The development of higher order thinking laboratory (hot-lab) model related to heat transfer topic

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Abstract. The Higher Order Thinking Laboratory (HOT-Lab) model has been developed to enhance the critical thinking skills of pre-service physics teachers. This research aims to develop HOT-Lab model concerning critical thinking skills of pre-service physics teachers about topic heat transfer. The subjects of this study are 60 students of Physics Education Program UIN Sunan Gunung Djati Bandung. Research method using model ADDIE (Analyzing, Designing, Developing, Implementing, and Evaluating). The ADDIE model has already been extensively developed from the phase of analysis of the program up to the evaluation. The results research shows that the HOT-Lab model characteristic contains context-rich issues with some constraints. This problem must be solved through laboratory activities involving higher order thinking. Moreover, it has alternatives of non-trivial answers and troubleshooting results, which should be presented. The HOT-Lab model is able to develop the critical thinking skills of pre-service physics teachers with gain > score included in the medium category. It can be concluded that HOT-Lab model has been tested and it could improve the critical thinking skills of pre-service physics teachers about topic heat transfer.

1. Introduction

Learners learn about how to study physics, viewed as a process, followed by the emergence of scientific attitude can be obtained through laboratory activities recommended for application in teaching science [1-4]. Traditional physics labs at the high school level are often closed-ended. The outcomes are known in advance and students replicate procedures recommended by the teacher [5]. The traditional lab report is known to create several pedagogical shortcomings in the introductory physics course, particularly with regard to promoting student engagement and encouraging quality writing [6]. Although experiments are the hallmark of science, and for physics learning, they are essential to developing concepts and principles but traditional laboratory has some limitations and problems regarding develop concepts [7, 8]. Haagen-Schuetzenhoefer suggests that ritualized and restricted lab procedures leave hardly any opportunity for students to engage individually and frequently result in poor quality lab reports and moderate learning processes [9].
Some experts have different views in overcoming the various weaknesses found in traditional physics labs, so as to bring up various methods or practice manuals with different focus competencies developed. Some practicum models have been developed by experts among others: inquiry laboratory [10, 11], problem solving laboratory [12], contextual laboratory [13] and conceptual laboratory [14]. The laboratory should engage each student in significant experiences with experimental processes, including some experience, observation, investigation, and generally aim to improve the students’ abilities by providing observation for conducting the experiments and help student’s master basic physics concepts [15, 16]. Each college has both internal and external opportunities and challenges in the face of the 21st century [17-20]. Based on an analysis of the weaknesses of traditional physics labs and the need to develop high-order thinking skills, the Higher Order Thinking Laboratory (HOT-Lab) model was developed.

The topic of heat transfer is a very important topic to learn and students should understand this topic as a prerequisite for studying the kinetic theory of gases. The process of energy transfer by heat can also be called conduction or thermal conduction. In this process, the transfer can be represented on an atomic scale as an exchange of kinetic energy between microscopic particles-molecules, atoms, and free electrons-in which less-energetic particles gain energy in collisions with more energetic particles [21]. The rate of thermal conduction depends on the properties of the substance being heated and conduction occurs only if there is a difference in temperature between two parts of the conducting medium. Convection is the flow of heat transfer fluid accompanied by fluid movement [22]. In convection, a warm substance transfers energy from one location to another. The third means of energy transfer that we shall discuss is radiation. All objects radiate energy continuously in the form of electromagnetic waves produced by thermal vibrations of the molecules [21]. Several studies related to the topic heat transfer have been done before [23-24]. However, research aimed at how to develop the HOT-Lab model related to heat transfer topic is considered an innovation.

2. Experimental Method
The ADDIE model of research methods has been utilized to develop HOT-Lab model, which includes the steps of: Analyzing, Design, Development, Implementation, and Evaluation. Analyzing stages are done through interviews, questionnaires and literature studies to collect various information about practice manuals applied in various universities and schools on heat transfer topics, Design stage is done to design various activities in HOT-Lab model. Development stage is done to construct various activity and systematically in the HOT-Lab model stage that has been made at the Design stage. HOT-Lab is developed based on problem-solving to develop high-level thinking skills through laboratory activities. Stage Implementation is performed to test the use of HOT-Lab model which is developed in improving transferable skills especially critical thinking skills of student. Evaluation stage to see the impact of HOT-Lab model in improving critical thinking of students and looking for any information that can make students' critical thinking skills increase. Research subjects as many as 60 student’s semester V in the academic year 2016/2017 of Physics Education Program UIN Sunan Gunung Djati Bandung. The critical thinking skills test in essay form is used to measure the impact of HOT Lab model. The improved students' critical thinking skills were analyzed using the Hake formula and categories [25].

3. Result and Discussion
The development of HOT-Lab model on the topic heat transfer is more emphasized on the development of manual problem solving laboratory. The real problem in HOT-Lab model contains a rich context that contains various non-trivial answers in solving the problem, containing the limitations that require critical thinking skills in solving problems, problem solving is done through practicum and problem solving results are presented. The development of HOT-Lab model used with ADDIE model, which includes stage, 1) Analyzing, 2) Design, 3) Development, 4) Implementation and 5) Evaluation.

3.1. Analyzing
The analysis stage is the needs assessment process such as the stage to identify the research problem and to perform the analysis of activity stages in conducting the laboratory. The analyzing stage is pre-
planning in the form of HOT-Lab model, by identifying it in accordance with characteristic of students, laboratory purpose, content of laboratory, learning environment, and procedure of laboratory. The result of interview to the lecturer in Physics Education Program at several universities in Indonesia (Universitas Pendidikan Indonesia, Universitas Negeri Jakarta, Universitas Negeri Malang, Universitas Sriwijaya, Universitas Jambi) shows the practice instructions, especially the topic heat transfer used in the form of lab verification, guided inquiry and laboratory problem solving. The results of questionnaires to 25 high schools in West Java showed the laboratory instructions about heat transfer that used the majority of the verification lab. The researchers made a fundamental revision of the existing practice manual. The practice manual has been developed based on real context problems encountered in everyday life and trained critical thinking skills through the HOT-Lab model. The fundamental revision of the practice manual, the analytical process resulted in the development of an increasingly trained HOT-Lab model and improved students' critical thinking skills. Stage analysis is the process of needs assessment such as the stage to identify the problem of research (needs) and to perform the analysis of activity stages in doing the lab. The analysis stage is the process of needs assessment such as the stage to identify the research problem (needs) and to perform the analysis of activity stages in conducting.

3.2. Desain

This stage is known for making blue-print, designing new product concept (design) on paper. The design in question is a HOT Lab practice manual used in practical activities. The HOT-Lab practice manual is focused on the systematic stages of activity in carrying out the laboratory through the application of the concept of heat transfer to solve the real problems that rich context encountered in everyday life. The HOT-Lab model framework is compiled based on the merging of both models of Creative Problem Solving (CPS) and Problem Solving Laboratory (PSL). The HOT-Lab model consists of five stages: 1) understanding the challenges, 2) producing ideas, 3) preparing for practicum activities, 4) conducting practicum activities, and 5) communicating and evaluating the results of activities [17]. These five stages are then broken down into 11 activities [18]. An explanation of 11 activities in the HOT-Lab model is presented in the Table 1.

| Stages Models                  | Activity                          | Event Description                                                                 |
|--------------------------------|-----------------------------------|-----------------------------------------------------------------------------------|
| Understand the challenges provided | 1. Understanding the real world problem | Presented daily problems, laboratory activities include:                             |
|                                |                                   | a. Explore the problems presented                                                  |
|                                |                                   | b. Analyze the data and information presented                                      |
|                                |                                   | c. Analyze the structure of the problems presented                                 |
|                                |                                   | In this stage the proposed problem has several characteristics:                    |
|                                |                                   | 1) Familiar with everyday life                                                     |
|                                |                                   | 2) Objective                                                                        |
|                                |                                   | 3) Loading motivation                                                              |
|                                |                                   | 4) There are limitations in terms of problem solving                               |
|                                |                                   | 5) There is an alternative choice of answers                                        |
|                                |                                   | 6) The solution to the error is not trivial, but requires analysis                 |
|                                |                                   | 7) Analysis is not mathematical                                                     |
|                                |                                   | 8) Solutions can only be tested through experimental activities                    |
|                                |                                   | 9) Applying the basic concepts or principles of physics                            |
|                                |                                   | 10) Requires two or more steps in terms of problem solving                         |
| Producing ideas                | 2. Determining and evaluating ideas | Student activities at this stage include:                                           |
|                                |                                   | a. Analyze proposed ideas for solving problems including the relevance of ideas with supportive information |
|                                |                                   | b. Evaluate the proposed ideas to see the effectiveness, advantages and disadvantages of each idea |
|                                |                                   | c. Determining the best idea to serve as an answer to real world                   |
| Prepare for experimental activities | 3. Answering experiments questions | Student activities at this stage include assigning tasks to analyze information/directions/data/facts about work criteria/principles as a fundamental for determining materials and equipment to |
| Stages Models | Activity | Event Description |
|---------------|----------|-------------------|
|               | test the problem solving selected |                     |
| 4.            | Preparing materials and equipment | Student activities at this stage include assigning tasks to determine the equipment and materials to be used to test the resolution of the selected problem |
| 5.            | Answering predictions | Student activities at this stage include assigning tasks to predict the relationship between the variables to be measured in the test. Students must formulate predictions about what will happen before collecting and analyzing data. |
| 6.            | Answering the method question | This question will help in answering predictive questions and helps in planning how to analyze data. Student activities at this stage include assigning tasks to analyze information / relationships that will be used as the fundamental for preparing hypotheses, experimental procedures, data analysis and conclusions. |
| 7.            | Conducting exploration | Student activities at this stage include: a. Determine the right answer alternative to solve the problem based on the result of group discussion b. Determine the steps of experimental steps to be implemented systematically c. Test the functionality of the equipment before it is used to ensure that all tools work properly when used in measurement d. Design and test the set / system of work of choice of answers that have been determined to solve the problem |
| 8.            | Taking measurement | Student activities at this stage include: a. Measurement of predetermined variables b. Variable measurements are repeated at least three times c. Data collection of required experimental results d. Writing of experimental data in the observation table e. Process the data that has been collected by using the calculator / Microsoft excel / Math lab f. Determine the relative uncertainty of the measured data g. Write down important figures from the results of data processing |
| 9.            | Conducting analysis | Student activities at this stage include: a. Analyze the results of the data to test compliance with predictions b. The resulting analysts serve as the fundamental for conclusion |
| 10.           | Concluding | Student activities at this stage include: a. Summing up the experimental results based on the results of data analysis b. Summing up the effectiveness of the proposed solution c. The conclusions obtained are used as the fundamental for checking the truth of the proposed predictions |
| 11.           | Present for results | Student activities at this stage that is present the results of experiments obtained in both verbal and non-verbal forms (power point). Present the idea of choice of answer to the problem, the prediction put forward, the measurement results obtained, data analysis and conclusion. |
3.3. Develop
The development stage is the process of realizing a blueprint or design into reality. Develop stage based on product design result; to develop the necessary tools in developing and creating instruments to measure product performance. This means that every activity in the HOT-Lab model has been clearly and systematically described in order to be executed by the student according to the intended purpose. For example, the activities in the HOT-Lab model steps that have been prepared at the development stage are shown in Figure 1, Figure 2 and Figure 3.

![Figure 1. Example of activity answering prediction on HOT-Lab model](image)

### Figure 1.
What object shape and surface area are placed at which position is the fastest in heating the water until it reaches the boiling temperature?

![Figure 2. Example of exploration activities on HOT-Lab model](image)

WARNING: You will work with concave mirrors, mineral bottles or black-painted cans that can produce convergent and heat-generating reflections. Unauthorized use can cause concave mirrors to break and sun reflections become divergent. To avoid danger, concave mirrors are placed in a safe position. Never grip the surface of a concave mirror.

Draw a schematic set of tools for experimental activities to check your predictions.

![Figure 3. Example of activity performing analysis on HOT-Lab model](image)

### Figure 3.
Based on experimental data, how can the shape, location, and surface area of a body accelerate the heating of water until it reaches the boiling temperature? What factors can accelerate the heating of water until it reaches the boiling temperature?

3.4. Implementation
Implementation stage is a concrete step to apply the HOT Lab model that has been created. That is, at this stage all that has been developed is arranged in accordance with the role or function to be implemented. The implementation phase looks back at the various development goals of the HOT-Lab model, the interaction between students during the lab and asks for feedback as the beginning of the evaluation process. As soon as the HOT-Lab model is ready to be applied, the experiment is then evaluated and revised to produce a final HOT-Lab model ready for dissemination.

3.5. Evaluation
The evaluation stage measures the achievement of the HOT-Lab model workshop objectives, measuring what students have been able to achieve, reviewing the impact of using the HOT-Lab model, and finding out what information can make students achieve better results. The score of gain critical thinking skill of physics teacher candidate after applied HOT-Lab model related to heat transfer topic is 0.51 including medium category. The results of this study reinforce previous research, the application of HOT-Lab can improve high-level thinking skills such as critical thinking, creative thinking, scientific communication [26-29]. Table 2 shows the percentage of the number of students in each category enhancement students' critical thinking skills on the topic heat transfer.
Table 2. Percentage of category enhancement critical thinking skills of student

| Increased category of critical thinking skills | Number of students | Percentage (%) |
|-----------------------------------------------|--------------------|----------------|
| High                                          | 21                 | 35.0           |
| Medium                                        | 23                 | 38.3           |
| Low                                           | 16                 | 26.7           |

Results of research on the use of The HOT-Lab model on the topic heat transfer showed improvement of students' critical thinking skill on high category by 35%, medium category 38.3% and low category 26.7%. The results of this study in accordance with the application of hott lab related electrical circuit concept, improving the thinking skills of majority students are in the medium category [30].

4. Conclusion
In general, we have successfully developed the HOT Lab lab guide through the ADDIE model. 1) contains context-rich issues, 2) problem solving is done through practice, 4) contains limitations in terms of problem-solving, 5) requires creative and critical thinking in solving problems, 6) has an alternative choice of answers that are not trivial, 7) the results of the problem-solving should be presented. Having implemented HOT Lab can improve students' critical thinking skills, so it can be applied to improve other high-level thinking skills. The HOT Lab practice manuals can also be applied to other physics concepts and at other levels of education other than college.

Acknowledgments
The researcher would like to thank the Lab operator and laboratory assistant of the Physics Education Program UIN Sunan Gunung Djati Bandung who gave permission and helped conduct the research.

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