Development of ILAU based on PBL-STEM model with formative assessment as an opportunity to improve problem solving skills in heat and temperature topics

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Abstract. Independent Learning Activity Unit (ILAU) is a learning media that can develop independent learning strategies. However, instructional media that are based on contextual issues, practice aspects of STEM, and use independent learning strategies have not been developed. The purpose of this study was to develop and test the feasibility of ILAU based on Problem Based Learning (PBL)-STEM with formative assessment so that it was feasible to function as an opportunity to improve problem solving skills in heat and temperature topics for XIth grade of senior high school. The research design used Borg & Gall's research and development model which consisted of three main steps: (1) initial study, (2) product development; (3) product testing. The instruments in this study were: (1) Learning Implementation Plan validation questionnaire; (2) ILAU validation questionnaire; (3) ILAU readability test questionnaire. The results of expert and practitioner validation showed that Learning Implementation Plan developed had average feasibility percentage of 100%, and ILAU had average feasibility percentage of 99%. The results of the readability test by 33 students showed that ILAU had average readability percentage of 93%. Thus, it can be concluded that Learning Implementation Plan and ILAU developed based on the PBL-STEM model with Formative Assessment have very feasible category so they can be used to improve problem solving skills.

1. Introduction
The 2013 curriculum requires active learning for students to be able to solve contextual problems [1]. The purpose of physics learning is students can apply their knowledge to solve real world problems [2]. Training student's ability to solve problems is difficult to implement because most students find it easier to gain knowledge about physics than to apply knowledge to solve various problems [3].

Problem solving skills is an important element in physics learning [4]. PISA problem solving framework recommends the problem solving process not only focus on the end result, but on the process and understanding of concepts to find solutions of problems [5]. Students have problem solving skills if they fulfill five problem solving indicators as follows; useful description, physics approach, specific application of physics, mathematical procedure, logical progression [6]. The results of the 2015 PISA survey showed that the problem solving skills of students in Indonesia were still low, ranked 62nd out of 70 countries with science score of 403 [7]. Other study showed that the percentage of students' problem solving skills only reaches 30.25% [8]. Based on the results of the pretest to 32 students of XIth grade of SMAN 7 Malang, 31 students had problem solving skills in the low category. The low skills of problem solving is due to the less oriented learning process towards real phenomena [9].

Heat and temperature are important physical concepts because they can be used in everyday work and life [10]. However, many students still have misconceptions on heat and temperature topics [11]. One of the reasons is abstract and theoretical concepts [12]. From the results of an interview by one of the teachers at SMAN 2 Palembang, the daily test scores on heat and temperature material were lower compared to other physics material [13]. Difficulty of understanding can affect students' problem solving skills.
solving skills [14]. Meanwhile, student difficulties in problem solving is caused by many factors, one of which is the use of media or teaching materials that has not been maximized [15].

There have been many learning media developed to improve students' problem-solving skills. The creation of a multi-representation based physics learning module on heat and temperature topics could improve student learning outcomes with a passing percentage of more than 75% [16]. The development of heat and temperature learning modules based on problem could increase student learning interest with positive response percentage of 73.43% [17]. It appears that in previous studies there were still rarely used learning media which were based on contextual problems, practiced engineering, and used an independent learning strategy. The learning media used by students in learning should not only generate interest in learning but can be used to practice independently [18].

The Independent Learning Activity Unit (ILAU) can develop independent learning strategies that help students learning completeness. In the 2013 Curriculum, ILAU is used as a learning tool for students to achieve competency knowledge and skills using the Semester Credit System (SKS) [19]. ILAU prioritizes providing a learning stimulus that allows the growth of independent learning through student centered learning which encourages Higher Order Thinking Skills (HOTS) [20]. The application of ILAU in work and energy topics could improve students' conceptual understanding with the acquisition of gain value of 0.49 categorized as moderate increase. Based on the results of the student response questionnaire to ILAU and learning, 70% of students responded positively to the ILAU in work and energy topics [21].

The use of ILAU developed by teachers is still not in accordance with the expected goals. The researcher conducted an interview with a physics teacher using ILAU in one of the different public senior high schools in Malang. The physics teacher at the first school explained that the ILAU developed by the subject teacher facilitated students to learn in accordance with their respective learning speeds. Through the developed ILAU, teachers could maximally know the level of student learning progress. The physics teacher at the second school explained that the use of ILAU that was developed by the teacher in learning was still not optimal. There had been no significant difference in learning outcomes during implementing ILAU in learning. Based on literature studies related to ILAU that have been developed, it is necessary to develop ILAU with independent learning strategies and based on contextual problems that support the improvement of students' problem-solving skills in heat and temperature topics.

Problem based learning is a learning model that uses contextual problems so that students learn critical thinking and problem solving skills, and acquire essential knowledge and concepts from the subject matter [22, 23]. Problem based learning has the following characteristics; asking questions or problems, focusing on interdisciplinary knowledges, authentic investigation, producing products or works [24]. In implementing problem based learning, there are five phases that must be carried out by the teacher, as follows; Orient Students to the Problems, Organize Students for Study, Assist Independent and Group Investigation, Develop and Present Artifacts and Exhibits, Analyze and Evaluate the Problem Solving Process [25]. The advantages of problem based learning models are students are focused on problem based learning, allow students to develop general skills and attitudes required for future practice, help students learn deeply, and involve constructivist approach [26].

Problems on problem based learning model related to engineering in Science, Technology, Engineering, and Mathematics (STEM) [27]. STEM is an interdisciplinary approach in learning activities that combines academic concepts with science, technology, engineering and mathematics in order to create people who are able to compete globally [28]. Integration of PBL with STEM can increase knowledge and ability to solve problems in the real world [27, 29]. To monitor the progress and achievements of students in carrying out learning using the PBL-STEM model, it is necessary to have an assessment that monitors the process and progress of student learning without seeing the final result.

Formative assessment is an activity carried out by teachers and students to provide feedback to students and increase student achievement during the learning process [30], [31]. The five basic elements (Key Strategies) of formative assessment are (1) KS1 Sharing Learning (clarifying, sharing learning
intentions and success criteria); (2) KS2 Questioning (engineering effective classroom discussions, questions, and learning tasks that elicit evidence of learning); (3) KS 3 Feedback (providing feedback that drives students to more advanced); (4) KS 4 Peer assessment (activating students as the owners of their own learning); (5) KS 5 Self assessment (activating students as instructional resources for one another) [32, 33, 34].

The ILAU developed in this research and development was based on Problem Based Learning-STEM model integrated with formative assessment in heat and temperature topics. The heat and temperature topics presented in it implemented problem-based learning-STEM with formative assessment so that students were actively involved in the process of investigating problem solutions that could improve students’ problem-solving skills. Therefore, the purpose of this study was to develop and test the feasibility of Independent Learning Activity Unit Based on Problem Based Learning (PBL)-STEM Model with formative assessment as an opportunity to improve problem solving skills in heat and temperature topics for XI\textsuperscript{th} grade of senior high school.

2. Method

This study used research and development method (Research and Development) which was aimed to produce a product, test the feasibility and readability of the product. The product developed was Learning Implementation Plan and ILAU based on PBL-STEM model with formative assessment in heat and temperature topics and for XI\textsuperscript{th} grade of senior high school. The design of this study used Borg & Gall research and development model which consisted of three main steps: initial study, product development, product testing.

The type of data in this study was quantitative data, in the form of data from the product validation questionnaire by lecturer (expert) and teachers (practitioners) and ILAU readability questionnaires by students and qualitative data in the form of comments and/or written suggestions from validators and students. The validity of the instrument was arranged according to the Guttman scale by following the following categories: agree = 1, disagree = 0. The data obtained from the product validation questionnaire and the readability test questionnaire were then analyzed using the mean value analysis technique. So, the average value calculation can be formulated as follows.

\[ P = \frac{\sum x_i}{\sum x} \times 100\% \]  

Description:
\( P \) = feasibility percentage  
\( \sum x_i \) = total score  
\( \sum x \) = total score maximum  

In interpreting and concluding the data, percentage of product feasibility was used. Feasibility of product was determined based on the criteria shown in Table 1 below.

| Score   | Interpretation Criteria |
|---------|-------------------------|
| 0-20%   | Very poor               |
| 21-40%  | Poor                    |
| 41-60%  | Enough                  |
| 61-80%  | Feasible                |
| 81-100% | Very feasible           |

The qualitative descriptive analysis of feasibility and readability data of the product from the validators and respondents/students then became consideration in product development and improvement.
3. Results and Discussion
The product developed was ILAU equipped with Learning Implementation Plan based on PBL-STEM model with formative assessment in heat and temperature topics. The development of ILAU was a strategy to create learning media that could facilitate students to learn independently in order to achieve learning completeness [19]. The developed ILAU consecutively contained the title ILAU, ILAU identity, concept map, instructions for use, activity components, learning stages, and learning activities consisting of preliminary activities, core activities, and closing activities. In broad outline, the systematics of the ILAU developed were in accordance with the 2017 ILAU Development Guidebook. The ILAU cover page consists of ILAU code, ILAU title, the basis for developing ILAU used, Curriculum 2013 logo, five pictures that represent the subtopics of heat and temperature, higher education institution logo, and ILAU author names. The ILAU cover page is presented in Figure 1.

![Figure 1. Cover Page of ILAU](image)

The ILAU preliminary activity was in the form of checking the prerequisite material for heat and temperature topics, which contains discussion activities and practice questions to determine students' mastery of prerequisite material. The exercises presented were in the form of problems in daily life regarding the concepts of heat and temperature that have been studied by students at the junior high school level. Daily contextual problem was characteristic of problem-based learning models [24]. In the core activity, four learning activities were presented, consisting of Learning Activities 1 Temperature and Expansion, Learning Activities 2 Effects of Temperature on Changes in Temperature and Substance, Learning Activities 3 Black Principles, and Learning Activities 4 Heat Transfer. In each learning activity, references to daily problems were presented in the form of learning videos that could be accessed directly by students by scanning the QR code or opening the provided video link. Through these video observations, students were expected to be able to organize the information from the problem statement into an appropriate representation and summarize important information [6]. The developed Learning Implementation Plan and ILAU follow five steps of problem based learning-STEM model with formative assessment: Orients Students to the Problems, Organize Students for Study, Assist Independent and Group Investigation, Develop and Present Artifacts and Exhibits, Analyze and Evaluate the Problem Solving Process [25]. The five basic elements (Key Strategies) of formative assessment are (1) KS1 Sharing Learning, (2) KS2 Questioning, (3) KS 3 Feedback, (4) KS 4 Peer assessment, (5) KS 5 Self assessment [32,33,34]. To fulfill the opportunities for increasing student
problem solving, the developed Learning Implementation Plan were also equipped with problem solving questions along with an assessment rubric and scoring guidelines. Indicators of problem-solving skills used in Learning Implementation Plan and ILAU were in accordance with the rubric of assessing the problem-solving skills indicators; useful description, physics approach, specific application of physics, mathematical procedure, logical progression [6].

At the end of each ILAU Learning Activity two assessments were presented. Self assessment helps shape metacognitive and uses previous knowledge to create new relationships [35]. Peer assessments encourage students to be able to communicate well through the ability to think and communicate clearly and accurately, be able to accept peer criticism, improve performance, be able to put themselves in all situations, and train to be able to work with others [35]. In self and peer assessment activities, students filled out a questionnaire in the attachment section of ILAU according to the Learning Activities conducted. The questionnaire was related to students' understanding after completing learning activities and student attitudes while participating in learning activities in class.

The closing activity of ILAU contained self-reflection activities and follow-up instructions containing information on activities that must be carried out as a prerequisite before doing the next ILAU. Self-reflection activities were presented at the end of ILAU after students complete all Learning Activities at ILAU. Students reflected on the learning they have mastered using their own language. Self reflection as a component of formative assessment makes students reflect on the meaning of material for themselves [20]. Independent learning helps students develop problem solving skills. PBL-STEM increases student involvement in learning activities [29]. ILAU based on PBL-STEM model with Formative Assessment could be used to improve problem solving skills.

The product feasibility test consists of the Learning Implementation Plan and ILAU feasibility test by one lecturer of the State University of Malang Physics Education Study Program and one physics teacher at SMAN 1 Malang and one physics teacher at SMAN 4 Malang who had been teaching or were at the time teaching class XI and are competent about the latest 2013 curriculum. A summary of the results of the average Learning Implementation Plan assessment is presented in Table 2 below.

| No | Aspects assessed | Average | Feasibility Percentage | Criteria |
|----|------------------|---------|------------------------|----------|
| 1. | Completeness of Learning Implementation Plan components | 1       | 100%                   | Very feasible |
| 2. | Content Feasibility | 1       | 100%                   | Very feasible |
| 3. | Language         | 1       | 100%                   | Very feasible |
| **Average value of feasibility** | **1.00** | **100%**               | **Very feasible** |

The results of Learning Implementation Plan feasibility test had average feasibility percentage of 100% with very feasible criteria. Thus, the development of Learning Implementation Plan could be used as learning guide in the classroom.

| No | Aspects assessed | Average | Feasibility Percentage | Criteria |
|----|------------------|---------|------------------------|----------|
| 1. | Completeness of ILAU components | 0.98    | 98%                    | Very feasible |
| 2. | Learning Activities | 0.98    | 98%                    | Very feasible |
| 3. | Fulfillment of the Characteristics of ILAU | 1.00    | 100%                   | Very feasible |

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| No | Aspects assessed | Average | Feasibility Percentage | Criteria |
|----|------------------|---------|------------------------|----------|
| 1. | Completeness of Learning Implementation Plan components | 1       | 100%                   | Very feasible |
| 2. | Content Feasibility | 1       | 100%                   | Very feasible |
| 3. | Language         | 1       | 100%                   | Very feasible |
| **Average value of feasibility** | **1.00** | **100%**               | **Very feasible** |

The results of Learning Implementation Plan feasibility test had average feasibility percentage of 100% with very feasible criteria. Thus, the development of Learning Implementation Plan could be used as learning guide in the classroom.
The results of the ILAU feasibility test had average feasibility percentage of 99% with very feasible criteria. Thus, the development of ILAU based on PBL-STEM model with Formative Assessment in heat and temperature topics can be used as a learning media that supports the achievement of improving the skills of solving physical problems.

The ILAU readability test performed produces quantitative data and qualitative data obtained from 16 students of XI<sup>th</sup> grade of SMAN 1 Malang and 17 students of XI<sup>th</sup> grade of SMAN 4 Malang. Quantitative data were obtained from the scores given on the Guttman scale questionnaire. From the results of the ILAU readability test by 33 students of XI<sup>th</sup> grade against 18 statements against the developed ILAU, feasibility percentage obtained was 93% with very feasible criteria.

Based on the results of the ILAU feasibility validity test, ILAU based on PBL-STEM model with formative assessment is feasible to function as an opportunity to improve problem solving skills. This is consistent with research that the problem based learning model is able to make students active and enthusiastic in participating in learning activities and develop problem solving skills well [36], STEM integrated problem based learning has succeeded in improving students' problem solving skills [37], and through PBL-STEM, students make science products as a form of solution to problems and then present them to get feedback in the form of comments, criticisms, and suggestions for product improvement [27].

### 4. Conclusion

Based on the results of research and product development in the form of a Learning Implementation Plan and Independent Learning Activity Unit (ILAU) Based on Problem Based Learning (PBL)-STEM with Formative Assessment in the Heat and Temperature, it can be concluded that the developed Learning Implementation Plan is very feasible with average percentage of 100%, developed ILAU is very feasible with an average feasibility percentage value of 99%. Based on the readability test, the developed ILAU was very feasible with an average readability percentage value of 93%. Thus, Learning Implementation Plan and ILAU based on Problem Based Learning (PBL)-STEM with Formative Assessment can be used to improve problem solving skills.

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