Profile of physics laboratory-based higher order thinking skills (HOTs) in Indonesian high schools

A Ismail¹,²*, A Setiawan¹, A Suhandi³ and A Rusli³

¹Science Education Program, Postgraduate School, Universitas Pendidikan Indonesia, Bandung, Indonesia
²Department of Physics Education, Institut Pendidikan Indonesia, Garut, Indonesia
³Department of Physics, Faculty of Science and Information Technology, Catholic Parahyangan University, Bandung, Indonesia

*Corresponding author’s e-mail: ai7garut@gmail.com

Abstract. The existing physics laboratory is a pivotal part of teaching and learning physics. Several skills required by students can be facilitated by physics laboratory such as HOTs. However, the conventional laboratory that leads to verification laboratory was not successful training students dealing with HOTs. This present study investigated profile of physics laboratory-based HOTs in Indonesian high schools. A case study was conducted to take several data from participants. The participants of this present study are 12 physics teachers and 32 students in Indonesian high schools. A Questionnaire and HOTs test are used to garner the data. The finding research reveals that there four main obstacles to train and develop laboratory activities-based HOTs: the limitation of time to conduct laboratory activities, the limitation of lab space, the low ability of physics teachers in designing laboratory activities-based HOTs, and low knowledge of students dealing with concepts and laws of physics. These obstacles also support another result which depicts the low of use of HOTs lab and low achievement of students’ HOTs. A consideration of this result present study opens deep insight and wider context in a new form of laboratory activities in Indonesia that is augmented reality laboratory.

1. Introduction
Entering 21st century, educational system in all over the world faces the complex challenges in preparing the quality of human resources which have to be ready to compete in globalization era. This consequence urges the schools, as a one of unit educational systems, consider several aspects in preparing their students facing both internal and external challenges in 21st century. Internal challenges refer to the problem emerging in each country while the external challenges lead to the challenges both in regional and international communities. For instance, Indonesia as a part of regional community such as Association South East Asian Nation (ASEAN) has to act toward the issues of economical society, environment, technological information development, shifting the power of world economic, impact of science-technology, and transformation in educational sectors. In educational context, the external challenges indeed deal with how students can obtain the skills that are appropriate with the challenges in this era.

The problems emerging in 21st century, they are the similar problems faced by developing countries in the world. In this context, Indonesia tried to make penetration so as the quality of students can compete
globally. An effort that leads to this condition is to enforce new design of national curriculum (i.e. Curriculum-2013). The objective of this curriculum indeed responds the world challenges so that the graduates have the skills needed, namely competitive, innovative, critical, creative, and collaborative and also good character. In the real application in the classroom, all skills required by students have to be implemented in innovative instructional model for training and integrating HOTs, literacy, strengthening character education, and 4C that refers to Creativity and innovation, Critical thinking and problem solving, Communication, and Collaboration [1].

One of the point of departures for preparing students responding the world problems, they have to have HOTs. HOTs can link the real words problems with the teaching materials in which students should learn. One of the ways to train HOTs can be achieved by using laboratory activities in the classroom. By laboratory activities, students are provided great opportunities for experiencing individually, following a process, observing an object, analysing, proving, and making conclusion individually dealing with one phenomenon. Many researchers [2-4] also argued that the laboratory activities can train several skills: scientific methods, inquiry, science process, critical thinking, creative thinking, problem solving, collaboration, communication, social interaction, decision-making, and ICT literacy. In other word, several activities related to scientific inquiry give the same opportunity to train HOTs [5]. Additionally, laboratory activities can embed conceptual understanding dealing with scientific knowledge and believe their comprehension toward the methods used in learning the knowledge [6]. Many scientists also believe that there is no the best way so as students can study a scientific method except, they have to act like a little scientist.

Despite the laboratory activities providing many advantages, there is always a gap between what students learn knowledge and how it is will be used. This problem is always faced by students because they did not find the appropriate method how to connect what they learn with the real problems. Therefore, the laboratory activities have to be designed in diverse ways so that they can be more contextual with students’ environment in which the teaching materials have to be chosen with applying fact, concepts, principles, procedures that are oriented to students’ needs. Some studies dealing with laboratory activities in Indonesia context tried to excavate how the laboratory activities are implemented, and what the obstacles were faced to implement the laboratory activities [7,8]. However, these studies were not directed to reveal to what extent the laboratory activities can provide HOTs.

This present study indeed wants investigating profile dealing with obstacles, potency, and implementation of laboratory activities which are conducted in physics in training HOTs in Indonesian high schools. The finding result of this present study can be utilized as a reference in developing physics laboratory models that can train HOTs. In addition, a consideration of the implication of this present study indeed can be deep insight and wider context in the laboratory activities in Indonesia.

2. Methods
The case study which refers to one of kind case studies taking several teachers and students as participants was carried out to garner the data dealing with the profile of laboratory activities. There are two types of participants: the first participant who contributed in this present study is 12 teachers who teach physics in senior high school, and they came from 8 different high schools in one city, Indonesia. These participants have large experiences in teaching and learning physics because they have taught physics for 10 years. In addition, the second participant is 32 students from one public senior high school in Indonesia. They consist of 20 males and 12 females in which they ever conducted laboratory activities in their learning experiences.

The process of taking data was carried out using questioners and students’ HOTs test (i.e. Critical Thinking (CT) test). Firstly, questionnaire related to laboratory activities to train HOTs was conducted by all participants in facilitating their students. There four aspects were investigated from participants: the frequency of implementing the laboratory activities every semester, the model of physics laboratory implemented in the classroom, the obstacles of implementation the laboratory activities-based HOTs, and carrying capacity of schools’ facilities toward physics laboratory-based HOTs. The total questions presented in questionnaire were 24 questions with closed answers. There were two answers of question,
namely yes which refers to the appropriateness of questions with their experiences and no which leads to opposite experiences or never to experiences. The analysis of the data obtained just only use proportion or percentage of total answers.

| The percentage of score (%) | Category          |
|-----------------------------|-------------------|
| 100-81                      | Very high         |
| 80-61                       | High              |
| 60-41                       | Intermediate      |
| 40-21                       | Low               |
| 20-0                        | Very low          |

Secondly, an instrument to investigate students’ HOTs was developed in essay form dealing with concepts of direct current. Five indicators which refer to Binkley’s framework [9] were utilized to develop 5 items of CT test. These indicators were to explain, analyze, synthesize, reason, and evaluate. The validity and reliability of CT test were valid ($r = 0.6$) and reliable ($\alpha = 0.9$). Analysis toward students’ CT score was conducted by categorizing the students’ answer with rubrics developed. After this phase, students’ CT skills are coded using the category of CT skills in table-1. The data obtained from categorizing students’ CT skills are used to depict the profile of students’ HOTs.

3. Results and Discussion

3.1. Result
The data of questionnaire were analyzed to obtain the information of implementation of physics laboratory-based HOTs in several senior high schools. According data in table-2, shows that not all teachers conducted physics laboratory in their schools, only 83% of total teachers facilitated students in carrying out physics laboratory while the teacher remaining did not conduct physics laboratory regularly, they just conducted when final examination. From 83% of teachers who conducted physics laboratory, a half of them facilitated students conducting physics laboratory between one and two times per semester. In addition, a quarter of them did the physics laboratory from 3-4 times per semester and 8% of them had the highest frequency that was 5-6 times per semester. These data depict that the implementation of physics laboratory is still less. For instance, the highest frequency of physics laboratory can be explained that the physics laboratory was conducted one time in a month. This finding result is appropriate with other evidences which are investigated by other researchers [8] that depict the lowness of implementation physics laboratories in Indonesian high school.

The other data come from questionnaire which assess model of physics laboratory used in senior high schools (see table-3). All teachers who carried out the physics laboratory argued that they used model of verification laboratory when conducting the laboratory activities in the classroom. There were 17% of teachers who are participated in conducting the problem solving and inquiry laboratory. In this case, shows that the implementation of physics laboratory-based HOTs in Indonesian high school are rarely conducted because there are many obstacles or challenges experienced by teachers to do the physics laboratory-based HOTs.

The data dealing with obstacles in implementation of physics laboratory-based HOTs in the classroom were also explored by the teachers’ response toward questionnaire (see table-4). Data portray that there are four main obstacles experienced by physics teachers in conducting physics laboratory-based HOTs: limitation of time to conduct physics laboratory (92%), the lab presented in the school not to support (83%), teachers have difficulty in designing laboratory activity (92%), and the prior knowledge of students related to concepts of physics is low (83%). These data are to be evidence that almost all main obstacles have the high percentage that almost reaches a hundred percent.
Table 2. Frequency of implementation of physics laboratory

| Items                                      | The number of teachers’ response |
|--------------------------------------------|----------------------------------|
|                                            | yes    | No    |
| Physics laboratory never be conducted      | 2      | 10    |
| Intensity of physics laboratory 1-2 times per semester | 6      | 6     |
| Intensity of physics laboratory 3-4 times per semester | 3      | 9     |
| Intensity of physics laboratory 5-6 times per semester | 1      | 11    |
| Intensity of physics laboratory more than 7 per semester | 0      | 12    |
| All pivotal concepts taught by physics laboratory | 0      | 12    |

Table 3. Model of physics Laboratory

| Items                                      | The number of teachers’ response |
|--------------------------------------------|----------------------------------|
|                                            | yes    | No    |
| Real laboratory                            | 10     | 2     |
| Virtual laboratory                         | 3      | 9     |
| Combination of real-virtual laboratory     | 0      | 12    |
| Model of verification laboratory           | 10     | 2     |
| Model of inquiry laboratory                | 2      | 10    |
| Model of problem-solving laboratory        | 1      | 11    |

Table 4. The obstacles of implementation of physics laboratory-based HOTs

| Item                                      | The number of teachers’ response |
|-------------------------------------------|----------------------------------|
|                                            | yes    | No    |
| Limitation of time to conduct physics laboratory | 11     | 1     |
| There are broken apparatus in lab         | 8      | 4     |
| The existing physics lab does not support | 10     | 2     |
| There is no students’ workbook of physics laboratory | 9      | 3     |
| Teachers have a difficulty in designing physics laboratory | 11     | 1     |
| Students’ motivation is low               | 7      | 5     |
| The prior physics knowledge of students is low | 10     | 2     |

Table 5. Carrying capacity of schools’ facilities toward physics laboratory-based HOTs

| Item                                       | The number of teachers’ response |
|--------------------------------------------|----------------------------------|
|                                            | yes    | No    |
| School has physic lab                      | 10     | 2     |
| Schools has computer lab                   | 7      | 5     |
| The apparatus for physics laboratory is standardised | 5      | 7     |
| Lab is completed by students’ workbook     | 9      | 3     |
| Lab has laboratory assistant               | 4      | 8     |

The other data in this present study depict the carrying capacity of schools’ facilities toward physics laboratory (see table 5). Based on analysis data, obtained that only 8% of physics teachers said that their schools have physics lab while 66% of physics teachers said that their schools did not have physics lab. Almost all schools that were investigated just only had one lab used for many laboratory activities such physics, chemistry, and biology laboratory. On the other hands, there was 8% of physics teachers said that their schools did not have lab used for conducting laboratory activities. Another finding results also portray that the physics apparatus in the lab of schools was not appropriate with standard of physics lab. The limitations of many physics’ apparatuses, for instance, many broken apparatuses in the lab, urge the
teachers acquiring many difficulties in conducting physics laboratory-based. Overall, the carrying capacity of schools’ facilities to facilitate the physics laboratory-based HOTs are low. This evidence is similar to the teachers’ response in previous question dealing with the obstacles of implementation of physics laboratory-based HOTs. This situation indeed is predicted why the number of physics teachers (33%) just only did the physics laboratory more than 2 times in each semester.

The last data investigated through second participant are dealing with students’ CT skills. Almost all students have low CT skills (see table-6), in which the highest percentage was achieved for low category, there is 66% of students placed in this category. The intermediate category has second highest position, which is 22%. In addition, 12% of students obtained very low category and none of student acquire both in very high and high category.

3.2. Discussion

Practicum or laboratory activity is one pivotal part of teaching and learning physics. The laboratory activities are the best way to reflect the essence of science [5,10] because students can adopt how the real scientist learns about universe using scientific method [2]. In the other words, the laboratory activities are the basis foundation for anyone to work scientifically.

The existing laboratory activities in teaching and learning physics has a crucial role in training minds on and hands on skills, but many educators did not optimize these benefits. The finding result of this present study also has the similar result. The implementation of physics laboratory is low which is shown by the frequency physics teacher in facilitating this event. Moreover, the characteristics of physics laboratory conducted in several schools did not emphasize on HOTs which is required by students in facing the contextual problems in this era. This situation indeed does not emerge abruptly because there are several reasons why this is fail to be conducted.

Firstly, the schools’ facilities do not support the laboratory activities because there are many schools do not have a facility to do laboratory activity. The limitation of lab is main problem when there is no opportunity for students to carry out the laboratory activity. Sometimes, several schools have to use one lab for any event dealing with physics, chemistry, and biology laboratory. Indeed, this case making the difficulty physics teachers in designing laboratory activities, moreover in HOTs-lab context. The second reason why Laboratory activities-based HOTs was rarely conducted was due to the limitations of physics teachers related to the knowledge of laboratory activities-based HOTs. This condition also becomes the main problems because it will affect the difficulty of physics teachers in integrating the laboratory activities-based HOTs to curriculum used in the high schools. Indirectly effect is physics teachers back to carry out the verification laboratory so that it will neglect the metacognitive activity because students just follow several procedures in the lab not obtaining meaningful experiences [11]. By carrying out the verification laboratory continually, causing students has lack the opportunity to train and develop HOTs [12]. The last factor that stimulates the rare of laboratory activities-based HOTs come from students themselves. They do not have adequate knowledge dealing with this because they are not familiar with this type of laboratory activities. All these obstacles or problems faced educators and students emerge another impact that is low achievement of students’ HOTs. If these conditions are not fixed, the HOTs is not possible owned by students in the classrooms.

To familiarize students with laboratory activities-based HOTs, the physics teachers as a facilitator in the classroom have to master competencies dealing with model of laboratory activities-based based on
HOTs. By joining in many trainings that focus to train this competency, the ability of physics teachers will improve. But the other limitations related to the existing number of labs, it is solved with using new form of laboratory activities that provided wide opportunity to explore the laboratory activities. Today, virtual laboratory is one of solutions which can solve the limitation of laboratory space because other research depict that this can improve students’ HOTs and creative thinking [13,14]. In addition, the physics teachers can develop another form of laboratory activities with combining real and virtual laboratory to become augmented reality laboratory.

4. Conclusion
We concluded several finding results of profile of HOTs laboratory. There are four main obstacles faced by educators when applying physics laboratory -based HOTs. The limitation of time to conduct laboratory activities and lab space are early two main problems. Then, the problems that come from human factors are the low ability of physics teachers in designing laboratory activities-based HOTs, and low knowledge of students dealing with concepts and laws of physics. All these problems affect directly toward the low achievement in CT skills. These factors indeed open new type of laboratory activities, namely augmented reality laboratory as a consideration of solving the limitation faced physics teachers and students.

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