menengah Departemen Pendidikan dan Kebudayaan)
[28] Yee, MH, Yunos, JM, Othman, W, Hassan, R, Tee, TK, and Mohaffyza, M (2015), Disparity of learning styles and higher order thinking skills among technical students *Procedia - Social and Behavioral Sciences* **204** p 143-152
[29] Zohar A 2004 *Higher order thinking in science classrooms: students' learning and teachers' professional development* (Springer Science+Business Media Dordrecht)
[30] Zohar A and Dori Y J 2003 Higher order thinking skills and low-achieving students: Are they mutually exclusive? *The Journal of the Learning Sciences* **12(2)** p 145–181
[31] Zohar A & Nemet, F 2002 Fostering students' knowledge and argumentation skills through dilemmas in human genetics *Journal of Research in Science Teaching* **39(1)** p 35–62
[32] Zoller U 1993 Lecture and learning: Are they compatible? Maybe for locs; unlikely for hocs *Journal of Chemical Education* **70(3)** p 195–197
[33] Zoller U 1999 Teaching tomorrow's college science courses – Are we getting it right? *Journal of College Science Teaching* **29(6)** p 409–414
[34] Zoller U 2001 Alternative assessment as (critical) means of facilitating HOCS-promoting teaching and learning in chemistry education *Chemical Education Research and Practice in Europe* **2(1)** p 9–17

[35] Leou, M., Abder, P, Riordan, M. and Zoller, U (2006). Using 'HOCS-centered learning' as a pathway to promote science teachers' metacognitive development. *Research in Science Education*, 36, 69-84.