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Virtual Physics Laboratory Application Based on the Android Smartphone to Improve Learning Independence and Conceptual Understanding

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The research study concerned here was to: (1) produce a virtual physics laboratory application to be called ViPhyLab by using the Android smartphone as basis; (2) determine the appropriateness and quality of the virtual physics laboratory application that had been developed; and (3) describe the improvement in learning independence and conceptual understanding of rotational dynamics after using the ViPhyLab application. The study was research and development (R&D) in design. The product was validated by a physics expert, an instructional media expert, peer reviewers, and physics teachers. The product underwent one-on-one testing, restricted testing, and field testing. The field testing used the one-group pre-test post-test design. The test subjects were forty students of Senior High School (*Sekolah Menengah Atas*, SMA, in Indonesia), Pekanbaru. The data collection was conducted by using a questionnaire, learning independence test, and conceptual understanding test. The appropriateness and quality of the application were analyzed descriptively. Improvement in learning independence and conceptual understanding was analyzed through paired t-test. Results of the study indicated: (1) ViPhyLab is an Android application that could be operated for learning both at and outside school; (2) the ViPhyLab application is quite viable as learning media and of very good quality.

Keywords: virtual laboratory, Android, learning independence, conceptual understanding, rotational dynamics

INTRODUCTION

The concepts in rotational dynamics have roles that are important for students to understand because their applications are very much related to everyday life. However, some students meet difficulties in understanding the concepts in rotational dynamics.

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Their difficulties are in drawing the diagram of free forces causing rotation, interpreting quantities in physics, and understanding the concept of rolling motion (Syahrul & Setyarsih, 2015) and they could lead to failure in accomplishing practicum activity at school (Saltanat, et al., 2016). Teachers' limited time is for practicum implementation. The difficulties that they experience in using practicum equipment also become the problems in the learning of physics.

The problem concerning difficulties in learning and doing activities of practicum in rotational dynamics at school demands that students are independent in learning physics at home. At the level of higher education, students are still not sufficiently independent in learning physics so that their learning achievement is below the minimum standard (Clark & Lyons, 2011). Based on that finding, it could be assumed that independence in learning is a matter requiring special attention in the learning of physics. Teachers could utilize technology to overcome the problem of the practicum that could not be done in a conventional laboratory and to improve students' independence in learning. Computer-based learning media could support students' independence in learning. The computer-based learning that could be used by teachers takes the form of smartphone-based simulation technology (Arun, & Mohit, 2016).

A smartphone is a product of technology owned by the majority of the people. According to the results of observations in the field, almost every SMA student in the city of Pekanbaru owns a smartphone. Accordingly, Android-based smartphones have good potentials if utilized as interactive learning media for high school students. Smartphone utilization for activities of learning physics provides students with convenience in doing the learning (Gonzalez & Martin, 2015). The convenience covers flexibility in accessing learning of a higher level. Students could build their understanding through simulation and evaluation activities continuously and independently.

The usefulness of a smartphone, according to the explanations presented in the case here, is as solution to limitations in learning such matter as displaying a simulation of forces causing objects to rotate. However, according to the results of searches in Google apps, the availability of applications that could support the learning of physics is still difficult to find. Therefore, some research needs to be made with the purpose of developing a virtual physics laboratory application based on the Android smartphone focusing on materials of rotational dynamics to improve students' understanding of concepts in physics and students' independence in learning.

So the objective of the research concerned here was to result in a ViPhyLab application concerning rotational dynamics materials which was flexible and interactive, with high levels of appropriateness and quality, and able to improve students' independence in learning and their conceptual comprehension of rotational dynamics materials.

REVIEW OF LITERATURE

Materials about rotational dynamics are complex and related to everyday life. One of the methods that teachers could use to make it easier for students to understand the concepts in the rotational dynamics materials is the practicum method. Practicum activity could train students to become skillful in problem solving in accordance with the theories of physics learned in class (Danielsson, 2014).

The above exposition of the problem indicates that a learning design that fits the needs is required. Multimedia for learning with information technology as basis could help to improve learning independence and conceptual understanding. The learning multimedia refers to combinations of various audio-visual media that could be used in teaching and learning activities (Pacher & Leask 2014). A way for teachers in mediating interaction with students is through virtual learning. One of the virtual forms of the teacher-student interaction mediation is with media of simulation. Therefore, the learning multimedia in the research concerned here was designed with the concept of virtual laboratory through technology-based simulation. Microscopic and macroscopic phenomena could be portrayed on certain scales through simulation so that they could be clearly observed by students.

Simulation is applicable on rotational dynamics lesson materials involving such a macroscopic device as a wheel rotating on an inclined plane. In order that students could see the concept of that rotation, they had better be facilitated with a wheel in rotational motion and what causes the wheel to rotate. A virtual laboratory with simulation could be used as media for understanding concepts in rotational dynamics.

The teacher could train students' learning independence through learning media that are flexible from the point of time and place so that students are interested in reviewing the learning later. The multimedia with the Android smartphone as basis could set to work the function of flexibility in space and time in accordance with students' needs. The utilization of the learning with mobile means as basis (also called m-Learning) gives positive contributions to students' access to learning materials and to opportunities for them to learn independently (Rogozin, 2012).

Improvement in Students' Learning Independence

Learning independence is students' ability to undertake self-control and self-observation and to personally evaluate their cognitive processes (Schunk, 2012). Learning independence could be interpreted as a form of awareness appearing from within themselves of wanting to receive information, manage it, and relate one piece of information with another.

Students' learning independence is an aspect which is very important in supporting effectiveness in learning activities. The forms of participation that students could do, namely, controlling, monitoring, and arranging their cognition personally, would help teachers teach (Lee, 2010). It means that students' active participation in the learning is seen from their ability in building their knowledge with the accompaniment of supervision by the teacher so that transfer of knowledge is easy to do.

The teacher also has a role in training students' learning independence. He or she could train students' learning independence by making a plan of learning activity through assignments and learning media that make students' learning independence grow (Winters et al, 2008). One of the learning forms that could cause learning independence to grow is the technology-based learning. Computer-based learning gives students the chance to arrange, plan, and control learning activity with a high level of flexibility.

There are several important aspects that need to be paid attention to in training students' learning independence. These aspects are as follows: access, analysis, creating, reflection, and taking action (Pachler & Leask, 2014). With those aspects as basis, computer-based learning could be used to train students' learning independence. According to some previously discussed theories, some aspects of students' learning independence are planning, responsibility, initiative, self-confidence, discipline, and self-evaluation.

Improvement in Students' Conceptual Understanding

Understanding a concept is a thinking process done by a human individual to really understand an object or an event (Arends, 2012). In a learning activity, a concept is a generalization of thoughts of something so that facts and perceptions are needed to build a concept. Understanding concepts is the most important part of physics learning. Concepts in physics cover principles, laws, and theories of physics together with their applications in life. The learning is good when the teacher could build students' understanding of concepts through the activities and materials provided (Moss & Brookhart, 2012).

The understanding of physics concepts for students could be built by the teacher through activities of contextually explaining physics concepts. In delivering physics learning materials, the teacher should pay attention to students' needs, make analogies of physics concepts in life, and use good language in order that the information is delivered well (Lee, 2004). With everyday language and experience being involved, students' reasoning would be stimulated to relate the phenomena in their daily life to the physics concepts explained by the teacher.

METHOD

Type of Research

The research was of the type known as R&D (Research & Development). The type was chosen because the objective was to develop a learning application product acquiring fine levels of appropriateness and quality through a process of validation and field testing activity. The application product developed in the research took the form of a piece of software with the Android operating system as basis that could be operated in an Android-based smartphone with the (.apk) extension, the initiation of an Android application program.

Model of Development

The developing model used was the result of adaptation of and collaboration with the research and development model of Borg and Gall (2003), the learning design model of Dick, et al. (2001), and the multimedia development model of Lee and Owens (2004). The adaptation was done to acquire a development model fitting the characteristics of the ViPhyLab application research and development.

Procedure of Development

The procedure of development in the research covered stages adapted to the model of development. The stages consisted of, among others, activities of analysis, design, and development, validation, and product evaluation. A needs analysis was done through observations of and interviews with teachers and students. The objective of the needs analysis activity was to obtain data that would be useful for developing the ViPhyLab application in accordance with the problems confronted in the learning of the rotational dynamics materials in physics.

After the needs analysis activity, then the stage of design and development was conducted. The result of design and development was then evaluated in terms of its appropriateness and quality through the stage of product validation. The validation was done by experts in physics materials and in the learning media. Besides experts' validation, evaluation was also done by the researcher's colleagues and teachers of physics. Then the validation result was analyzed to get information of the quality and to come up with suggestions for product improvement.

Besides validation by experts, teachers, and colleagues, product evaluation was also done. The evaluation was done through individual (or one-to-one) testing, restricted testing, and field testing. In the individual testing, the respondents were six students. It was done to obtain students' preliminary response to the original product resulting from the development. The restricted testing was done with fifteen students of Grade XI in IPA. The restricted testing result was then analyzed so that, after further possible improvements, the product could be used in the field testing.

The field testing was product testing in class to get information of any improvement in students' learning independence and conceptual comprehension. The subjects in the field testing were students of Grade XI in IPA at a state high school, SMA Negeri 5, City of Pekanbaru, forty in number. The testing done used the One Group Pretest-Posttest Design, meaning that the testing used one population as experimental class only.

Data Collection Instruments

The research data were collected by using a questionnaire and a test of conceptual understanding. The questionnaire was used in the validation by experts and evaluation by teachers, colleagues, and students. Besides, the questionnaire was also used to get data related to the level of students' learning independence in the class of physics. The conceptual understanding test was given to obtain data concerning the level of students' conceptual understanding of rotational dynamics materials. It consisted of objective test items and was administered to students at pre-test time, namely, when the students had not yet used the ViPhyLab application, and at post-test time, namely, when they had already used the ViPhyLab application.

Media Assessment Instrument

The media assessment instrument in this research is a questionnaire. Questionnaires are used to find out about the validity of ViPhyLab's learning apps and apps based on expert judgments (media experts and material experts). The design of media assessment questionnaire was developed based on the theory of assessment criteria of multimedia learning according to some experts who have been described in the study of theory. Questionnaire validation developed in the form of a grid that contains aspects and indicators of data characteristics required in this study.

Questionnaire ViPhyLab learning application validation by media experts include 4 aspects of visual audio display, layout (layout), animation and simulation, and software engineering. Assessment was developed using a likert scale of 1-4 Likert scale that has been modified by omitting the middle value of a scale of 1-5 in order to avoid ambiguity during the analysis.

Questionnaire of ViPhyLab learning application validation by material experts covers 3 aspects: learning aspect, material aspect, and aspect evaluation. Assessment was developed using a likert scale of 1-4 that has been modified by omitting the middle value of a scale of 1-5 to avoid confusion during analysis.

User Response Instrument

The ViPhyLab learning application response instrument by users that includes teachers, peers, and students is developed to find out responses from app users after attempting to use this app in learning activities. Aspects of user responses developed consist of aspects of learning, materials, and media. The results of the analysis of this user response will be used as reference for improvement before ViPhyLab application is tested in the field.

Learning Independence Instrument

The instrument of measuring student's learning independence using questionnaires given to the students. Questionnaire is prepared based on a planning, responsibility, initiative, confidence, discipline and self-evaluation. Questionnaires are presented in the form of a statement using the preferred response at the Likert scale. Likert scale size used has been modified to only use a scale of 1-4. Modifications are done by removing the middle value from a scale of 1-5 in order not to occur confusion in data analysis.

Conceptual understanding Instrument

Students understanding of the concept of dynamics of rotation obtained concept understanding test. The contents and constructs of tests have been validated by instrument validators. Empirical validation was analysed using SPSS program. 25 test items are valid. $r_{count} > r_{table}$ at 5% significance level for the number of respondents 30 students.

Technique of Data Analysis

The research data were analyzed by descriptive and inferential analyses. The descriptive analysis was used to analyze the data of product validation and of improvement in learning independence and conceptual understanding. The inferential analysis was used to analyze any improvement in students' learning independence and conceptual understanding as a whole. In the analysis of data resulting from the application validation and quality evaluation, the qualitative data were converted and classified into categories indicating levels of appropriateness and quality of the application. Widoyoko (2011) makes a classification with comparison to the ideal average score (X_i) and the ideal standard deviation score (SB_i) as basis. The qualification level is divided into four categories with criteria as in Table 1.

Table 1
Qualification of score quality

No.	Score Range	Category
1.	$\bar{X} \geq X_i + 1{,}8\ SB_i$	Very good
2.	$X_i + 0{,}6\ SB_i \leq \bar{X} < X_i + 1{,}8\ SB_i$	Good
3.	$X_i - 1{,}8\ SB_i \leq \bar{X} < X_i + 0{,}6\ SB_i$	Poor
4.	$\bar{X} < X_i - 1{,}8\ SB_i$	Very poor

The analysis of the data obtained from the questionnaire on students' learning independence was done by converting the qualitative data into quantitative data. The scores for learning independence were calculated at session beginning and end times. The data of the conceptual understanding test resulted from the rotational dynamics conceptual comprehension test. The scores for conceptual understanding were calculated with the data from pretest and posttest times as basis. Each score resulting from the calculation was then converted by using Equation 1.

$$Converted\ Score = \frac{Obtained\ Score}{Maximum\ Score} \times 100 \qquad (1)$$

A comparison of the converted scores of students' learning independence and conceptual understanding is descriptively shown through a graph of converted scores of each aspect at beginning and end times.

Any improvement in each aspect of students' learning independence and conceptual understanding was descriptively obtained with the normalized gain score as basis. The data used to calculate the gain score were the ones from the questionnaire at session beginning and end times. The gain score calculation could be done by using the following gain equation (Equation 2) according to Hake (1998).

$$g = \frac{S_f - S_i}{100 - S_i} \qquad (2)$$

with S_f as the final score obtained at session end or at posttest time, S_t as the initial score obtained at session beginning or at pretest time, and g as the descriptive gain score. The interpretation of the gain in each aspect observed could be done with the gain score criteria according to Hake (1998) as basis, shown in Table 2.

Table 2
Criteria of gain score

No	Gain Score	Criteria
1	$g \geq 0{,}70$	High
2	$0{,}30 \leq g < 0{,}70$	Medium
3	$g < 0{,}30$	Low

The inferential analysis was used to analyze the data on gain/increase/ improvement in conceptual understanding and learning independence. Before the data analysis was done, a test of analysis prerequisite needed to be done. The purpose of doing the analysis prerequisite test was to get information of whether the data would be analyzed by using parametric or non-parametric statistics. The analysis prerequisite test done to the sample data was the Kolmogorov-Smirnov normality test.

The data resulting from the normality test were then analyzed to know the conclusion related to gain/increase/improvement in the variables of students' conceptual understanding of rotational dynamics and their learning independence. The inferential analysis used if the data were normally distributed was a parametric analysis, namely, the paired t-test. If the data were not normally distributed, a non-parametric statistical test with the Wilcoxon matched-pairs test model was used.

The analysis using the paired t-test and the Wilcoxon matched- pairs test was done with the help of the SPSS statistical processing software. The analysis used the one-tailed test and value of df = 40-1. The criteria for rejecting Ho for a left-tailed test are that if the level of significance is less than 0.05 and $t_{obtained} < t_{table}$, it could be concluded that there is improvement in students' conceptual understanding and learning independence (that is, Ho is rejected).

FINDINGS AND DISCUSSION

The ViPhyLab application was developed in accordance with the characteristics of m-Learning application. The learning with mobile means as basis (or m-Learning) has the characteristics of being spontaneous, connected, and informal (Kitchenham, 2011). It explicitly means that there are no specific rules restricting individuals in doing the learning activity when using the mobile device.

The ViPhyLab application is a virtual laboratory application that has been developed by using the tool called Adobe AIR for Android, which is a sub-program of Adobe Flash CS 6, ActionScript 3.0. The steps of the application development started with flowchart and storyboard designing. The components resulting from the development that are found in the application cover instruction, competency, material, virtual practicum, and exercise item. In appearance, the ViPhyLab application resulting from the designing activity is as seen in Figures 1 and 2.

Figure 1
ViPhyLab application initial appearance

Figure 2
Rotational kinetic energy virtual practicum appearance

Appropriateness and Quality of the ViPhyLab Application

The levels of appropriateness and quality of the product resulting from the development as learning multimedia were then measured. The level of appropriateness was measured through validation by experts in learning materials and media while the level of quality was measured through evaluation by colleagues, teachers, and students.

The results of validation by material experts could be seen in Table 3.

Table 3
Material validation results

No.	Aspect	Score	Max Score	Category
1.	Learning	26	28	Very Appropriate
2.	Material	37	40	Very Appropriate
3.	Evaluation	24	24	Very Appropriate
	Total	87	92	Very Appropriate

Results of validation by material experts indicate that the ViPhyLab application in terms of its material is declared valid. With the material validation results as basis, there were some notes for improvements that needed to be paid attention to in relation with grammar and appropriateness of values and picture size. All aspects are categorized as very appropriate with the total obtained score of 87, which is 94.56% of the maximum score.

The validation of application appearance and programming was done by media experts. The validation by media experts covered the following aspects: audio-visual matter, layout and navigation, animation and simulation, and software engineering. The validation was done by using a questionnaire with a 1-4 Likert scale. Results of the validation could be seen in Table 4.

Table 4
Media validation results

No.	Aspect	Score	Max Score	Category
1.	Audio- Visual Matter	37	40	Very Appropriate
2.	Layout and Navigation	20	20	Very Appropriate
3.	Animation and Simulation	8	8	Very Appropriate
4.	RPL	27	28	Very Appropriate
Total		92	96	Very Appropriate

Results of validation by media experts indicate that the aspects evaluated are all declared valid. With the results of media validation as basis, there were some notes for improvements in relation with feedback concerning students' response to the torque practicum component and with the availability of home page navigation button in the exercise component. Based on the media validation results, all aspects of the ViPhyLab application evaluated are categorized as very appropriate with the total obtained score of 92, which is 95.83% of the maximum score.

The media quality was measured with the evaluation by physics teachers and colleagues as basis. Their evaluation was of the following aspects: the learning, the material, and the media. A recapitulation of the average scores of evaluation by three physics teachers could be seen in Table 5. On the whole, the three physics teachers' evaluation is categorized as very good. The total mean score is 82.33, which is 93.56% of the maximum score and within the category of being very good.

Table 5
Evaluation by physics teachers

No.	Aspect	Mean	Max Score	Category
1.	Learning	33,00	36	Very good
2.	Material	23,33	24	Very good
3.	Evaluation	26	28	Very good
Total		82.33	88	Very good

A recapitulation of the application quality evaluation by three colleagues (as peer reviewers) could be seen in Table 6. The evaluation by peer reviewers on the whole is within the category of being very good with the total mean score of 82.67, which is 93.94% of the maximum score.

Table 6
Evaluation by peer reviewers

No.	Aspect	Mean	Max Score	Category
1.	Learning	34.00	36	Very good
2.	Material	22.67	24	Very good
3.	Evaluation	26.00	28	Very good
Total		82.67	88	Very good

Figure 3
Online task in ViPhyLab

The aspects of learning independence in the ViPhyLab application are displayed in the application programming which is designed in a flexible and interactive manner. With such programming, students could monitor their learning personally. The learning media that could help students monitor their learning activity constitute forms of training in students' learning independence (Greene & Azevedo, 2009). The ViPhyLab application is also supplemented with online tasks so that the teacher could control students' learning. An example of the appearance of an online task in the ViPhyLab application could be seen in Figure 3.

The data of improvement in students' independence in learning by using the ViPhyLab application were obtained through a questionnaire. Results of analysis on data from the learning independence questionnaire with the highest, lowest, and mean scores of forty students at session beginning and end times as basis could be seen in Figure 4.

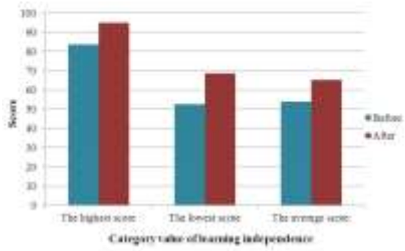

Figure 4
Learning independence scores at before and after treatments

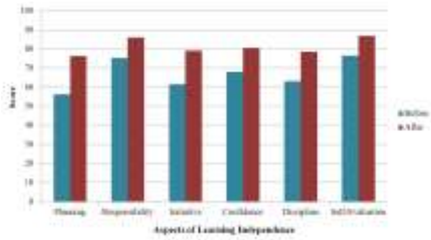

Figure 5
Graph of score comparison for each aspect of learning independence

There was a difference between students' learning independence scores obtained before their use of the ViPhyLab application and those obtained after it. The difference between the highest score at session beginning and that at session end was up to 11.25. The difference between the lowest score at session beginning and that at session end was up to 16.25. The forty students' learning independence average score underwent a rise totaling to 14.03.

Table 7
Gain scores of learning independence aspects

No.	Aspect	Gain	Category
1.	Planning	0.46	Medium
2.	Responsibility	0.43	Medium
3.	Initiative	0.45	Medium
4.	Self Confidence	0.39	Medium
5.	Discipline	0.42	Medium
6.	Self-Evaluation	0.44	Medium

The comparison between each aspect of learning independence at session beginning time and that at session end time could be seen in Figure 5. Each learning independence aspect underwent an increase. The increase in each learning independence aspect was also analyzed with the gain score as basis. The gain score of each learning independence aspect could be seen in Table 7.

The learning independence aspect attaining the highest gain score (i.e., 0.46) was planning. The aspect with the lowest gain score was self-confidence. The increase in learning independence from that at session beginning time to that at session end time for the aspects on the whole was within the medium category.

Results of the research provide the information that optimum use of the ViPhyLab application could increase students' learning independence. A technology-based learning atmosphere could train students' ability in planning their learning (Winters et al., 2008). Students' learning independence is trained through the assignment of learning tasks to be independently done, the learning which is interesting, and the support of a learning activity design enabling students to arrange the order of their own learning.In the ViPhyLab application, how the learning materials appear is developed by using the language that is standard but easily understood by users. One of the forms of material appearance in the ViPhyLab application could be seen in Figure 6.

Figure 6
Appearance of material in ViP hyLab

Figure 7
Appearance of virtual practicum in moment of inertia

In the ViPhyLab application, students' conceptual understanding is built not only through learning material but also through virtual practicum. Virtual practicum being made the choice provides students with convenience in building concepts because it could simplify the visualization which is complex in nature into one which is easy to understand (Kozhevnikov, 2013). How virtual practicum appears in the ViPhyLAb application is made in the form of simulation and animation. A virtual practicum appearance found in ViPhyLab could be seen in Figure 7.

The improvement in students' conceptual understanding of rotational dynamics materials was viewed from the point of various aspects of understanding. Aspects of understanding were divided into three sub-categories, which were, respectively, of translation, interpretation, and extrapolation abilities (Bloom et al., 1956). The conceptual understanding test instrument was constructed with those aspects as basis.

The conceptual understanding test instrument was designed in the form of twenty multiple-choice test items. The data resulting from students' conceptual understanding test were divided into pretest and posttest ones. The pretest was the conceptual understanding test given before students used the ViPhyLab application while the posttest was the conceptual understanding test given after students used the ViPhyLab application.

A graph comparing results of testing of students' conceptual understanding test instrument at pretest and posttest times could be seen in Figure 8. Change in the test scores for students' conceptual understanding of rotational dynamics materials could be descriptively known from the increase in average score. Students' conceptual understanding pretest average score was 45.8 but after their use of the ViPhyLab application, students' conceptual understanding test average score had an increase of 32.6 into 78.4.

A comparison involving each aspect of conceptual understanding could be seen in Figure 9. Figure 9 shows that all aspects of students' conceptual understanding of rotational dynamics underwent improvement. The improvement in aspects of conceptual understanding could be seen from the gain score. The gain score of each aspect of conceptual understanding is presented in Table 8.

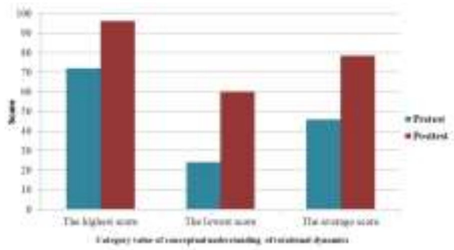

Figure 8
Comparison of initial and final conceptual understanding scores.

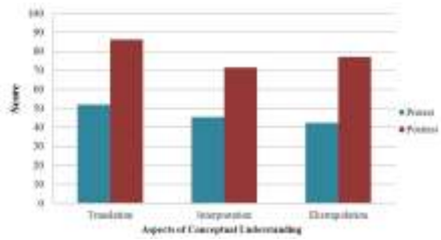

Figure 9
Score comparison of each conceptual understanding aspect.

Table 8
Gain scores of conceptual understanding aspects.

No.	Aspect	Gain	Category
1.	Translation	0.72	High
2.	Interpretation	0.48	Medium
3.	Extrapolation	0.60	Medium

The conceptual understanding aspect with the highest gain score was translation with the gain score of 0.72. Based on the gain score category criteria according to Hake (1998), it was high in category. As for the other aspects of conceptual understanding, their gain scores were still medium in category.

Results of the field testing indicated that the ViPhyLab application could improve students' conceptual understanding. That finding showed that technology-based learning could improve students' conceptual understanding.

A character of the learning material and practicum in the ViPhyLab application is that they adopt the recommended stages of concept learning implementation. The stages are of giving contextual examples, inviting students to give response, giving them opportunities to describe concepts, and enabling them to evaluate concepts. In the application, students also could evaluate concepts through such an exercise item.

CONCLUSION

The ViPhyLab application is a set of physics learning media, with virtual practicum in rotational dynamics materials as basis, developed in the Android operating system. A characteristic of the ViPhyLab application is that it could be operated in the smartphone device and used at learning time at school or outside school. The application is also equipped with material presentation, virtual practicum, exercise items, and media with interesting and interactive appearance. The ViPhyLab is quite appropriate and quite good to use as learning media, according to experts' and users' evaluation. According to field testing results, the ViPhyLab application could improve students' learning independence and conceptual understanding.

RECOMMENDATIONS

Teachers could use ViPhyLab as media for training students' learning independence and improving their conceptual understanding of rotational dynamics learning materials.

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