The development of harmonic oscillation e-module based on problem based learning (pbl) for helping improvement of students’ higher order thinking skills (hots)

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Abstract. This study aims to develop a harmonic oscillation e-module based on pbl for helping hots improvement of senior high school students at SMA N 23 Jakarta. The ADDIE Model of research and development was applied in developing such e-module prior to measure improvement of students’ hots. The validation results of experts indicated the values of 78.1%, 77.7% and 93.8% for media, learning model and content, respectively. The trial result of teachers and a small and big group of students respectively indicated an average score of 93.95% and 95.1% and 86.5% for all aspects of content eligibility, presentation, language and graphical eligibilities. Furthermore, The $t_{gain}$ test calculation shown that the $t_{gain}$ count (2.58) was bigger than $t_{gain}$ table (1.67) with 5% significance level. The analyzed result indicated that the improvement of hots of students which was taught with the pbl based e-module was better than those who utilized the non pbl based e-module of the harmonic oscillation. Meanwhile, the result of d’Cohen test indicated that the developed e-module was very decent to be utilized as learning media with contribution category of medium (based on d’Cohen test result of 0.64) for improving hots of senior high school students.

1. Introduction

The quality of education in Indonesia was still low which indicated based on the results of the 2015 Program for International Student Assessment (PISA) showed that Indonesian education was at position of 64 within 65 countries, especially in Mathematics and Science subjects [1]. The results of the Trends in International Mathematics and Science Study (TIMSS) of 2015 indicated that Indonesian education was ranked to be 44th out of 49 countries and 44th out of 47 countries in Mathematics and Science subjects, respectively [2]. The center for educational assessment released the results of the 2017/2018 national examination of the senior high school students showed that the students’ absorption in learning sciences was less than 55 and was only 36.53 for the harmonic oscillation material [3]. Many students have difficulty in using mathematical representation, reading and describing graphs of positions due to time, and determining factors that influences the period of the spring and pendulum [4].

Students were taught using hots will have a better achievements and skills in art and language [5]. Applying hots in learning science using inquiry learning method will develop positive attitude and a good emotional and cognitive [6]. Students who have hots would be able to create new knowledge and to make right and rational decision [7].
However, development of effective electronic courses of physics would be important in the context of improving efficiency of students’ independent work when competency approach was used to train students in enhancing their competitiveness [8]. While, the interactive e-learning module of pharmacology was moderately effective and well perceived by the students [9]. E-Module of online learning could make difference in students’ conceptual understanding and representational fluency in physics as well as make them more aware of their learning processes [10].

Furthermore, a learning model would be necessary in developing e-module to fulfill the needs of teachers and students as a source of self-independent learning for students. As shown in previous research that the use of pbl could improve students critical thinking skills in the learning process [11]. E-module based on pbl is feasible to improve students’ science process skill for high school students [12]. So, as a learning model, pbl would be possible to be applied in developing an e-module of physics material. Based on those reasons, the research will develop harmonic oscillation e-module based on pbl for helping improvement of students’ hots.

2. Research methods
The development of this e-module uses the research and development method of ADDIE (Analysis, Design, Develop, Implementation, Evaluation) model was applied in developing harmonic oscillation e-module based on pbl. The research subject used consisted of 65 students of grade X of SMAN 23 Jakarta. Data collection is carried out in the even semester of the 2019/2020 school year. The e-module was developed using display 3d page flip professional software. The following picture shows a view of displayed pages of the developed e-module:

![Displayed pages of the developed e-module.](image)

The developed e-module of harmonic oscillation was arranged based on the process of pbl model as follows [13]:

| Stage of model                  | The design e-module                                                                 |
|---------------------------------|------------------------------------------------------------------------------------|
| Student orientation to problems | At this stage, students were provided with the daily life phenomena through a video prior to answer question and to analyze the related problems. |
| Organizing students for learning| At this stage, students were guided to discuss the question and to prepare the result of discussion for such given case. |
| Guiding individual or group investigations | At this stage, students were provided with supported materials that include related theory or concept of course for discussing the given problems or cases. |
| Developing and presenting the work | At this stage, students were provided with experiment simulation or to carry out an experiment and to their work in forms of experiment result as well as the result of discussion. |
| Analyzing and evaluating process | At this stage, students made their conclusion and summary of the courses that have been learned and to answer ten available hots questions. |
The harmonic oscillation e-module based on pbl was validated by the learning media, learning model and content validators and teachers as well as it was tried out by the selected small and big groups of students. The data were collected using questioners with the likert scale scores of 1 to 4. Following the validation and final revision processes based on the inputs of validation and trial out activities, the developed e-module was used in class experiment in parallel with class control that used a non pbl based e-module to measure the developed e-module is worthy to be used to help students in improving their hots. The both of control and experiment classes were randomly selected prior to provide them with the pre and the post tests.

3. Results and discussion
The purpose of validator of learning media, learning model and content is to test the feasibility and know opinions about the e-module, the material in e-module, the stages of learning presented in the e-module developed and obtain information in the form of improvements, suggestions and criticism for the evaluation and revision of e-module. The validation results of the developed e-module as shown in following table:

Table 2. The validation result of validator of learning media.

| Aspects         | Result  |
|-----------------|---------|
| Self instruction| 80.00%  |
| Self contained  | 78.13%  |
| Stand alone     | 80.00%  |
| Adaptive        | 75.00%  |
| User friendly   | 77.50%  |
| Average of all aspects | 78.13% |

Table 3. The validation result of validator of learning model.

| Aspects                                    | Result  |
|--------------------------------------------|---------|
| Student orientation to problems            | 90.60%  |
| Organizing students for learning           | 75.00%  |
| Guiding individual or group investigations | 75.00%  |
| Developing and presenting the work         | 79.00%  |
| Analyzing and evaluating the problem solving process | 68.70% |
| Student orientation to problems            | 78.10%  |
| Average of all aspects                     | 77.70%  |

Table 4. The validation result of validator of content.

| Aspects       | Result  |
|---------------|---------|
| Content eligibility | 91.80%  |
| Language      | 95.80%  |
| Average of all aspects | 93.80% |

An average of 78.13% due to the all aspects of e-module as learning media as shown in table 2 above was achieved based on the validation result of validator. The table 3 and table 4 also shown an average of 77.7% and 93.8% for all aspects based on the validation results of learning model and content validators.
Based on the validation result of teacher as shown in figure 2 indicated that an average of 93.5% was given to all aspects such as the content eligibility, presentation, language and graphics.

An average of 93.1% and 86.5% for all aspects including content eligibility, presentation, language and graphics were counted as the trial results of small and big groups of students as shown in figure 3 and figure 4, respectively.

Generally, a total average of 87.53% for all related aspects was calculated from all validation results of validators, teachers and students. It was stated that the pbl based e-module could be interpreted as a worthy learning media to be used in the learning and teaching process of harmonic oscillation.

Prior to understand the improvement of hots of students by using the developed pbl based e-module, the data were tested using the Chi-Square test that was normally distributed. In this case, the calculation of $\chi^2$ count of control class (9.2) was less than $\chi^2$ table (12.6). While, the calculation of $\chi^2$ count of experiment class (3.03) was less than $\chi^2$ table (12.6). Both measurements used a degree of freedom of 5%. However, in order to find out whether data collected was homogeneous or not, the Fisher test was used to understand the homogeneity of data. The result of calculation with Fisher test shown that F-count (1.46) is less than F-table (1.79), it can be understood that the data is homogeneous.

A total of 11 out of 30 multiple choice type of hots questions were used in the research after process of validation using the biserial correlation equation. While, the Kuder and Richardson (KR-20) was applied to measure reliability of the questions. Both of level of difficulties and discrimination power tests were also carried out to select appropriate of multiple choice of hots item test. By using $P = \frac{B}{J_s}$ in which $P$ is difficulty level or index of difficulty, $B$ is the number of students responding correctly to the item, and $J_s$ is the total number of students responding to the item with standard level as shown in table 5, it was identified that 5 and 6 items test were categorized medium and difficult, respectively.
Table 5. Standard of difficulties level test.

| Interval  | Category |
|-----------|----------|
| 0.00-0.29 | difficult|
| 0.30-0.69 | medium   |
| 0.70-1.00 | easy     |

Discrimination power test using $D = \frac{B_A}{J_A} - \frac{B_B}{J_B}$ where $B_A$ is the number of students in the upper group who answer the item correctly, $B_B$ is the number of students in the lower group who answer the item correctly, $J_A$ is the number of all students in the upper group, and $J_B$ is the number of all students in the lower group. It was identified that 9 and 2 of out of 11 items were respectively categorized good and satisfactory by using the standard as shown in the table 6.

Table 6. Standard of discrimination power test.

| Interval  | Category  |
|-----------|-----------|
| 0.00-0.19 | very poor |
| 0.20-0.29 | poor      |
| 0.30-0.39 | satisfactory|
| 0.40-0.70 | good      |
| 0.70-1.00 | very good |

To find out the improvement different of hots students who utilized the pbl based e-module and with those who used the non pbl based e-module of the harmonic oscillation, the $t_{gain}$ test was used to examine the hypothesis to find out whether $H_0$ was rejected or accepted. The hypotheses are:

- $H_0$: $\mu_1 = \mu_2$ (there was no difference between gain value of control and experiment classes)
- $H_1$: $\mu_1 \neq \mu_2$ (there was a difference between gain value of control and experiment classes).

The $t_{gain}$ test calculation shown that the $t_{gain}$ count (2.58) was bigger than $t_{gain}$ table (1.669) with 5% significance level. It means that $H_0$ is rejected and $H_1$ is accepted. The analyzed result indicated that the improvement of hots of students which was taught with the pbl based e-module was better than those who utilized the non pbl based e-module of the harmonic oscillation. It could be interpreted that the developed e-module was worthy to be used to improve the hots of students in learning physics. The results of this study were supported by the results of previous study on the development of pbl training e-modules in nursing education [14].

However, an effect size as an essential component for evaluating the statistical claim was further calculated to understand a quantitative measure of the magnitude of the phenomenon [15] using d’Cohen test. The result of the d’Cohen test was 0.64 that was categorized as medium in according the following standard [16] as shown in table 7 below.

Table 7. Effect size criteria.

| Effect size | Category |
|-------------|----------|
| $D < 0.2$   | small    |
| $0.2 < D < 0.8$ | medium  |
| $D > 0.8$   | big      |

It could be said that the pbl based e-modules of the harmonic oscillation provide a medium size contribution to improve hots of students in learning physics. It also observed that the students” interest was significantly improved in learning by using the pbl based e-modules of the harmonic oscillation in the experimental class. The pbl based e-modules of the harmonic oscillation was presented with interesting illustrations. Stages of the pbl model which made students to learn independently or in a group and think critically, creatively and innovatively. Stages of pbl in the e-module written clearly so that it leaded to students in the process of thinking in learning. At the investigation stage, students should be able to understand theories presented as support materials that were applied in doing experiment or
discussion as well as to help students to present their work at the next stage of the work presentation. At the end, the students would work to answer the questions of the available quiz as an evaluation stage to measure their learning mastery. It was different with the non pbl based e-module used in control class which was not equipped with stages of learning so it cannot lead students to learn independently.

4. Conclusion
The harmonic oscillation e-module based on pbl which have been developed in this study have been appropriately validated by the validators, teachers and students with a total average of 87.53%. This result was supported by the result of experiment step in the study shown that the developed e-module could be worthy applied in learning physics. The $t_{\text{p}}$ and effect size tests using d’Cohen identified that the developed e-module would be used and provided medium size contribution in improving hots of senior high school.

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