Development of TPACK based-physics learning media using macro VBA to enhance critical thinking skills

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Abstract. We developed a TPACK-based physics learning media. This development was using 4D methods. Researchers analysed the need for learning media that can improve students’ critical thinking skills with technological offerings. This research took place in SMA ABBS Surakarta. The research subjects were three senior high school physics teachers and fifty-one students. We observed the facilities of the school then concluded that the facilities supported TPACK based learning activity. We also gave the questionnaire to teachers about the learning activity. The data gathering was carried out using observation rubric, students’ worksheets, presentation scoring rubrics, report scoring rubrics, and two tiers multiple-choice test instrument on critical thinking skills. Two lecturers, two physics teachers, and two peer reviewers validated the media. Then it tried out in the small group. In the big group, the media is proven could develop critical thinking skills with the difference between pre-test and post-test results were significant.

1. Introduction

In industrial revolution 4.0 era, students need to be prepared with 21st century skills, i.e., creative thinking, problem-solving, critical thinking, communication, and cooperative as well as ICT-literate, so they must be able to adapt flexibly to changing situations, think independently, work competently with the information, be sociable, work independently, think critically, possess internal requirement and ability to self-improvement [1-3]. But students in Indonesia actually lag behind in some of those aspects such as critical thinking and problem solving indicated in the PISA test. According to the results of the 2015 PISA test, Indonesia increased the rank even though it was still at the lower level [4]. Students in Indonesia need to be familiar with PISA questions that require critical thinking skills. The Indonesian Ministry of Education and Culture familiarizes students with questions that require higher-order thinking skills (HOTS), including the National Examination which inserts HOTS items. Critical thinking ability is one of the characteristics of HOTS [5].

People who think critically are people who do everything with a clear reason and purpose. He can also find solutions to the problems he faces. Critical thinking can be taught to students through various learning media, models, and methods [6].

Research description of students' needs for learning to develop HOTS especially critical thinking skills has been done [7]. Instruments for measuring HOTS with two-tiers multiple-choice instruments that had been widely used [8]. The important factor of learning physics is the student will be motivated if learning activity is content-based, meaningful, and provides the learning facilities so the knowledge is useful [3]. There are many studies that are related to the knowledge of material content that is
applicable to everyday life, combined with pedagogic knowledge that can provide learning stimuli that are interesting and easy for students to understand the material in Technological, Pedagogical, and Content Knowledge (TPACK) based learning [9-10]. Physics learning media must contain applications in daily life, according to the characteristics of learners and technology-based to the digital face of the era in the 4.0 industrial revolution [12]. In the 21st century, there are important components of education, i.e. science, technology, engineering, and mathematics (STEM). In a physics learning activity, mathematical skills can be integrated into the data processing of tables and graphs in the virtual lab [12]. This is an application of ICT use in the classroom.

Learning with ICT is a demand today, besides it makes it easy to convey science concepts but also provides learning motivation to students. The study of 100 students in the Malaysian Tamil school stated that 90.2% of respondents agreed that learning with ICT motivated them [13]. Learning science is often constrained by difficult material problems or expensive lab materials, even though it needs to provide learning experiences to students, this can be overcome by simple simulations using Excel spreadsheets [14-16].

The use of excel spreadsheets will be more dynamic and interactive with the development of Visual Basic for Application (VBA) or more popularly termed macros used in Microsoft Office applications, including Microsoft Office Excel [16]. The development of media learning physics using VBA will maximize the potential of school and physics teachers. The school already has many learning support facilities such as LCD projectors, but their use is not maximized to support learning. Similarly, physics teachers have been provided with material about the media of physics learning in university but have not been used in classroom learning when teaching. That's why efforts are needed to bring these two potentials together so that classroom learning is more effective and interesting [17].

In this study, it was explained about the needs of students for HOTS-based learning media that were especially helpful in critical thinking skills. The data from the TPACK based learning media with VBA.

2. Methods
This study involved fifty-one students as samples and three physics teachers as research subjects in Surakarta ABBS High School. Students are given critical thinking skills-based questions in the form of two-tier multiple choice along with a needs analysis questionnaire. The teacher is given a questionnaire of needs analysis and interviews.

These data were used as the foundation to develop the physics learning media by VBA. Development was done by using Define, Design, Develop, and Disseminate (4D) methods. Then the effectiveness in increasing critical thinking skills was examined using pretest-posttest design. Based on the design, Figure 1 express the procedure to develop the media.

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Figure 1. The procedure to develop the media
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The data are processed and analysed with the following steps: The first step is to tabulate data to facilitate reading data categorization based on frequency, the second step is to analyse quantitative
data to find the effectiveness of the learning media, and the third step is to draw conclusions of the interpretation from the data analysed.

3. Result and Discussion

3.1. Product Validity

The background of the experts engaged are listed in Table 1 below to show the coverage of expertise for the entire domain (target learners, media, concept). The lecturers are the Ph.D. holders in Universitas Sebelas Maret. The teachers are excellent teachers, they graduated with honors from Universitas Sebelas Maret, they teach Olympiad of physics, astronomy, and geosciences. The peer reviewers are the student of pascasarjana in Universitas Sebelas Maret

| Experts’ Title          | Institution                      | Expertise                                      |
|-------------------------|----------------------------------|------------------------------------------------|
| Lecturer (E1)           | Universitas Sebelas Maret        | Physics Learning Media, Physics Education, TPACK |
| Lecturer (E2)           | Universitas Sebelas Maret        | Computational Physics, Theoretical Physics     |
| Peer Reviewer (E3)      | Universitas Sebelas Maret        | Development of Assessment Instrument           |
| Peer Reviewer (E4)      | Universitas Sebelas Maret        | Development of physics module                  |
| Physics Teacher (E5)    | SMA ABBs Surakarta               | Physics Education                              |
| Physics Teacher (E6)    | SMA ABBs Surakarta               | Physics Education                              |

Table 2 shows the presentation of the experts’ scores in the percentage calculation method. The total score is 91.5% so this media can be used in physics learning with the purposes to enhance the critical thinking and scientific attitude.

| Items                                    | E1 | E2 | E3 | E4 | E5 | E6 | Percentage |
|------------------------------------------|----|----|----|----|----|----|------------|
| Suitable for Student                     | 1  | 0  | 1  | 1  | 1  | 1  | 83%        |
| Can be implemented perfectly             | 0  | 1  | 1  | 1  | 1  | 1  | 83%        |
| Can enhance critical thinking            | 1  | 1  | 1  | 1  | 1  | 1  | 100%       |
| Can enhance scientific attitude          | 1  | 1  | 1  | 1  | 1  | 1  | 100%       |
| Total Score                              | 3  | 3  | 4  | 4  | 4  | 4  | 91.5%      |

This media is tried out to the small group of five students to know the usability and to get the suggestion. Table 3 shows the student judgment in the small group. The Validators and students in the small group gave the suggestion about to make better the display of the program, to decrease the numeric calculation, to give the interpretation of the physics meaning of the numeric calculation. Then we made the media better as the suggestions. We decreased the display of numeric to strengthen the physics concept and made the media more interesting to try out to the big group.

| Items                          | Judgment                      |
|--------------------------------|-------------------------------|
| Content                        | Based on curriculum           |
| Display                        | Applicable in daily activity  |
| Language interactions          | So many numeric               |
| Experiment and exercise        | Good                          |

The results of the questionnaire and interviews with physics teachers stated that it was usual to apply animation-based learning that indicated that supporting facilities were available. But only a physics teacher that used to introduce HOTS to students. The three physics teachers also do not know the concept of TPACK. Based on all information and data shows that students need learning that familiarizes them with critical thinking, which is also supported by school facilities. Because of it, we
did the research by developing physics learning media using the visual basic for application as shown in figure 2. By this media, students did the learning activities that could develop their critical thinking.

![Virtual Physics Laboratory to Observe Parabolic Motion](image)

**Figure 2.** The Screen shoot of the physics learning media

The indicators of critical thinking, which was arranged by Anderson and Krathwohl are analyzing (differentiating, organizing, attributing), evaluating (checking, criticizing, judging) and creating (formulating, planning, producing) included in the goal of the learning activity [19]. Table 4 shows the relationship pattern between media, learning activities, and indicators of critical thinking.

| Scientific Session in Media | Learning Activity | Indicators of Competency Achievement | Indicators of Critical-Thinking |
|-----------------------------|-------------------|--------------------------------------|--------------------------------|
| Observe Apperception        | Observe video and picture | Adjust to the source | Analysing |
| Ask Simulation              | Ask the terms and quantities | Ask and answer questions | Interpret the term |
| Try Experiment, Theory and Evaluation | Do the experiment | Determine an action | Analyze the argument |
| Reasoning                   | Analyze the comparison data | Evaluate and generalize | Evaluate |
| Communicate -               | Present the report of experiment | Consider conclusions | Creating |

| Criteria                                | Score |
|-----------------------------------------|-------|
| No answer and reason, or answer and reason are wrong | 0     |
| Wrong answer-right reason                | 1     |
| Right answer-wrong reason                 | 2     |
| Right answer-right reason                 | 3     |

3.2. Product Effectiveness

The assessment to collect data of students' ability to understand HOTS with a two-tier multiple-choice instrument. The scoring standards instrument is shown in the following Table 5.

**Table 5.** The scoring on two-tier multiple choice

The results of the pre-test and post-test were analyzed to determine the level of requirements critical thinking skills of students specified are excellent, good, enough, and poor. This category level
is used to show the result of pre-test and post-test in table 6. Table 6 shows there are still many
students who were not used to answering HOTS questions. The last step was to give the post-test to
know the effect of the media. Table 4 shows that the average score increased from 32.57 at pretest
results became 59.45 and there is no student in poor category at post-test results. The category also
changed from enough to become good. So, this media can be shared with the other school.

Table 6. HOTS test results

| Interval Score | Category   | Pre test | Post-test |
|----------------|------------|----------|-----------|
|                |            | Frequency| Percentage| Frequency| Percentage |
| 100-76         | Excellent  | 4        | 7.84      | 11        | 21.57      |
| 75-51          | Good       | 6        | 11.76     | 31        | 60.78      |
| 50-26          | Enough     | 16       | 31.37     | 16        | 31.37      |
| 25-1           | Poor       | 24       | 47.06     | 0         | 0          |
| Sum            |            | 51       | 100       | 51        | 100        |

The pre-test and post-test results were not normal distribution in the calculation of Kolmogorov-
Smirnov, so we used Levene’s test for homogeneity test. We got W = 3.38 and F = 4.04 so these data
are homogeneity. Then we calculated these data by Wilcoxon test and we got t<sub>1</sub> = 212 and t<sub>2</sub> = 466, so we
conclude there was a different variance. The pre-test and post-test results gave the information that the
media could develop students’ critical thinking skills with N-gain score is 0.4 (medium).

3.3. Students’ Responses
The results of the student questionnaire are shown in the following Table 7.

Table 7. Results of questionnaire analysis of student needs

| Criteria                        | Frequency |
|---------------------------------|-----------|
| Exercise of HOTS                | 43        |
| Contextual Learning             | 43        |
| Virtual Experiment              | 36        |
| Learning Media which is interesting | 30        |

Table 7 analyzed the student Needs of 51 students in this research. The results of questionnaires
and interviews with students reinforce that students really need learning that can develop their critical
thinking skills. Students need to prepare themselves to face national examination questions that
contain HOTS questions. This media is suitable for student needs, so it can be used for other schools.

4. Conclusion
Critical thinking skills is part of HOTS which has been proclaimed by the government to be applied in
the National Examination. But in practice, many students are not familiar with HOTS type problems,
so they experience difficulties in terms of analysis. This research showed that teachers and students in
ABBS Surakarta High School need learning activity to develop critical thinking skills. With the
support of existing facilities, learning activity with developing critical thinking skills can be presented
in a learning media that present the application of physics in daily life, which is called a TPACK,
based learning media. The results of the questionnaire stated that needed TPACK based physics
learning media. The media was developed, validated and tried in the small group before trying in the
big group. The result of the pre-test and post-test with TTMC instrument test showed that the media
could develop the students’ critical thinking skills. The media could be used to the other school to help
the students develop their critical thinking skills.

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