Received : 1 October 2019
Revised : 26 October 2019
Accepted : 1 November 2019
Online : 5 November 2019
Published: 30 December 2019

DOI: doi.org/10.21009/1.05207

Development of Interactive Physics Mobile Learning Media for Enhancing Students' HOTS in Impulse and Momentum with Scaffolding Learning Approach

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Abstract

The study objectives are to (1) produce an android-based Interactive Physics Mobile Learning Media (IPMLM) product in impulse and momentum material that is feasible to improve higher-order thinking skills (HOTS) of high school students; (2) know the effectiveness of android-based IPMLM in impulse and momentum material with a scaffolding approach toward HOTS of high school students. This research was Research and Development (R&D) with a 4D model. The development steps were: (1) Defining, including needs analysis activities; (2) Designing, the selection and design of research instruments and IPMLM activities; (4) Developing, an activity of developing research instruments and IPMLM, assessment of the feasibility of learning instruments, validation of research instruments, and assessment of the feasibility of IPMLM by experts, limited tests, and extensive tests; (4) Disseminating, an IPMLM dissemination activity. IPMLM feasibility assessment was carried out to determine the feasibility of IPMLM. Products that have been assessed by experts were further limited and extensively tested. The limited test subjects consisted of 13 students in the SMA Yayasan Pendidikan Kristen, Pontianak, while the extensive test subjects consisted of 48 students in SMA Koperasi Pontianak. The results show: (1) IPMLM is feasible to be used for enhancing students' HOTS with "very feasible" criteria based on expert judgment; (2) IPMLM is effective for enhancing students' HOTS. The learning process assisted by IPMLM media with a scaffolding approach can help student complete tasks in the HOTS aspect and improve learning with 21st-century learning-based activities.

Keywords: media, mobile learning, interactive, scaffolding approach, higher-order thinking skills

INTRODUCTION

The purpose of global education states that 21st-century learning needs to integrate aspects of learning and innovation skills. These skills include creativity and innovation skills, critical thinking, and problem-solving (O'Sullivan 2018). The education curriculum in Indonesia also has a similar objective. The objective of curriculum in Indonesia, precisely, in physics subjects of Senior High School is to develop skills in analyzing and applying physics concepts as well as modifying or designing in applying physics concepts (Badan Standar Nasional Pendidikan [BSNP] 2016). These skills are known as higher-order thinking skills (HOTS) (Krathwohl 2002; Brookhart 2010). HOTS need to be developed so that students can compete globally in the future. For example, students who can think critically will be able to analyze, make decisions, evaluate, and solve problems (Fisher 2011). Therefore, learning in class should integrate activities that aimed at developing these skills.

The results of interviews and observations with physics teachers on physics learning show that teachers have implemented activities that integrate HOTS skills. However, this application is still not optimal. Learning is still dominated by traditional learning methods such as lectures and the use of textbooks. Meanwhile, the results show that the majority of HOTS students are in a low category (Istiyono 2017). These findings prove that the HOTS of students in Indonesia is still low.

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). Several studies have shown the positive results of mobile learning towards attitudes (Hwang & Wu 2014), students' problem-solving abilities (Yang 2012), and student creativity (Ulfa, Sugiyarto & Ikhsan 2017). The results of the study stated that mobile learning could be used to develop HOTS students. However, research on the development of HOTS-oriented teaching materials in the field of physics has not been widely conducted (Adi & Suparno, 2017) specifically for senior high school students in West Kalimantan. Besides, the results of interviews in several schools in Pontianak City, West Kalimantan showed the availability of physics learning media is still small. As a result, students and teachers only rely on textbooks as the primary material for help and learning resources. Therefore, the study's purpose is to develop the HOTS oriented Android IPMLM application as a learning medium to improve the HOTS of senior high school students. IPMLM is developed specifically for enhancing students' HOTS. Android application is chosen because it has several advantages such as being easily accessible anywhere and anytime. The results of the study also state that android-based mobile learning media is appropriate for student learning activities in the classroom and can improve students' HOTS (Mardiana & Kuswanto 2017). So, aside from being a way of implementing HOTS skill-based learning, the android application is also used for technology-based learning or mobile devices.

For learning to be successful in improving students' HOTS skills, teachers should not only use the right media but must also apply the right learning approach. Vygotsky revealed that one learns through the help of more skilled people. There is a term called the zone of proximal development (ZPD), which is the distance between the ability to complete tasks without assistance and the ability to complete tasks with the help of more skilled people (McDevitt & Omrod 2014). Children will complete the tasks that are in their ZPD only if they collaborate or are assisted by people who are more expert. If the teachers apply Vygotsky's opinion, they need to determine the right learning approach.

One learning approach based on Vygotsky's theory is the scaffolding approach. Scaffolding approach is a learning approach by assisting students in completing difficult learning tasks (in their ZPD) to achieve their potential abilities (Anghileri 2006). The results of the study show that the scaffolding approach is appropriate for developing students' potential abilities (Nurhayati 2016; Chotirat & Teosakul 2017). The scaffolding approach can also improve students' learning activities (Ariani, Baidowi, & Azmi 2014). Thus, the implementation of the scaffolding approach enables collaboration and communication activities between teachers and students and between students and students. The teacher helps students through collaborative and communication activities.

METHODS

This research was research and development (R&D) research with a 4-D model (Thiagarajan, Semmel, & Semmel 1974). The research step consisted of defining, designing, developing, and disseminating. In the first stage, the researcher conducted an initial analysis related to the needs, students, curriculum in the school through interviews and observations with physics teachers at the school. In the second stage, the researcher chose and design research instruments and IPMLM. Data collection techniques are test and non-test, while types of instruments include tests, questionnaires, and observation. Instruments used in this research are HOTS test, teacher response questionnaire, student response questionnaire, feasibility assessment sheet, validation sheet, and observation sheet of the lesson plan implementation.

In addition to the instruments mentioned before, a learning instrument development was carried out; it is the lesson plan using the scaffolding approach from Anghileri (2006). The scaffolding approach used was an interaction between the teacher and students and between students and students during the learning process. The interactions consist of three-level namely environmental provisions, explaining, reviewing, and restructuring, and developing conceptual thinking. Environmental provisions include classroom organization interaction, which is teacher arranged groups and students' seats. Explaining, reviewing, and restructuring includes teachers explaining and simplifying problems of physics concepts in IPMLM's material, students' looking, touching, and verbalizing of physics concepts in students' worksheet, and students' explaining and justifying of the physics concepts in students' worksheet. Developing conceptual thinking includes making connections activity, which is teacher together with students summarized the material they were learning. The relationship between the material studied, and HOTS aspects show in TABLE 1.

IPMLM contents and IPMLM specifications were determined in this second step. Content and specifications were designed to improve HOTS. IPMLM content consisted of instructions for use, competencies, material, student worksheets, assessment, and developer profile. The material and student worksheets menu was designed by providing content such as pictures, videos, and animations related to the physics concepts that were studied. The student worksheets menu also contained discussion and experiment activities that were designed to be as attractive as possible. The students will analyze the concepts in the learning process.

TABLE 1. The Relationship Between The Material Studied and HOTS Aspects

Material	HOTS Aspects
The concept of impulse and momentum	*Animation 1:* Car and truck moved at the same speed, crashing into a wall for a few seconds and stop. *Animation 2:* Two identical cars moved at a different speed, crashing into a wall for a few seconds and stop. *Animation 3:* Two identical cars move at different speeds. The first car hit the wall, and the second car hit the wall covered with foam. 1. Students analyzed the animation presented in IPMLM (C4). 2. Students compared the three animations presented in IPMLM (C4).
The law of conservation of momentum	Collision video between marbles 1. Students analyzed the law of conservation of momentum from the marbles collision video presented in IPMLM (C4) 2. Students solved problems related to the law of conservation of momentum (C5)
Collisions	The experiment determined the coefficient of restitution of free fall balls. 1. Students distinguished types of collisions from experimental activities carried out (C4) 2. Students made conclusions based on experimental results (C5) 3. Students determined the magnitude coefficient of restitution from experimental activities (C4)

At the developing stage, activities were carried out for developing research instruments and IPMLM, assessment of the feasibility and validation of research instruments and IPMLM by experts, limited testing, and extensive testing. IPMLM was designed with an attractive appearance, and it was not boring. The limited test included empirical tests regarding HOTS and IPMLM readability test. The purpose of the empirical test is to determine the validity and reliability of items. The readability test of IPMLM was conducted to determine students' responses to IPMLM. Opinions, comments or suggestions from students were used as guidelines for the revision of IPMLM. After the revised IPMLM, then extensive testing was carried out to determine the effectiveness of IPMLM in terms of students' HOTS.

The limited test subjects consisted of 13 high school students of the Yayasan Pendidikan Kristen, Pontianak, West Kalimantan. The extensive test subjects consisted of 26 students from the experimental class and 22 students from the control class in SMA Koperasi, Pontianak, West Kalimantan. Students' HOTS that has measured were aspects of analyzing (C4) and evaluating (C5) on Bloom's taxonomy. Students' HOTS were measured before and after the learning process.

Pretest-posttest control group design was used as an extensive test experimental design, as shown in TABLE 2. In the last stage, disseminating was the activity of disseminating the final product of research results through scientific publications.

TABLE 2. Pretest-Posttest Control Group Design

Class	Pre-test	Treatment	Post-test
Experimental	O_1	X_1	O_2
Control	O_3	X_2	O_4

Where O_1 was a pretest for the experimental class, O_2 was a posttest for the experimental class, O_3 was a pretest for the control class, O_4 was a posttest for the control class, X_1 was learning by using IPMLM media with a scaffolding approach, and X_2 was learning using textbook media with the lecture method (Sugiyono 2016). At the disseminating stage, activities were disseminated the final product to the school and through publication. Each data obtained were analyzed descriptively and inferentially.

Analysis of Feasibility Assessment of the instrument, Students' and Teachers' responses

Data from the results of the feasibility assessment, students' and teachers' responses were analyzed by converting the assessment results of the validator and making categories of those values. Then, the value was compared with the categories that have been created. Convert values into categories were using five scale assessment criteria techniques as seen in TABLE 3.

TABLE 3. Assessment Criteria

Respondent Score	Converting Results of Respondents Score	Categories of Instruments and IPMLM	Categories of Students' and Teachers' Responses
$X > \bar{X}_i + 1{,}8\ SBi$	$X > 85$	Very feasible	Very Good
$\bar{X}_i + 0{,}6\ SBi < X \leq \bar{X}_i + 1{,}8\ SBi$	$70 < X \leq 85$	Feasible	Good
$\bar{X}_i - 0{,}6\ SBi < X \leq \bar{X}_i + 0{,}6\ SBi$	$55 < X \leq 70$	Fair	Fair
$\bar{X}_i - 1{,}8\ SBi < X \leq \bar{X}_i - 0{,}6\ SBi$	$40 < X \leq 55$	Poor	Poor
$X \leq \bar{X}_i - 1{,}8\ SBi$	$X \leq 40$	Very Poor	Very Poor

(Widoyoko 2009)

Analysis of Validation of HOTS Question

HOTS questions that have been validated are analyzed by calculating the coefficient of Aiken (1985). Determination of the Aiken coefficient (V) for each item assessed by n experts/raters used the following formula.

$$V = \frac{\sum s}{[n(c-1)]} \qquad (1)$$

With $s = r - l_o$, lo = minimum value, c = maximum value, r = value given by rater. The value of the Aiken coefficient (V) was then compared with the Aiken table value for n experts (number of raters) with the fourth-class category score (number of rating categories). The range of V values of Aiken was 0-1 (Aiken 1985).

Data from HOTS empirical test results were analyzed with item response theory. The items were analyzed with a one-parameter logistic (1PL) model that involved the level of difficulty of item (b) or Rasch modeling (Sumintono & Widhiarso 2015). The validity of items was known by looking at the goodness of fit of the model. Determination of suitability followed the rules of Adam and Khoo (1996) if the value of INFIT Mean of Square (INFIT MNSQ) was at the limit from 0.77 to 1.30.

The item reliability is known through item estimate and case estimate. The higher the reliability value, the more items that fit the model (Subali & Suyata 2011). The reliability criteria of the questions (Sumintono & Widhiarso 2015) were shown in TABLE 4.

The determination of difficulty level of test items was based on value b. If the value b is smaller than -2 than the category of difficulty is easy. If the value b is greater than 2, then category of difficulty level is hard. If the value b is between -2 and 2 or equal to -2 or 2, then the category difficulty level is average (Arifin & Yusoff 2017).

TABLE 4. Reliability Criteria

Range of Item Reliability	Categories
< 0,67	Weak
0,67-0,80	Enough
0,81-0,90	Good
0,91-0,94	Very good

> 0,94	Excellent

(Sumintono & Widhiarso) 2015

Analysis of Lesson Plan Implementation Observation

The data obtained were analyzed with the value of the Inter Judge Agreement (IJA) (Pee, Woodman, Fry, & Davenport 2002), follow this equation.

$$IJA = \frac{A_y}{A_y + A_N} \times 100\% \qquad (2)$$

where A_y = activities that have been carried out, AN= activities that were not carryout. Lesson plan was feasible to use when the IJA value was above 75%.

IPMLM Effectiveness Analysis

The analysis of the effectiveness of IPMLM from the results of extensive tests used independent sample t-test on students' n-gain percent of HOTS scores. The test hypothesis was as follows.

H0: There were no significant differences in scores of students' HOTS between the class that was taught by using IPMLM with the scaffolding approach and the class that was taught by using textbooks with the lecture method.

H1: There were significant differences in scores of students' HOTS between the class that was taught by using IPMLM with the scaffolding approach and the class that was taught by using textbooks with the lecture method.

The test criterion was H0 was accepted if the significance value $> \alpha = 0.05$ (Djudin 2013).

RESULTS AND DISCUSSIONS

Instruments Feasibility

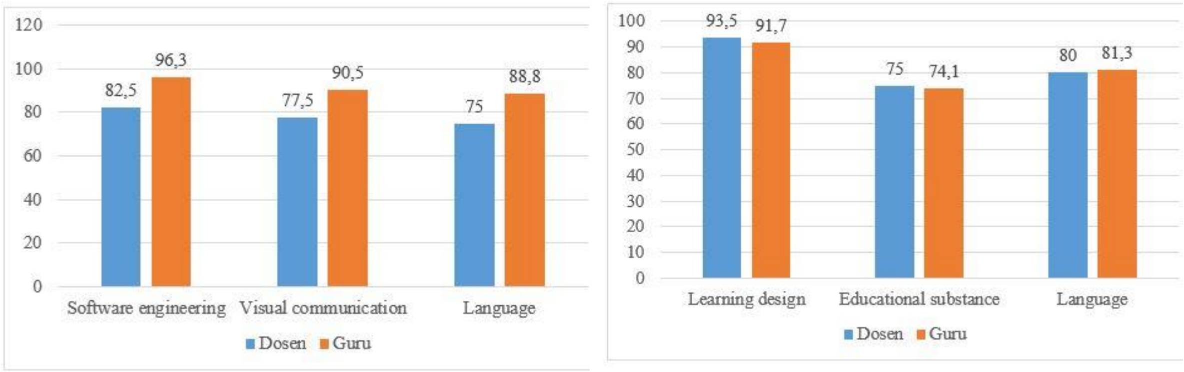
The feasibility assessment of learning instruments and devices is carried out by lecturers, teachers, and peers. The results of the analysis of the feasibility criteria for each instrument are as in TABLE 5.

TABLE 5. Results of Instruments Feasibility Assessment and Validation

Instruments	Average Score	Category
Lesson Plan	89.7	
Student Worksheets	98.3	
Teacher Responses Questionnaire	96,5	
Student Responses Questionnaire	91.3	Very feasible
IPMLM feasibility assessment sheet by media experts	92.0	
IPMLM feasibility assessment sheet by media experts	93.8	
Observation sheet of the lesson plan implementation	86.7	

IPMLM Feasibility

The developed IPMLM can be operated via a smartphone with an Android operating system. IPMLM is designed as interactive and interesting as possible, so it is not boring by providing challenging activities, images, videos, and animations. The developed IPMLM is then assessed for feasibility by material experts and media experts. The experts are lecturers and teachers. Material experts assess IPMLM in terms of learning design, educational substance, and language. Media experts assess IPMLM in terms of software engineering, visual communication, and language. The results of the feasibility assessment by aspect are shown in FIGURE 1.



(a) (b)

FIGURE 1. Results of IPMLM Feasibility Assessment by (a) Material Experts (b) Media Experts in Every Aspect

The results of the IPMLM feasibility assessment by material experts and media experts in total are shown in TABLE 6.

TABLE 6. IPMLM Feasibility Assessment by Experts in Total

Instruments	Average Score	Category
Material Experts	90.1	Very feasible
Media Experts	85.8	

The results of the feasibility assessment from FIGURE 1 and TABLE 6 state that the IPMLM is appropriate for use in learning activities. IPMLM that has been feasible is then tested namely limited testing and field trials.

HOTS Instruments Validation, Responses of Student and Teacher on IPMLM

Limited trials carry out empirical testing or HOTS test and media readability testing. An empirical test is carried out by asking high school students in XI graders to answer HOTS questions. TABLE 7 shows the results of the empirical test.

TABLE 7. HOTS Instruments Validation

Analysis	Results	Interpretation
Validity	INFIT MNSQ (0,99-1,04)	Valid
Reliability	Item reliability (0,86) Person reliability (0,00)	Reliable
Difficulty	Item difficulty (-0,99-0,89)	Medium

A Person Reliability value of 0.00 indicates that students work on questions carelessly. However, the reliability item value of 0.86 indicates that the item quality can already be said to be good. Apart from the results of the empirical test, the validity of HOTS items is also seen from the assessment of experts. The validity of the contents of the expert assessment results is analyzed by Aiken. The calculation results show that the range of Aiken's coefficient values for all items is 0.83-1.00. Hence, the HOTS question item is valid.

The limited test also carries out a media readability test. This test is conducted by asking X graders students to respond to IPMLM that is developed by using the student response questionnaire. Students provide responses related to the appearance, content, usage, functions, and language of the media. After being analyzed, the results of the student response criteria are shown in TABLE 8.

TABLE 8. Students' Responses on IPMLM

Aspects	Results of Analysis	Category
Appearance	74,4	Good
Content	77,5	
Usage	74,4	
Functions	75	
Language	78,3	
Total	75,7	

The results of students' responses are concluded in good category. Some students give comments or suggestions on IPMLM as the video duration should be longer. Such comments or suggestions are used as guidelines for the revision of IPMLM. IPMLM is then extensively tested.

Feature IPMLM

The relationship between feature IPMLM and HOTS aspects are shown in TABLE 9.

TABLE 9. Feature IPMLM

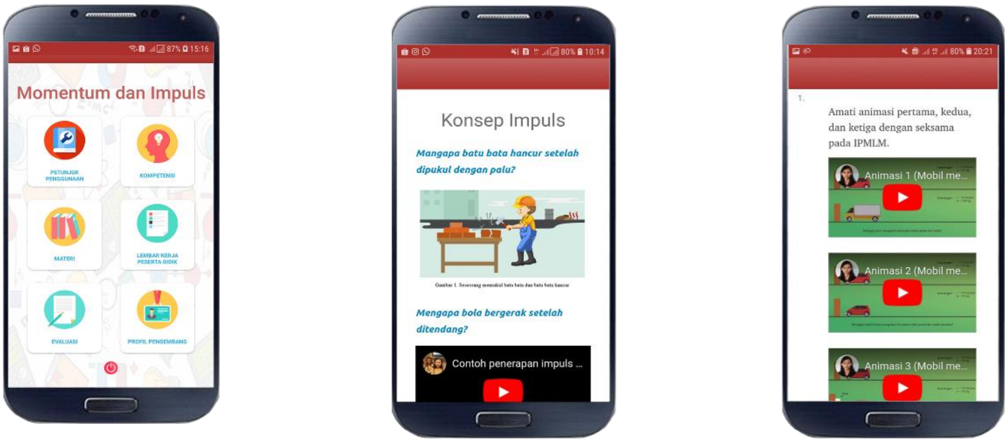
IPMLM Contents	HOTS Aspects	Example of Material Being Studied and Questions
The material was presented interestingly consisted of explanations of material, pictures, videos, animations, and a sample of problems	C4	The animations show two identical cars move at different speeds. The first car hit the wall and the second car hit the wall covered with foam. The first car was suffered more damage than the second car. *Why the first car suffered more damage than the second car.*
Student Worksheets consisted of animations, videos, experimental activities, and discussion questions were developed on HOTS aspects	C4, C5	
The question exercise consisted of questions in the HOTS aspect along with work instructions	C4, C5	A table displays data of rifle mass, bullet mass, rifle speed due to repulsion of bullets for several types of rifles. *Which rifle has the highest bullet speed?*
The assessment consisted of questions in the HOTS aspect to evaluate student learning results and display the score of the results of student answer	C4, C5	

Student worksheets in IPMLM are presented to allow students to develop their HOTS. There are animations, videos, experimental activities, discussion questions, case questions on student worksheets so that students conduct discussion activities together with the teacher and peers to answer the questions given. In this activity, the teacher helps students to achieve their HOTS. Examples of activities in IPMLM are shown in TABLE 9. In TABLE 9, the teacher displays an animated concept of impulse and momentum. Students are asked to observe animations and answer discussion questions and case questions. The questions were developed based on HOTS aspects. The teacher helps students during the learning activities so students can complete or answer the questions given.

Effectiveness of IPMLM with a Scaffolding Approach

Extensive tests are carried out to find out the effectiveness of IPMLM. To find out the effectiveness, the researcher applies learning using IPMLM media with a scaffolding approach in the classroom. As a comparison, the researcher applies other learning methods; it is by using textbook media and lecture methods to see students' HOTS before and after learning.

Observations are carried out during learning activities. The results of observing the implementation of the lesson plan concluded that the lesson plan is appropriate for use in the learning process because more than 75% of the learning activities are carried out. Observation results also show the improvement of student participation and successful learning activities showed 21st century based learning activities. Activities that are aimed at improving skills, collaboration, and communication are successfully applied. The IPMLM used by the experimental class is shown in FIGURE 2.



(a) (b) (c)

FIGURE 2. IPMLM Used in The Experimental Class (a) Main Menu, (b) Material Menu, (c) Students' Worksheet Menu.

Independent samples t-test is used to analyze the effectiveness of learning using IPMLM media with a scaffolding approach on students' HOTS. Test results are shown in TABLE 10.

TABLE 10. Independent Sample T-Test

		Levene's Test for Equality of Variances		t-test for Equality of Means		
		F	Sig.	t	df	Sig. (2-tailed)
HOTS	Equal variances assumed	5.255	.027	2.556	46	.014
	Equal variances not assumed			2.665	41.232	.011

The table above (TABLE 11) shows a significance value of 0.01 which is smaller than 0.05 so H_0 is rejected. There is a significant difference between the experimental class and the control class. This difference is shown by the mean difference of each class towards students' n-gain percent of HOTS scores. The mean of n-gain percent of the experimental class is 13,95, while the mean of n-gain percent of the control class is 2,73.

Based on the results of the inferential analysis above, it can be concluded that the experimental class that is taught by using IPMLM media with the scaffolding approach is more effective than the control class that is taught by using textbook media with the lecture method. A similar result was found by Agustihana and Suparno (2018) that the application of learning by using HOTS-oriented media effectively improve students' HOTS. Alfi and Suparno (2018) also found that learning with a scaffolding approach using HOTS-oriented media can improve students' HOTS. The results indicate that the HOTS of students has improved with the gain score of 0.69 (medium category). The application of android-based learning is effective in improving students' HOTS (Mardiana & Kuswanto 2017). The scaffolding approach that is implemented with technology supports the learning environment of students by providing various cognitive processes and cognitive activities (Sharma & Hanafin 2007). IPMLM with a scaffolding approach can improve the aspects of skills, collaboration, and communication in learning activities.

CONCLUSIONS

The developed IPMLM is appropriate to be used based on the assessment of material experts and media experts. IPMLM with a scaffolding approach presents learning activities that can enhance aspects of students' HOTS. Scaffolding approach learning has succeeded in improving collaboration and communication in learning activities that are fit 21st century based learning. There are some suggestions in conducting this media using scaffolding approach, that is: 1) sufficient time is required, 2) the teacher needs to master the scaffolding approach, 3) it will be good if every or all student can access the application.

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