Jurnal Pendidikan Fisika
p-ISSN 2252-732X
e-ISSN 2301-7651

INTERACTIVE MOBILE LEARNING MEDIA TO IMPROVE STUDENTS' HOTS ABILITY SUPPORTED WITH PROBLEM-BASED LEARNING MODEL

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Abstract. Education in the 21st century has entered the era of smartphone technology. The purpose of this research was to test the feasibility and the effectiveness of interactive mobile learning media supported with problem-based learning model to improve students' HOTS ability. The research and development (R & D) with a 4D model (Define, Design, Develop, Disseminate). The field testing was a quasi-experiment with a pretest and posttest control group design. The research subjects consisted of four lecturers as expert validators, two teachers and two groups of 72 students in a senior high school 2 Batang Regency, Central Java. Data collection techniques through questionnaires, observation, interviews, and written test. Product feasibility test by material experts get a score of 3.65, media experts with a score of 3.68 and student responses with a score 3.46 all in very good category. The results of the Normalized-gain test were 70.60 for the experiment group and 35.69 for the control group. This shows that there were differences in the increase of students' HOTS ability between the experiment group and the control group. Based on the results of the Multivariate Test on GLM with partial eta squared, it was found that this media made an effective contribution of 88.5% to improving students' HOTS abilities.

Keywords: *HOTS Ability, Interactive Mobile Learning Media, Problem-Based Learning, Thermodynamics Law*

INTRODUCTION

The 2013 curriculum requires learning Higher Order Thinking Skills (HOTS) to familiarize learners with higher-order thinking skills. In addition, the Ministry of Education has begun to apply international standards on the Computer-Based National Examination, both for Mathematics, Literacy and for Natural Sciences, which require reasoning power high, or HOTS (Ariyana et al., 2019). The emergence of the digital information era also requires problem-oriented learning, critical thinking and higher-order thinking skills (HOTS) for future success.

The aim of global education is that 21st century learning needs to integrate aspects of learning and innovation skills. These skills include creativity and innovation skills, critical thinking, strong character (responsible, social, tolerant, productive, adaptive) and problem solving supported by the ability to use information and communicate (O'Sullivan, 2018). These competencies are summarized in 4Cs, namely "Critical Thinking, Creativity, Communication, and Collaboration" which are 21st Century skills (Soulé & Warrick, 2015; Kivunja, 2014).

21st Century skills are the answer to the challenges of the 4.0 industrial revolution era. The state needs to change three things in terms of education to answer the challenges of the industrial revolution 4.0, first: changing the nature and mindset of children today (character), second: schools must be able to hone and develop a child's talent (critical and creative), third: educational institutions are able to change the learning model according to the needs of the times (communication, collaborative and networking) (Utami, 2019).

Physics learning is the activity of studying symptoms or phenomena that occur in the universe, especially those close to daily life. Chiappetta & Koballa (2010) states that physics as part of science is essentially: (1) body of knowledge, (2) way of thinking, (3) way of investigating about the universe, (4) interactions with technology and social. Physics learning provides ability to someone regardless of gender in order to have knowledge and problem solving skills in the era of globalization in the 21st century (Baran, 2016; Bates et al., 2013). The 21st century learning paradigm demands students' ability to think critically, creatively, master information technology, be able to collaborate, and be communicative (Trisdiono, 2013). Rapidly developing technology makes learning activities more dynamic.

Implementation of the 2013 curriculum according to Indonesian Minister of Education and Culture Regulation No. 22 of 2016 concerning the process standards, one of the learning models that are expected to improveHOTS ability is Problem-Based Learning (PBL) model. PBL is one of the learning models that demands students' higher-order thinking ability activities to understand a concept of learning through situations and problems presented at the beginning of learning (Tatar & Oktay, 2011). PBL model requires students to use a variety of individual and group thinking skills to solve the problems presented by digging up as much information as possible then analyzing and finding solutions to existing problems (Seng, 2004; Nurlaela et al., 2019: 94). The purpose of PBL is to improve the ability to apply concepts to new / real problems, the integration of the HOTS concept, the desire to learn, direct independent learning (Barret, 2017). The steps that can be designed by the teacher based on the PBL model syntax according to (Arends, 2012) are as follows: (1) students' orientation to the problem, (2) organizing students to learn, (3) guiding individual or group investigations, (4) develop and present the work, (5) analyze and evaluate the problem solving process.

Today, the development of mobile devices has attracted the attention of researchers and educators. Attention is focused on the use of this device in learning (mobile learning). Interactive mobile learning media has a positive impact on improving students' understanding of concepts (Andarini et al., 2016). Agreeing with this, Ramganesh (2012) states that interactive multimedia can improve problem-solving abilities to improve problem-solving abilities. In addition, the use Digital Game-Based Learning (DGBL) can be exploited as a useful and productive tool to support students in problem solving while enhancing the classroom atmosphere (Yang, 2012), and student creativity (Ulfa et al., 2017). Other research results stated that the Android-based mobile learning media is suitable for student learning activities in the classroom and can increase students' HOTS (Mardiana & Kuswanto, 2017) because it has been developed in accordance with their thinking levels. The use of learning media is strongly related to thinking levels because through learning media, what is abstract could be made concrete and what is complex could be simplified. This shows that the learning process requires media that supports the delivery of subject matter.

According to observations and interviews with teachers and students concerning the physics learning activity in particular at SMA Negeri in Batang Regency, the following is found: (1) there are students who think that learning physics as learning abstract and difficult to understand, (2) the learning process is still using the lecture method and practice exercises only, so that makes students bored and lacking enthusiasm, (3) there is a lack of teachers' ability and creativity to develop learning media based digital that are interactive, inspiring, fun and motivating students, (4) time constraints and basic competency demands that have not been met.

Meanwhile, data in the field shows that students are still weak in HOTS abilities such as analyzing, evaluating, and creating. This was revealed from the report on the results of the Computer-Based National Examination (UNBK) in 2019, shows that the most difficult physics material nationally is thermodynamics. The number of students who answered the thermodynamic material correctly was only 42.51%, while the analysis of the items for each indicator showed that the indicator analyze the quantities that must be changed so that the efficiency of the Carnot engine increases, only reaching 28.11% (Puspendik, 2019).

Thermodynamics is a branch of physics that studies the relationship between energy and work of a system. Thermodynamics has various concepts, some of which are abstract, such as the concepts of heat and entropy (Hakim et al., 2017). Most students had difficulties in understanding the second law of thermodynamics (Sari et al., 2019). This is causing difficulties in the learning process. According to (Gunawan et al., 2019), multimedia is a system that supports communication of teachers with students during the learning process through text, audio, image, animation, video, and graphic. The application of interactive multimedia combined with the problem-based learning approach could help students in developing several thinking abilities (Tatar & Oktay, 2011). According to Hosnan, (2014), problem-based learning helps students build critical thinking and problem-solving skills. The implementation of computer technology in learning physics could help teachers overcome difficulties in visualizing abstract concepts. Furthermore, (Pratidhina et al., (2019) added that computer-based learning effectively increased student achievement.

Interactive mobile learning media is an example of the use of smartphone in learning processes to make a transformation of learning experience and direct students to develop divergent thinking, analyzing, and planning skills (which belong to the category of HOTS). The advantage of interactive mobile learning media is that students can access material from home without having to meet face to face, so students can read the material every time they have free time both online and offline. Interactive mobile learning media also provides supporting learning videos that can enrich student information. There is also a forum for discussion between teachers and students and students and other students.

Based on the description above, it was necessary to conduct research that aims to analyze (1) the feasibility of interactive mobile learning media through a problem-based learning model and (2) the effectiveness of interactive mobile learning media through a problem-based learning model on students' HOTS ability.

RESEARCH METHODS

Research Approach

This research includes research and development using the 4-D model (Define, Design, Develop, and Disseminate) developed by Thiagarajan in 1974 (Arifin, 2016) as shown in Figure 1.

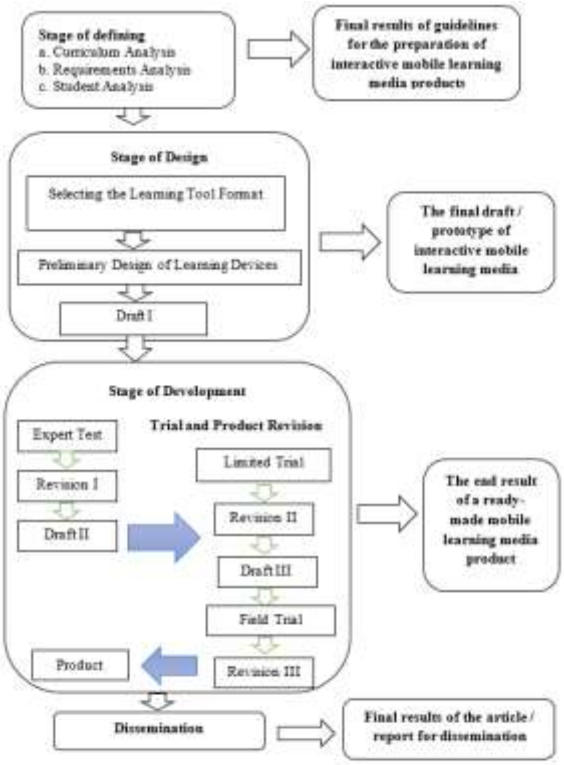


Figure 1. Development Stages of 4-D Model

The field trials was a quasi-experiment with a pretest and posttest control group design (Campbell & Stanley, 2015) which can be seen in Table 1. This method is used to determine the effectiveness of interactive multimedia products developed. The effectiveness is related to an increase in HOTS ability. The experimental group was taught with the help of interactive mobile learning media, while the control group uses common modules used by the teacher. The problem-based learning was employed in both control and experimental groups as the instruction model.

Table 1. Research Design

Group	*Pretest*	Treatment	*Posttest*
	Y		Y
Experiment	T_1	X_1	T_2
Control	T_1	X_2	T_2

Where T_1 is pretest, T_2 is posttest, Y is HOTS ability, X_1 are groups using problem-based learning model supported with interactive mobile learning media and X_2 are groups using problem-based learning model supported with the teacher general module.

Participants

The research subjects consisted of four lecturers as expert judgement (material and media expert), two physics teachers, limited trials subject were conducted on five students (respondents) class XI Mathematic and Natural Sciences of Senior High School 2 in Batang Regency academic years 2019/2020. Afterwards, the effectiveness test was carried out in two groups consisting of 72 students, where 36 students were assigned in the experiment group and 36 students in the control group at the same school. Whereas the subject of dissemination was High School Physics Subject Teacher's Meeting (MGMP) in Batang Regency.

Data Collection

Data collection in this research was carried out quantitatively and qualitatively. The assessment for effectiveness of the product required quantitative data from the HOTS ability test. Moreover, to the purposes of perfecting and validating interactive mobile learning media, the qualitative data were collected through users' responses in the questionnaires and observation, documentation, and interviews with users during and after the classroom implementation.

The validation sheets by media experts, material experts, and teachers are used to determine the feasibility of the product being developed. While questionnaire student responses for limited scale trials is used to as material for evaluation and improvement of interactive mobile learning media. The research instrument was in the form of a cognitive ability test consisting of ten items arranged according to HOTS indicators on the thermodynamics law material. The HOTS indicators according Anderson & Krathwohl (2001) are the ability of the process of analyzing, evaluating, and creating. In addition, the observation sheet is used to analyze needs, curriculum and students. Observations were made as material of analysis before the process of implementing interactive mobile learning media.

Data Analysis

Analysis of the results of the assessment of the feasibility of Interactive mobile learning media practicality were based on student responses in the form of an assessment in the range of scores from 1 to 4. Total score of all aspects of assessment divided by the number of evaluators will produce an average score of each item for all aspects of product assessment

$$\bar{X} = \frac{\sum X}{n}$$

To convert the data to scaled standard scores (Widoyoko, 2017) ideal assessment criteria are used that can be seen in Table 2,

Jurnal Pendidikan Fisika
p-ISSN 2252-732X
e-ISSN 2301-7651

Table 2. Ideal Assessment Criteria

Score Range	Categories	Index
$\bar{X} \geq X_i + 1.8\,Sbi$	Excellent	5
$X_i + 0.6\,Sbi < \bar{X} \leq X_i + 1.8Sbi$	Good	4
$X_i - 0.6\,Sbi < \bar{X} \leq X_i + 0.6Sbi$	Fair good	3
$X_i - 1.8Sbi < \bar{X} \leq X_i - 0.6Sbi$	Less	2
$\leq X_i - 1.8Sbi$	Very Less	1

Information:
$\bar{X}$: *Mean* Score
X_i : *Mean* Ideal Score
$$X_i = {}^{1}/_{2}\,(maximum\ score + minimum\ score)$$
Sbi : Ideal Standard Deviation of Scores
$$Sbi = {}^{1}/_{6}\,(maximum\ score - minimum\ score)$$

Mean score was using a standard five-scale assessment category and categorized according to Table 3.

Table 3. Feasibility Criteria for Assessment Standard Five-Scale

Range of Scores	Category
$\bar{X} > 3{,}4$	Very good
$2.8 < \bar{X} \leq 3.4$	Good
$2.2 < \bar{X} \leq 2.8$	Fair
$1.6 < \bar{X} \leq 2.2$	Less good
$\bar{X} \leq 1.6$	Not good

The effectiveness of interactive mobile learning media supported with problem-based learning model to improve student HOTS ability was determined based on an assumption test analysis consisting of tests of normality and homogeneity of the students' pretest and posttest results. Normality test is carried out based on Kolmogorov-Smirnov statistics. The sample is said to come from a normally distributed population if the significance value (Sig.) Is more than 0.05. While the homogeneity test is performed to determine whether the sample used has the same variance or not. The sample used in the study was said to be homogeneous if it obtained a significance value (Sig.) greater than 0.05 based on the Levene's test.

The effectiveness of interactive mobile learning media through a problem-based learning model on students' HOTS ability was determined based on normalized average gain scores (Meltzer, 2005).

$$N_{gain} = \frac{S_{Post-test} - S_{Pretest}}{S_{max} - S_{Pretest}} \times 100\%$$

Where N-gain is a normalized gain, S_{max} is the maximum score from the initial test and the final test, S_{post} is the final test score, while S_{pre} is the initial test score. The *N-Gain* scores can be classified as follows: (1) if g > 70, then the *N-Gain* is in the high category, (2) if 30 ≤ g ≤ 70, then the *N-Gain* is in the medium category, and (3) if g < 30, then the *N-Gain* is in the low category. The independent sample test calculation was calculated using the SPSS 23 program for Windows, aimed to differentiate two groups of samples that do not influence each other. The independent sample test calculation was calculated using the SPSS 23 program for Windows, aimed to differentiate two groups of samples that do not influence each other.

Additional information about the effective contribution of the use of interactive mobile learning multimedia media in learning activities as a means to improve the HOTS ability of students can be seen from the results of the Multivariate Test analysis on GLM based on partial eta squared values based on the results of the pretest and posttest.

RESULTS AND DISCUSSIONS

Process

The Interactive mobile learning media is built using html5 files and then converted to apk files with software website 2 apk builder. This media interactive mobile learning media can be accessed offline using a smartphone. The interactive learning media was divided into several sections: the opening section, main section, material section, evaluation section, and other information. The main menu consists of "basic competency", "material", "evaluation", "literature", "video", and "profile" of the media. Students could use this media interactively by selecting the corresponding menu are shown in the following Figure 2.

Figure 2. The Main menu of Interactive Interactive Mobile Learning Media

The material page contains various kinds of information about thermodynamics. The concepts in thermodynamics such as the concept of heat, heat

Jurnal Pendidikan Fisika
p-ISSN 2252-732X
e-ISSN 2301-7651

transfer, Carnot's law, and others. Students could learn thermodynamic in the form of simulations, texts, and videos are shown in the following Figure 3.

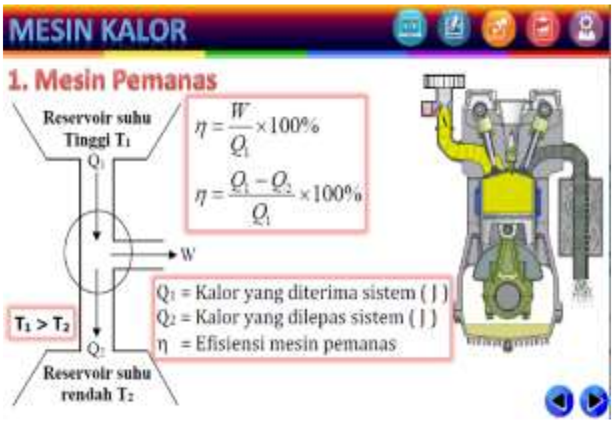


Figure 3. The Material Section of Interactive Interactive Mobile Learning Media

The evaluation page presented 20 interactive question related to thermodynamic material. The evaluation section has several multiple-choice questions with five-choices. Each question is adjusted to the competence related to thermodynamic material. While working on student evaluation questions, the time limit is 120 minutes and students can also immediately find out the value obtained are shown in the following Figure 4.

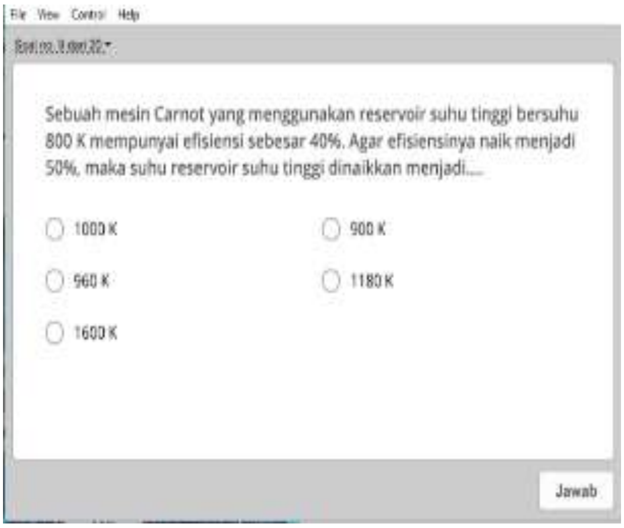


Figure 4. The Evaluation Section of Interactive Interactive Mobile Learning Media

Other information in the form of learning videos and virtual laboratories are shown in Figure 5,

Figure 5. The other information of Interactive Mobile Learning Media

Media Validation Result

Revised interactive mobile learning media, then validated by 2 material experts, 2 media experts. and 4 physics teachers. Data obtained in the form of assessments in the range of scores from 1 to 4. Problem-based learning on thermodynamics material with interactive mobile learning media that developed to improve students' HOTS ability was adapted from (Anderson & Krathwohl, 2001).

Interactive mobile learning media assessment based on material aspects is done by 2 material expert lecturers and 4 physics teachers. Assessment of interactive mobile learning media on material aspects includes 3 sub aspects, namely contents, learning design and language. Analysis of the results of the appraisal of the categorized aspects of interactive mobile learning media material is presented in Table 4.

The assessment of interactive mobile learning media products based on the contents sub-aspects in Table 4 using a scale 5 assessment category an average value of 3.67 which is classified as a very good category. Ratings provided by the validator are included with suggestions for improvement. Suggestions for improvement given by the validator include researchers improving the physical quantity units used to match the actual events in everyday life such as the m^3 volume unit replaced with liters.

The learning design sub-aspect obtained a mean value of 3.86 and was classified as a very good category. Suggestions for improvement given by the validator are to improve mathematical equations related to the concept of the cooling engine performance coefficient to make it easier for students to understand. The sub-aspect of language obtained a mean value of 3.43 and was classified as a very good category. Suggestions for improvement given by the validator are that researchers are asked to improve sentences related to the concept of law II thermodynamics to be more effective and easily understood.

Table 4. Results of Analysis Assessment of Interactive Mobile Learning Media According to Material Expert

Aspect	Item	Rater Rating Score						Average per item	Average per aspect	Categories
		1	2	3	4	5	6			
Contents	Substance	4	4	4	4	4	4	4.00	3.67	Very good
	Material Coverage	4	4	3	3	3	3	3.33		
	Conformity of Material	4	4	4	3	3	4	3.67		
	Use of symbols, equations and units	4	4	3	4	3	4	3.67		
	Legibility	4	4	4	3	3	4	3.67		
Learning Design	Title	4	4	4	4	4	3	3.83	3.86	Very good
	Core Competencies, Basic Competencies, Indicators and Learning Objectives	4	4	4	3	4	4	3.83		
	Material	4	3	4	4	3	4	3.67		
	Exercises	4	4	4	3	4	4	3.83		
	Composer	4	4	4	4	4	4	4.00		
	Reference	4	4	4	4	4	4	4.00		
Language	Language rules	3	4	3	3	4	3	3.43	3.43	Very good
Average of All Aspects									3.65	Very good

Overall analysis of the aspects of content, learning design and language obtained a mean value of 3.67 and showed that the interactive mobile learning media that were developed were included in the excellent category. These results prove that the interactive mobile learning media developed is suitable for use in learning activities.

Interactive mobile learning media assessment based on media aspects is done by 1 media expert lecturer and 4 physics teachers. Assessment of interactive mobile learning media aspects of the media includes 2 sub aspects, namely display and software engineering. The results of product assessment based on media aspects were analyzed using five-scale standardized assessment categories. Analysis of the results of the feasibility assessment of the media aspects to interactive mobile learning media is presented in Table 5.

Table 5. Results of Analysis Assessment of Interactive Mobile Learning Media According to Media Expert

Aspect	Item	Rater Rating Score						Average per item	Average per aspect	Categories
		1	2	3	4	5	6			
Display	Media identity	4	4	4	4	4	4	4.00	3.61	Very good
	Text	4	4	4	3	3	4	3.67		
	Color	4	4	3	4	3	3	3.50		
	Layout	3	4	4	3	3	3	3.33		
	Images, animations and simulations	3	4	4	3	3	3	3.33		
	Navigasi	4	4	3	4	4	4	3.83		
Software engineering	Installation and performance	4	4	4	3	4	3	3.67	3.75	Very good
	Creativity and innovation	3	4	4	4	4	4	3.83		
Average of All Aspects									3.68	Very good

The evaluation of interactive mobile learning media products based on the display sub-aspects in Table 5 using the scale 5 assessment category obtained an average value of 3.61, which is classified as a very good category. Ratings provided by the validator are included with suggestions for improvement. Suggestions for improvement provided by the validator include improvements to the background, navigation buttons and animated content that are consistent with the concept of the material. The software engineering sub-aspect obtained a mean value of 3.75 and was classified as a very good category. Suggestions for improvement given by the validator are that researchers are asked to increase multimedia content and virtual laboratories related to the concept of material that can be integrated into interactive mobile learning media.

Overall analysis of the aspects of appearance and software engineering obtained a mean value of 3.68 and showed that the interactive mobile learning media that were developed were included in the excellent category. These results prove that the interactive mobile learning media developed is appropriate for use in learning activities.

Students' Responses

The limited trial aims to determine students' responses to interactive mobile learning media that have previously been through revisions based on the results of expert validation. During the learning process, students were given interactive mobile learning media for learning thermodynamics. Researchers observed the students' attitude towards the developed product and notified the problems that arise in the use of interactive mobile learning media. In the end of the learning session, the students filled out questionnaires about the use of interactive mobile learning media. The results of the researchers' observations and the results of student responses during limited trial activities are presented in Table 6.

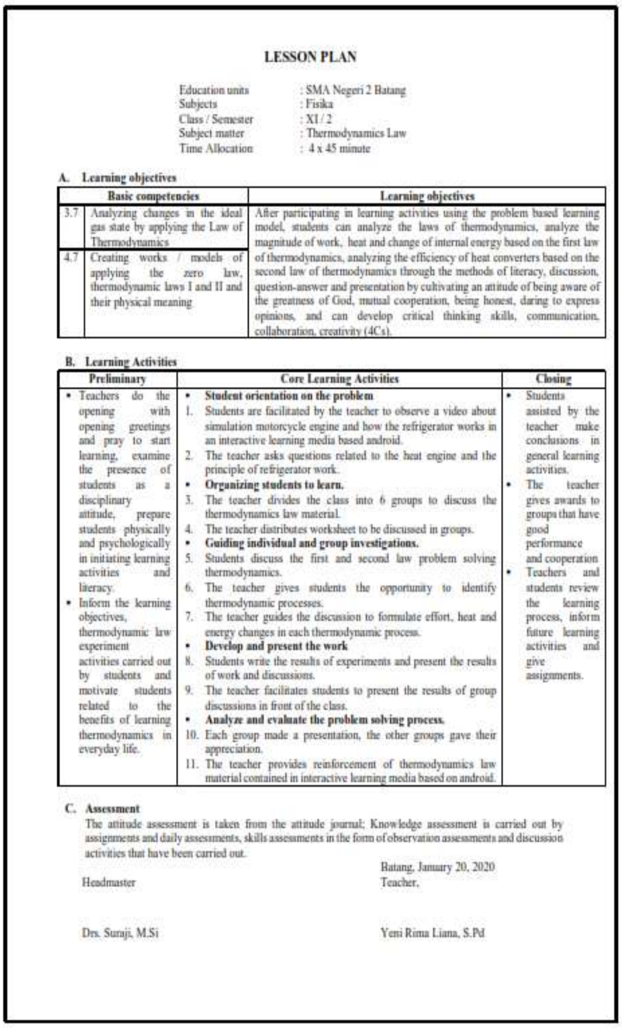
Table 6 shows the average value of the learning aspect of 3.83 which is included in very good category, display aspect obtained an average per aspect of 3.37 with good category, and the language aspect of 3.20 with a good category. Suggestions from students regarding interactive mobile learning media are to improve the menu button and give a score in the practice questions in each sub material. Overall student assessment of interactive mobile learning media is included very good category and states that the product is suitable for use in physics learning.

Table 6. Students Responses to Limited Trials

Aspect	Number of participants	Average per aspect	Category
Learning	5	3.83	Very Good
Display		3.37	
Language		3.20	

Field Testing

The implementation of field trials was carried out at Senior High School in Batang Regency with a sample of 36 students from 72 in science XI grade students. A total of 36 experimental group students used interactive mobile learning and 36 students in control group used the general module of the teacher. Experimental group field trials were carried out through direct instruction with a problem solving approach. The stages of problem solving skills start from preparing a lesson plan according to the syntax of the Problem-based learning model like Figure 6.


LESSON PLAN

Education units : SMA Negeri 2 Batang
Subjects : Fisika
Class / Semester : XI / 2
Subject matter : Thermodynamics Law
Time Allocation : 4 x 45 minute

A. Learning objectives

Basic competencies		Learning objectives
3.7	Analyzing changes in the ideal gas state by applying the Law of Thermodynamics	After participating in learning activities using the problem based learning model, students can analyze the laws of thermodynamics, analyze the magnitude of work, heat and change of internal energy based on the first law of thermodynamics, analyzing the efficiency of heat converters based on the second law of thermodynamics through the methods of literacy, discussion, question-answer and presentation by cultivating an attitude of being aware of the greatness of God, mutual cooperation, being honest, daring to express opinions, and can develop critical thinking skills, communication, collaboration, creativity (4Cs).
4.7	Creating works / models of applying the zero law, thermodynamic laws I and II and their physical meaning	

B. Learning Activities

Preliminary	Core Learning Activities	Closing
• Teachers do the opening with opening greetings and pray to start learning, examine the presence of students as a disciplinary attitude, prepare students physically and psychologically in initiating learning activities and literacy. • Inform the learning objectives, thermodynamic law experiment activities carried out by students and motivate students related to the benefits of learning thermodynamics in everyday life.	• **Student orientation on the problem** 1. Students are facilitated by the teacher to observe a video about simulation motorcycle engine and how the refrigerator works in an interactive learning media based android. 2. The teacher asks questions related to the heat engine and the principle of refrigerator work. • **Organizing students to learn.** 3. The teacher divides the class into 6 groups to discuss the thermodynamics law material. 4. The teacher distributes worksheet to be discussed in groups. • **Guiding individual and group investigations.** 5. Students discuss the first and second law problem solving thermodynamics. 6. The teacher gives students the opportunity to identify thermodynamic processes. 7. The teacher guides the discussion to formulate effort, heat and energy changes in each thermodynamic process. • **Develop and present the work** 8. Students write the results of experiments and present the results of work and discussions. 9. The teacher facilitates students to present the results of group discussions in front of the class. • **Analyze and evaluate the problem solving process.** 10. Each group made a presentation, the other groups gave their appreciation. 11. The teacher provides reinforcement of thermodynamics law material contained in interactive learning media based on android.	• Students assisted by the teacher make conclusions in general learning activities. • The teacher gives awards to groups that have good performance and cooperation • Teachers and students review the learning process, inform future learning activities and give assignments.

C. Assessment

The attitude assessment is taken from the attitude journal; Knowledge assessment is carried out by assignments and daily assessments, skills assessments in the form of observation assessments and discussion activities that have been carried out.

Batang, January 20, 2020

Headmaster Teacher,

Drs. Suraji, M.Si Yeni Rima Liana, S.Pd

Figure 6. Learning Activities with PBL Models

The field trial aims to find out the effectiveness of interactive mobile learning media in increasing students' HOTS. Data from the test results in the field are learning outcomes based on students' cognitive abilities, namely learning outcomes, the ability to analyze, evaluate, and create. Field testing is done by applying three steps, namely pretest, treatment and posttest. The results are presented in Table 8.

Table 8. HOTS test Result

Component	Group	Average	Standard Deviation
Pretest	Experiment	40.71	3.81
	Control	45.30	5.48
Posttest	Experiment	82.57	7.63
	Control	64.82	3.40

HOTS test results for the experimental group and control group, are presented in Table 8. Table 8 shows that the HOTS ability of students increases after using interactive mobile learning media.

Media Effectiveness

To find out the effectiveness of interactive mobile learning media in increasing students' HOTS, a multivariate test statistic test was analyzed on the Mixed Linear General Model (GLM) based on partial eta squared values. The prerequisites before conducting statistical tests related to hypotheses in the research are assumption tests consisting of tests of normality and homogeneity of the students' pretest and posttest results data.

Table 9. Results of The Normality Test Analysis

Test	Group	Kolmogorov-Smirnov		
		Statistics	df	Sig.
Pretest HOTS	Experiment	0.124	36	0.200
	Control	0.150	36	0.064
Posttest HOTS	Experiment	0.152	36	0.075
	Control	0.131	36	0.174

Table 9 shows the results of the normality test based on Kolmogorov-Smirnov statistics on the sample used. The results of the analysis of Table 9 shows the significance value (Sig.) For each variable greater than 0.05 ($p > 0.05$) which means that the sample used in the study came from populations that were normally distributed.

The next assumption test is the homogeneity test. Homogeneity test is performed to determine whether the sample used has the same variance or not. Homogeneity test results are presented in Table 10.

Table 10. Homogeneity Test Analysis Results

Test	F	df1	df2	Sig.
Pretest HOTS	0.061	2	89	0.941
Posttest HOTS	0.025	2	89	0.975

Table 10 shows the homogeneity test results based on Levene's statistical test. The results of the analysis in Table 10 show a significance value (Sig.) For each variable greater than 0.05 ($p > .05$) which means that the sample used in the study came from populations that had the same or homogeneous variance.

The effective contribution of the use of interactive mobile learning media and general teacher modules in learning activities as a means to improving students' HOTS on thermodynamics law material can be seen from the results of the Multivariate Test analysis on GLM based on partial eta squared values in Table 11.

Table 11. Multivariate HOTS Tests

Class		Sig.	Partial Eta Squared
Interactive mobile learning media	Hotelling's trace	0.00	0.885
Teacher general module	Hotelling's trace	0.00	0.363

The partial output value of eta squared type Hotelling's trace for interactive mobile learning media is 0.885. This value indicates that the effective contribution of interactive mobile learning media in learning activities to improve students' HOTS by 88.5%. The value of this effectiveness is higher than that the teacher general module by 36.3%.

Test for increasing HOTS ability using interactive learning media was done by giving essay questions for the experimental and the control groups. The results are presented in Table 12.

Table 12. Results for Each Indicator HOTS Ability

No.	Indicators	Experimental Group N = 36	Control Group N = 36
		N-Gain	*N-Gain*
1.	Analyze	70.60	35.69
2.	Evaluate	63.83	30.91
3.	Create	40.96	25.77

The results show an increase in HOTS ability on analyzing indicator of the experimental group with an average N-Gain value of 70.60 included in the high category while the mean control group N-Gain value is 35.69 which is in the medium category. This shows that interactive learning media is more effective in enhancing students' HOTS abilities than teacher general module.

The development of interactive mobile learning media aimed to simplify the learning process and students became easier to understand physics concepts. Interactive mobile learning media could be used as the tool to support interactive learning. The developed product consists of texts, images, graphics, sounds, videos, animations, virtual labs, and simulations that were put together into one unit to make it easier for students to understand thermodynamics concepts.

Abstract concepts can be visualized with the help of this interactive mobile learning media. According to (Adawiyah et al., 2019) stated that the addition of multimedia has been able to improve creative thinking skills. If the creativity of students increases, it will be easier for students to find their learning patterns that are suitable for maximum learning outcomes. The application of computer-based media that is integrated with the system is also proven to be able to increase student motivation (Ramadhani et al., 2019). Right motivation and creativity will highly support students' development, especially the development of special abilities, such as problem-solving skills. Interactive mobile learning media through problem-based learning approaches are learning activities that involve students directly in problem solving. Problem-based learning is a good learning approach to improve learning achievement through group discussions and independent learning (Argaw et al., 2017)

Interactive mobile learning media is applied at this stage to support the problem-solving process. For example, to solve problems with heat transfer, the first law of thermodynamics, the second law of thermodynamics, Carnot cycles, and others. Interactive media displays simple animations with appropriate usage instructions. In addition, the language presented is simple and does not give rise to double meanings so that students easily understand the material contained in interactive mobile learning media.

Interactive mobile learning media equipped with simulation content in the form of virtual labs that explain the process of thermal equilibrium. According (Hermansyah et al., 2019), the application of virtual labs can improve students' understanding of the concept of heat. Added that the use of virtual labs could improve students' creativity because students' creativity is very influential in students' conceptual understanding (Yahya et al., 2019). The difference in improvement in these two indicators is easy to understand because there is an initial frame of mind that already exists for each student. The learning process shows a tendency of students to maintain their frame of mind until they get a rational explanation or picture that causes a strengthening of the validity of the mindset. The shift in paradigm is in appropriate direction if the existing framework is not right.

In the classroom implementation, interactive learning multimedia makes it easy for teachers to help students to observe problems through a video display. As (Hidayat & Sutria, 2017) stated, giving problems at the beginning of learning with inquiry training helps students develop thinking abilities, problem-solving, intellectual skills, and become independent learners. This problem-based learning is focused on the development of student learning, not to help teachers collect information that will be given to students during the learning process.

Computer-based media is also able to prevent students from misunderstanding the concept (Yumuşak et al., 2015). In the process of developing high-level abilities, there is the possibility of miss thinking disposition, and the application of interactive mobile learning media can prevent that from happening.

Submission of information is the focus of multimedia use with the aim of being easily accessible, easily used repeatedly and can be used by every individual (Leow & Neo, 2014). Interactive mobile learning media is one form of interactive multimedia which are introduced to students as an introduction before learning activities begin. The aim is that students become more prepared and motivated to participate in learning (Chen et al., 2010; Sadaghiani, 2012). This shows that interactive mobile learning media supported with problem- based learning model is effective in improving students' HOTS abilities.

CONCLUSION AND SUGGESTION

Based on the result of the research, it can be concluded that (1) interactive mobile learning media on thermodynamics law concepts supported with problem-based learning can be used as a supplementary tool in learning process; (2) the developed thermodynamics law interactive mobile learning can improve students' HOTS ability.

The authors provide suggestions for further research that can apply interactive learning media to examine other thinking skills. For physics teachers, this development research can be used to improve students' understanding of concepts in thermodynamics law material. As a follow up, the teacher can develop similar android based learning modules with different Basic Competencies. Utilization of products in learning can be synergized with learning approaches based on student centered learning, HOTS oriented learning models, and enjoyable learning methods.

BIBLIOGRAPHY

Adawiyah, R., Gunawan, G., & Hnh, H. (2019). Interactive e-book of physics to increase students ' creative thinking skills on rotational dynamics concept. *IOP Conf. Series: Journal of Physics: Conf. Series*, (1153 (1)), 1–5. https://doi.org/10.1088/1742-6596/1153/1/012117

Andarini, H. D., Swasty, W., & Hidayat, D. (2016). Designing the interactive multimedia learning for elementary students grade 1st-3rd: A case of plants (Natural Science subject). *2016 4th International Conference on Information and Communication Technology, ICoICT 2016*, *4*(c), 1–5. https://doi.org/10.1109/ICoICT.2016.7571873

Anderson, L. W., & Krathwohl, D. R. (2001). *Taxonomy for Learning Teaching and Assessing*. New York: David McKay Company, Inc.

Argaw, A. S., Haile, B. B., Ayalew, B. T., & Kuma, S. G. (2017). The effect of problem based learning (PBL) instruction on students' motivation and problem solving skills of physics. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(3), 857–871. https://doi.org/10.12973/eurasia.2017.00647a

Arifin, Z. (2016). *Evaluasi Pembelajaran: Prinsip, Teknik, Prosedur*. Bandung: PT Remaja Rosdakarya Offset. Bandung.

Ariyana, Y., Pudjiastuti, A., Bestari, R., & Zamroni. (2019). Buku Pegangan Pembelajaran Berorientasi pada Keterampilan Berpikir Tingkat Tinggi. In *Direktorat Jenderal Guru dan Tenaga Kependidikan Kementrian Pendidikan dan Kebudayaan*.

Baran, M. (2016). An Analysis on High School Students' Perceptions of Physics Courses in Terms of Gender (A Sample from Turkey). *Journal of Education and Training Studies*, *4*(3), 150–160. https://doi.org/10.11114/jets.v4i3.1243

Bates, S., Donnelly, R., Macphee, C., Sands, D., Birch, M., & Walet, N. R. (2013). Gender differences in conceptual understanding of Newtonian mechanics: A UK cross-institution comparison. *European Journal of Physics*, *34*(2), 421–434. https://doi.org/10.1088/0143-0807/34/2/421

Campbell, D. T., & Stanley, J. C. (2015). *Experimental and quasi-experimental designs for research*.

Chen, Z., Stelzer, T., & Gladding, G. (2010). Using multimedia modules to better prepare students for introductory physics lecture. *Physical Review Special Topics - Physics Education Research*, *6*(1), 1–5. https://doi.org/https://doi.org/10.1103/PhysRevSTPER.6.010108

Chiappetta, E. L., & Koballa, T. R. (2010). *Science Instruction in the Middle and Secondary Schools: Developing Fundamental Knowledge and Skills*. New York: Pearson Education Inc.

Gunawan, G., Harjono, A., & Herayanti, L. (2019). Problem - Based Learning Approach with Supported Interactive Multimedia in Physics Course : Its Effects on Critical Thinking Disposition. *Juornal for the Education of Gifted Young Scientists*, *7*(4), 1075–1089. https://doi.org/http://dx.doi.org/10.17478/jegys.627162

Hermansyah, H., Gunawan, G., Harjono, A., & Adawiyah, R. (2019). Guided inquiry model with virtual labs to improve students' understanding on heat concept. *Journal of Physics: Conference Series*, *1153*(1), 1–6. https://doi.org/10.1088/1742-6596/1153/1/012116

Hidayat, M. I., & Sutria, Y. (2017). The Effect of Inquiry Training Models Using Interactive Multimedia Toward Students Learning Outcomes. *Jurnal Pendidika Fisika*, *8*(2), 109–113.

Hosnan, M. (2014). *Pendekatan Saintifik dan Kontekstual dalam Pembelajaran Abad 21: Kunci Sukses Implementasi Kurikulum 2013*. Bogor: Ghalia Indonesia.

Kivunja, C. (2014). Do You Want Your Students to Be Job-Ready with 21st Century Skills? Change Pedagogies: A Pedagogical Paradigm Shift from Vygotskyian Social Constructivism to Critical Thinking, Problem Solving and Siemens' Digital Connectivism. *International Journal of Higher Education*, *3*(3). https://doi.org/10.5430/ijhe.v3n3p81

Leow, F. T., & Neo, M. (2014). Interactive multimedia learning: Innovating classroom education in a Malaysian university. *Turkish Online Journal of Educational Technology*, *13*(2), 99–110.

Mardiana, N., & Kuswanto, H. (2017). Android-assisted physics mobile learning to improve senior high school students' divergent thinking skills and physics HOTS. *AIP Conference Proceedings*, *1868*. https://doi.org/10.1063/1.4995181

Meltzer, D. E. (2005). Relation between students' problem-solving performance and representational format. *American Journal of Physics*, *73*(5), 463–478. https://doi.org/10.1119/1.1862636

O'Sullivan, M. (2018). *Developing the cambridge learner attributes guide*.

Pratidhina, E., Pujianto, & Sumardi, Y. (2019). Developing computer program as a learning resource on gas law topics for high school students. *International Journal of Instruction*, *12*(2), 133–146. https://doi.org/10.29333/iji.2019.1229a

Puspendik. (2019). Laporan Penguasaan Materi Ujian Nasional.

Ramadhani, R., Umam, R., Abdurrahman, A., & Syazali, M. (2019). The effect of flipped-problem based learning model integrated with LMS-google classroom for senior high school students. *Journal for the Education of Gifted Young Scientists*, *7*(2), 137–158. https://doi.org/10.17478/jegys.548350

Ramganesh, E. (2012). *Effect of Self-regulatory Strategies with Interactive Multimedia on Problem solving ability of Higher secondary students in Physics*. *9180*, 1–5.

Sadaghiani, H. R. (2012). Controlled study on the effectiveness of multimedia learning modules for teaching mechanics. *Physical Review Special Topics - Physics Education Research*, *8*(1). https://doi.org/10.1103/PhysRevSTPER.8.010103

Sari, F. P., Ratnaningtyas, L., Wilujeng, I., Jumadi, & Kuswanto, H. (2019). Development of Android Comics media on Thermodynamic Experiment to Map the Science Process Skill for Senior High School. *Journal of Physics: Conference Series*, *1233*(1). https://doi.org/10.1088/1742-6596/1233/1/012052

Soulé, H., & Warrick, T. (2015). Defining 21st century readiness for all students: What we know and how to get there. *Psychology of Aesthetics, Creativity, and the Arts*, *9*(2), 178–186. https://doi.org/10.1037/aca0000017

Tatar, E., & Oktay, M. (2011). The effectiveness of problem-based learning on teaching the first law of thermodynamics. *Research in Science and Technological Education*, *29*(3), 315–332.

https://doi.org/10.1080/02635143.2011.599318

Trisdiono, H. (2013). Strategi Pembelajaran Abad 21. Retrieved from Jurnal Lembaga Penjaminan Mutu Pendidikan Prov. DIYogyakarta website: http://lpmpjogja.kemdikbud.go.id/strategi-pembelajaran-abad-21/

Ulfa, A. M., Sugiyarto, K. H., & Ikhsan, J. (2017). The effect of the use of android-based application in learning together to improve students' academic performance. *AIP Conference Proceedings*, *1847*. https://doi.org/10.1063/1.4983910

Utami, P. B. (2019). Pengembangan E-Learning Berbasis Problem based learning sebagai Komplemen Pembelajaran Alat Optik untuk menumbuhkan Higher Order Thinking Skills Siswa. https://doi.org/.1037//0033-2909.I26.1.78

Widoyoko, E. P. (2017). *Teknik Penyusunan Instrumen Penelitian.* (6 th ed). Yogyakarta: Pustaka Belajar.

Yahya, F., Hermansyah, & Fitriyanto, S. (2019). Virtual Experiment untuk Meningkatkan Pemahaman Siswa Pada Konsep Getaran dan Gelombang. *Jurnal Pendidikan Fisika Dan Teknologi*, *5*(1), 144–149. https://doi.org/http://dx.doi.org/10.29303/jpft.v5i1.1141

Yang, Y.-T. C. (2012). Building virtual cities, inspiring intelligent citizens: Digital games for developing students' problem solving and learning motivation. *Computers & Education*, *59*(2), 365–377.

Yumuşak, A., Maraş, I., & Şahin, M. (2015). Effects of computer-assisted instruction with conceptual change texts on removing the misconceptions of radioactivity. *Journal for the Education of Gifted Young Scientists*, *3*(2), 23–50. https://doi.org/10.17478/JEGYS.2015214277