Development of The Android-Based Interactive Physics Mobile Learning Media (IPMLM) to Improve Higher Order Thinking Skills (HOTS) of Senior High School Students

Beatrix Elvi Dasilva* and Suparno
Graduate School in Physics Education, Yogyakarta State University, Yogyakarta, Indonesia

Abstract. This study aims to find out: 1) generating useful android application IPMLM in termodynamic material on physics, 2) examining the impact of IPMLM toward students’ higher order thinking skill (HOTS). In order to find out the answer, the researcher used research and development method in 4-D model (defining, designing, developing and disseminating). The IPMLM application was assessed by media experts and physics expert. The limited test stage was conducted in SMAN 1 Kota Kupang with 32 students of 11th grade science program. Subjects were chosen by purposive sampling technique. The extensive test stage was conducted in SMAN 2 Kota Kupang, SMAN 3 Kota Kupang and SMAN 5 Kota Kupang with 210 students of 11th grade science program. Subjects were chosen by purposive sampling technique. The research design of extensive test was pretest-posttest control group design. Data collection was done by questionnaire and test. Instrument test to measure students’ HOTS instrument was reasoning multiple choice questions. The result shows that 1) the IPMLM application was eligible to be used in physics learning about thermodynamics, 2) using IPMLM in physics learning increased effectively the capability on HOTS aspect.

1. Introduction
Competencies based on the 21st century of learning paradigm are include the skills in learning and innovation, skills in using media and information, and life and career skills [1]. Kurikulum 2013 has tried to facilitate learning in accordance by demands of the 21st century of learning paradigm. One of them is the thinking ability must be achieved by students in learning especially learning physics. Peraturan Menteri Pendidikan Nasional No 21 Tahun 2016 about content standards for primary and secondary education has suggested in learning physics students must be able to analyze concepts, design or modify projects, create simple products, design experiments, carry out experiments, present experimental results, to conclude, and report an experimental results [2]. These competencies lead to high-level thinking abilities of students. In other words, the 2013 curriculum is requires students to achieve high order thinking skills. The results of research have shown that students with high level of thinking ability have a level of creativity in advanced level [3].
Physics is one branch of science so that it has in accordance with the nature of science that physics is learned through by scientific processes. Physics must be learned in such a way that the physics knowledge can be used to solve problems [4]. Physics learning must facilitate students to build their own knowledge and thinking skills [5]. However, physics learning process does not facilitate students to train their thinking skills [6]. The learning process has tended to a teacher centered [7], [8]. Teachers are less creative and less able to develop learning media based on ICT (specific instructional goals) are varied and fun for students [9]. Most teachers is only inform about how to solve physics problems using existing equations [10], [11]. Informative learning models will be difficult to train thinking skills, especially HOTS students [4]. This is evidenced by the research data of the Trends of the International Mathematics and Science Study (TIMSS) which shows that reasoning (in physics) ability of Indonesian students is ranked 40 out of 42 countries has been researched [12]. Other research conducted by Faizaha, Suparmi and Aminah showed students’ HOTS in 11th grade MIA in Sragen Regency was still low with 19.01% in the very low of HOTS category [13]. The data that has been described shows that HOTS students still need to be improved by using models, methods, approaches, strategies and learning media that are in accordance with the nature of physics.

Theoretical and empirical studies show that the 21st century learning paradigm has not been fulfilled. One of the ways to answer the demands of the 21st century learning paradigm is to integrate technology in the learning process. Several studies have proven is the use of technology in learning can improve students’ abilities in cognitive, affective, and psychomotor aspects. By integrating with certain learning methods, for example by Group Investigation, this media can improve critical thinking skills [14]; by method of inquiry can improve the performance of students [15]. In addition, by utilizing the android application, the teacher can use application-based comics to visualize abstract physics concepts [16]. An application for Android physics mobile learning media (IPMLM) was developed on the topic of thermodynamics. IPMLM is expected to be able to improve the ability of students, especially Higher Order Thinking Skills (HOTS).

2. Methods
Research had done included the type of Research and Development (R & D). The product developed is an android application on the subject of thermodynamics. The development procedure was adapted from the 4D development model (Defining, Designing, Developing, and Disseminating) [17]. The first stage of defining are consisted of preliminary studies in the form of field observations and literature reviews. The second stage of designing was in designing IPMLM applications. The third is developing is an application development consisting of several stages. Draft 1 in the form of the initial product is assessed for its eligibility by media experts and material experts. The result of the assessment are used to improve the application. The results of the repairs are in the form of Draft III. Draft III is then used in learning at the broad test stage. The final stage is disseminating namely the dissemination of applications and research results.

The subjects of limited trial were 11th grade science program students of SMAN 2 Kota Kupang has amount 32 students. The subject of empiric test for HOTS measurement instrument was 323 students of 12th grade science program in Kota Kupang. The subjects were chosen by stratified sampling technique. The subjects of the extensive trial were 210 11th grade science program students from SMAN 2 Kota Kupang, SMAN 3 Kota Kupang and SMAN 5 Kota Kupang. The subject for extensive trial were chosen by cluster sampling technique. The research was conducted in an even semester on January 2019.

Limited trials are concluded readability tests of IPMLM applications and empirical tests of HOTS measurement instrument. The content validity of each item can be found through Aiken’s validity coefficient and empiric validity and reliability through the QUEST output by looking at the compatibility of item with the PCM model or MNSQ infit. The question item is said to be compatible with the PCM model, if the MNSQ infit value is $\geq0.77$ and $\leq1.30$ [18]. Instrument reliability can be determined through the estimated reliance of items on QUEST output.
The research design has used in the extensive trial is the Pretest-Posttest Control Group Design as shown in Table 1 [19].

Table 1. Research designa.

| O₁b | X₁c | O₂d |
|-----|-----|-----|
| O₃e | X₂f | O₄g |

a pretest-posttest control group design  
b pretest score experiment group  
c learning assisted by IPMLM  
d posttest score experiment group  
e pretest score control group  
f Using conventional products commonly used by teachers in research schools (physics package book) 
g posttest score control group

Data collection technique are test and non-tests. The test technique is used to measure HOTS with a reasoning multiple choice questions. Non-test techniques are used to validate HOTS questions, assess media eligibility and respond to questionnaires by students. Validation of HOTS questions, assessment of media eligibility, and student responses were obtained by questionnaires with rating scales 1-4 (Likert Scale).

The eligibility of media has assessed by several aspects are namely software engineering, easiness and flexibility in accessing, presentation, interactivity and social communication. The eligibility of the material contained in IPMLM has assessed by two components are namely the learning component and the material component. In addition, students provide responses to the media. The aspects that are responded to are aspects of content, presentation, graphical and language.

Data on the results of the eligibility assessment were analyzed used by descriptive analysis. The average score for each aspect of the eligibility assessment of the learning device is converted to scale 5 [20]. The average score for each aspect of the assessment is converted to a value with the criteria as shown in Table 2. The eligibility of media is concluded according those criteria.

Table 2. Score quality classification

| Score of Respondent | Criteria | Categories |
|---------------------|----------|------------|
| \( X \geq X_i + 1,8 SB_i \) | \( X \geq 85 \) | Very high |
| \( X_i + 0,6 SB_i < X \leq X_i + 1,8 SB_i \) | \( 70 < X \leq 85 \) | High |
| \( X_i - 0,6 SB_i < X \leq X_i + 0,6 SB_i \) | \( 55 < X \leq 70 \) | Fair |
| \( X_i - 1,8 SB_i < X \leq X_i - 0,6 SB_i \) | \( 40 < X \leq 55 \) | Low |
| \( X \leq X_i - 1,8 SB_i \) | \( X \leq 40 \) | Very low |

\( X_i = \frac{1}{2} \) (maximum ideal score + minimum ideals score); \( = \frac{1}{6} \) (maximum ideal score - minimum ideals score)

The HOTS measurement instrument was validated by 7 experts. The results of the assessment are then analyzed using Aikens’ validity coefficient \( (V) \). The validity coefficient \( V \) of single item by n raters calculated by the Equation 1 [21].

\[
V = \frac{\sum s}{[n (c-i)]}
\]

\( S = r-lo; \ lo = \) lowest validity rating; \( r = \) the number given by a rater; \( c = \) highest validity rating.
The validity coefficient is compared to the Aiken’ table. The item is concluded to be valid if the validity coefficient (V) is greater or equal to the minimum value stated in the Aiken table. The empirical validation of the questions was analyzed using the QUEST program to determine the validity and reliability of items according to item response theory (IRT).

Students’ HOTS achievements are grouped according to the 4 categories, which are very good, good, fair good, less good. Increased HOTS is known by calculating the standard gain (g) obtained through Equation 2.

\[
Std \ gain \ (g) = \frac{X_{posttest} - X_{pretest}}{X - X_{pretest}}
\]

\(X_{posttest}\): average score after learning; \(X_{pretest}\): average score before learning; \(X\): maximum score

The standard gain criteria are shown in Table 3 [22].

| Standard gain (g) score | Categories |
|-------------------------|------------|
| (g) ≥ 0.7               | High       |
| 0.7 > (g) ≥ 0.3         | Medium     |
| (g) < 0.3               | Low        |

3. Results and discussion

3.1. Defining Stage

The results of the initial analysis have shown that SMAN 2 Kota Kupang, SMAN 3 Kota Kupang and SMAN 5 Kota Kupang have not integrated technology in learning physics yet. However, students are permitted to use mobile phones at school. SMAN 2 Kota Kupang and SMAN 3 Kota Kupang provide wifi facilities for students and teachers, while SMAN 5 Kota Kupang does not provide wifi facilities. The teaching material analyzed is thermodynamic material. Core competencies (Kompetensi Inti/KI) and basic competencies (Kompetensi Dasar/KD) from the Kurikulum 2013 are reviewed and analyzed. Kompetensi Dasar is described again as an Indicator of Learning Achievement (IPK) and learning objectives. The description refers to HOTS abilities. HOTS capabilities that are honed and measured are the ability to analyze (C4) and the ability to evaluate (C5). Table 4 shows the results of curriculum analysis.

| Basic Competencies (KD)                          | Indicators of Competence Achievement (IPK)                                                                 |
|--------------------------------------------------|-------------------------------------------------------------------------------------------------------------|
| 3.7 Analyzing changes of the ideal gas state using the laws of Thermodynamics | **First meeting**  
3.7.1 Explain the Zeroth Law of Thermodynamics  
3.7.2 Differentiates thermodynamic processes: isothermic, isobaric, isochoric, and adiabatic  
3.7.3 Explaining the First Law of Thermodynamics | **Second meeting**  
3.7.4 Formulate the First Law of Thermodynamics in gases by various thermodynamic processes.  
3.7.5 Solve problems related to the the First Law of Thermodynamics | **Third Meeting**  
3.7.6 Analyze the working principle of a carnot engine, heat engine and cooling machine  
3.7.7 Assessing the Second Law of Thermodynamics  
3.7.8 Solve problems related to the working principle of the Carnot engine, heat engine and cooling engine |
4.7 Creating a work or model about apply of the First Law of Thermodynamics and the Second Law of Thermodynamics

| Second meeting |
|----------------|
| 4.7.1 Designing tools in experiments to prove the First Law of Thermodynamics Conduct an experiment ‘burning balloons’ to prove the First Law of Thermodynamics |
| 4.7.2 Doing experiments to prove the First Law of Thermodynamics Conduct an experiment ‘burning balloons’ to prove the First Law of Thermodynamics |

2.1. Designing stage

Product design is designed flowcharts and story boards which contained an overview of the applications developed. Flowchart and story board are used to determine what will be displayed on the learning media. The IPMLM application is contained several menus has namely Petunjuk Penggunaan, Kompetensi, Materi, LKPD, Evaluasi and Profil Pengembang. HOTS evaluation menu is equipped with a timer and when students finish working on the questions, the score will be immediately displayed. In addition, the application is also equipped with a chat room feature that allows teachers and students to give feedback to each other regarding learning materials. Figure 1, Figure 2, Figure 3, and Figure 4 show the example of the IPMLM appearance.

![Figure 1. Appearance of the IPMLM initial display](image1)

![Figure 2. Appearance of the IPMLM menus.](image2)
2.2. Developing stage

IPMLM was developed through several stages. The development begins with the creation of content about thermodynamics as outlined in the application. The content developed is material consisting of experimental videos, animated videos, illustrations, images and text. In addition, 24 items of HOTS were also developed. The results of the development are described as follows.
2.2.1. **Product validation**
The eligibility of IPMLM is assessed by material expert lecturers and media experts. Table 5 shows the results of the assessment by media expert and material expert.

| Aspects                      | Score | Categories |
|------------------------------|-------|------------|
| Media expert                 |       |            |
| Software engineering         | 75    | High       |
| Easiness and flexibility in accessing | 72    | High       |
| Presentation                 | 71    | High       |
| Interactivity                | 81    | High       |
| Social communication         | 75    | High       |
| **Average**                  | **74.80** | **High**  |
| Material expert              |       |            |
| Learning                     | 92    | Very high  |
| Material                     | 91    | Very high  |
| **Average**                  | **91.5** | **Very high**  |

Table 5 shows that every aspect of the media reaches “high” category and every aspects of material in IPMLM reaches “very high” category. So, IPMLM is eligible to be used in physics learning about thermodynamics in accordance with the suggested revision given by the assessor.

Similar development research has been done by Mardiani and Kuswanto [23]. The product developed is an interactive android application. The aspects of the android based media that assessed by experts were learning aspect, material aspect, audio-visual appearance aspect and software technology aspect. The results of the development show that every aspect of the application achieves the “very good” category. The application is used in learning and proven to reduce students’ misconceptions in temperature and heat material [23]. Application development based on local wisdom developed by Lestari and Kuswanto has shown that the combination of physics material, local wisdom (rowing boat), and technology (android) is valid and easy to use in physics learning [24].

HOTS measurement instruments are validated through two stages, namely validation by experts and empirical tests. Referring to the Aiken’s validity coefficient (V) table, the minimum value received with a 1% error rate is 0.86 (Aiken, 1985). The results of content validation have shown that the validity coefficient (V) of each item HOTS was more than a minimum value of 0.86 with the lowest value V = 0.90 and the highest value V = 1.00. Thus all HOTS items are valid in terms of content.

The result of empiric test shows that each item of HOTS instruments are fit to partial credit model (PCM). So can be concluded that the instrument is valid. Meanwhile, the reliability of instrument is known by reliability of estimate in QUEST program output. The results show that person reliability of person estimate is 0.00 dan reliability of item estimate is 0.72. The coefficient reliability show that the HOTS items are quite reliable however, the consistency of students’ answers is weak. In spite of that HOTS instruments is still acceptable because the items’ reliability is good enough.
3.3.2 IPMLM revision
Results assessment of material experts and media experts is used to improve the application. Table 6 shows the comments/suggestions from media experts and material experts as well as improvements made to the application.

Table 6. Revision of IPMLM applications

| No | Comments/Suggestions                                                                 | Revised Results                                                                 |
|----|--------------------------------------------------------------------------------------|----------------------------------------------------------------------------------|
| 1  | The initial login should only use authentication once during registration / initial use, then the user can simply log in with a username and password. | It is easier for users to register and login, using only a username and password. |
| 2  | The teacher has not been able to give feedback (there are no facilities for feedback or teacher comments). | There is an additional "chat room" feature so students can ask questions and the teacher can answer the question. |
| 3  | Material layout does not showed hierarchy                                            | The composition of the material sub-menu is arranged that shows the level of difficulty of the material from the easiest to the most difficult material. |
| 4  | New media has the role of replacing books, not increasing physical understanding. Add narration to the animation to clarify the physics process. | There are additional narratives on videos and animations to facilitate physical understanding by pupils. |
Some equations are italicized and vector quantities are bold.

Physics equations are italicized. In addition, scalar and vector quantities have not been differentiated.

3.3.3. **Limited trial**

The limited trial is about empirical validation of the HOTS measurement instrument and readability of IPMLM by 32 students. The QUEST analysis shows that all items are within the acceptance limit area ≥0.77 and ≤1.30. So it can be concluded that all the items tested are fit to the PCM model (valid) based on four categories of politomus data. In addition, the QUEST output has shown the coefficient reliability is 0.72. This value states that the items in the instrument are quite reliable.

The research on HOTS problem development was also done by Istiyono, Mardapi, and Suparno namely PhysTHOTS instruments which were developed in the form of reasoning multiple choice on the ability to analyze, evaluate, and create for physics material [12]. PhysTHOTS instruments have fulfilled content validity by expert judgment and have obtained empirical evidence of fit construct validity in the Partial Credit Model (PCM) based on four categories of politomus data. In addition, PhysTHOTS reliability is high, by a reliability coefficient of more than 0.90 [12].

The IPMLM application is used by students in a limited trials to test readability. Readability test results are shown in Figure 5.

![Figure 5. Results of readability of IPMLM applications on limited trial](image-url)
Figure 5 showed that the readability of IPMLM media reaches the category of “high” with an average score is 81. The results of student responses indicate that the application is eligible to use in physics learning. Some students stated that IPMLM applications are very interesting and applications should also be developed for other materials. However, sometimes the LKPD sheet still has an error. Figure 6 and Figure 7 show examples of limited trial subjects responses to the application.

Another suggestion from students is said that the media should be made offline and also made for other Physics material. However, fully offline mode cannot be realized because the evaluation and upload process of student answers to the LKPD must be uploaded (requires internet connection) so the results can be recapitulated by the teacher on the application dashboard.

3.3.4. Extensive Trials

Extensive trials were carried out at SMAN 2 Kota Kupang, SMAN 3 Kota Kupang, SMAN 5 Kota Kupang. Each school consists of one experimental class and one control class. The learning process in the experimental class uses IPMLM, while in the control class uses the physics package books that are commonly used by teachers. Table 7 showed the results of the assessment of the application by students of extensive.

| Aspect       | Score | Categories |
|--------------|-------|------------|
| Content      | 82    | Good       |
| Presentation | 82    | Good       |
| Graphical    | 83    | Good       |
| Linguistik   | 83    | Good       |
| **Average**  | **82.50** | **Good**  |

Table 7 showed that IPMLM applications are considered good by students. So, IPMLM media is good to be used as a media of learning in the classroom.

The effectiveness of media use is known through HOTS achievement of students. Figure 8 shows HOTS achievement of control class pupils.
Figure 8. Results of HOTS achievement in control class students before learning (a) and after learning (b)

Figure 8 showed that after participating in learning only 4% of students achieved a very good category (A). There are even 20% of students who are still in the less good category (D). Figure 9 shows the achievement of HOTS experimental class students.

Figure 9. Results of HOTS achievement in experiment class students before learning (a) and after learning (b)

Figure 9 showed that students who used IPMLM are mostly reach very good category (A) which is as much as 47% and only 8% that reaches the fair good category (C). HOTS students experienced an increase in analyse aspect and evaluate aspect. The increase of those aspects is shown by Figure 10.
The increase in each aspect is also indicated by the achievement of the gain standard as show in Table 8.

**Table 8.** Comparison of Gain Standards (g) Experimental Classes and Control Classes

| HOTS Aspects | Control group | Experiment group |
|--------------|---------------|------------------|
|              | Gain Std (g)  | Categories       | Gain Std (g)  | Categories       |
| Analyze (C4) | 0.30          | Medium           | 0.56          | Medium           |
| Evaluate (C5)| 0.30          | Medium           | 0.63          | Medium           |

Figure 10 and Table 8 showed that the increase in HOTS in the experimental class is better than the control class. The standard gain value in the control class only reached 0.30 for each aspect of HOTS. So it can be concluded that increasing HOTS of students using IPMLM is better than not using IPMLM. These results support the research findings that there are differences in the increase of students’ creativity and cognitive learning outcomes between using the android-based chemistry instructional media integrated to learning together and learning together without the android-based instructional media [25].

Similar applications have also been used in learning namely ThinkLearn applications on the subject of energy transfer [15]. The results have shown that secondary school students using the ThinkLearn application experienced a significant increase in knowledge and have shown more critical thinking than the control group that did not use the ThinkLearn application. The results of follow-up tests show that students using the ThinkLearn application maintain information/material better than students who did not [15]. Learning using mobile devices provides benefits for students and also helps teachers in learning. The developed IPMLM is equipped with images. This facility helps understand the concept of physics using images that are familiar with students. The cognitive process that occurs is that students connect thermodynamic concepts to familiar environments or situations. The process can develop students' scientific understanding. Developing students' scientific understanding is one way to improve high-level thinking skills (HOTS) [26]. Besides images, IPMLM applications are equipped with videos. Video facilities in the application help students to develop students' scientific skills and understanding of a process [27]. Both of these are aspects related to high-level thinking skills [28].

The learning process has used technology enables the creation of a fun physics learning process. Some students stated that the learning process with IPMLM was very interesting and not boring. Such conditions,
help students to stay focused and also increase motivation to learn material. Figure 11, Figure 12 and Figure 13 show examples of student responses to the application.

![Figure 11. Response of first student](image1)

![Figure 12. Response of second Student](image2)

![Figure 13. Response of Third Student](image3)

3.4. Disseminating stage
The last stage is disseminating, namely the dissemination of application download links to students at SMAN 2 Kota Kupang, SMAN 3 Kota Kupang dan SMAN 5 Kota Kupang and presenting the results of research in scientific publication.

4. Conclusion
It has been successfully developed an android-based Interactive Physics Mobile Learning Media (IPMLM) that is suitable for use in learning in thermodynamic material. The results of media eligibility by media experts reached “high” category with an average score of 74.80. The media eligibility by material experts reached “very high” category with an average score of 91.5. The results of student responses in limited tests indicate that IPMLM is “eligible” with an average score of 81.

The extensive test results have shown that the IPMLM application is effective in increasing HOTS. The result shows that the more dominant aspect of HOTS is evaluating aspect. Standard gain in the experimental class for the analyzing aspect reach the “medium” category (g = 0.56) and for the evaluating aspect reach the “medium” category (g = 0.63). Standard gain (g) in the control class reaches the “medium” category, with g of 0.30 for each aspect. So, it could be concluded that learning uses IPMLM be more effective than using Physics package books in improving HOTS students.

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