TPACK and Augmented Reality in Kinematics Practicum Module: Forming HOTS Physics Education Students

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Abstract. High Order Thinking Skills (HOTS) are needed to support 21st-century skills. Students are required to think critically in overcoming a problem. HOTS can be trained through the lab activities. The method used in this research is research and development (R&D) with a Dick & Carey approach. This article described the implementation of TPACK and augmented reality in the kinematics practicum module to forming HOTS for physics education students. This practicum module has implemented integrated technology, pedagogy, content, and knowledge. The addition of augmented reality media makes it easier for students to understand practicum steps and forms of phenomena related to practicum. The module was declared feasible in terms of material, media, and pedagogical concepts in forming the HOTS abilities of physics education students. The stages of HOTS formation in the module present a video of real-world phenomena as a stimulus, and students are asked to answer the pre-test related to the stimulus video, students are asked to create observation tables according to the steps in the practicum, students are asked to process data, and analyze concepts regarding practical material which is related.

1. Introduction
The development of education in the 21st century requires logical, analytical, critical, and innovative thinking [1]. The 21st century competence requires higher-order thinking skills known as 4C skills, including communication, collaboration, critical thinking, and problem-solving, as well as being creative and innovative [2]. Physics education students must be able to develop HOTS to understand physics concepts [3]. HOTS can be trained through lab activities [4].

The model for implementation of the physics practicum that has been carried out is the cookbook model, which is all things related to the practicum, from practicum instructions to tools and materials that have been provided by module practicum. This model has a weakness; the enthusiasm for exploring student knowledge is low [5]. Problem-based learning is a model that can help students forming HOTS to solve problems and bridge the gap between theory and practice [6]. Problem-oriented students ensure that they find relevant solutions, this is because they practice finding solutions independently without any help from lecturer or lab assistant [7].

The practicum module should support the developments and demands of the 21st century, namely the integration of technology in pedagogy and content [8]. The practicum module supporting the development of the 21st century has three major components, including content, technology, and pedagogy, as well as the relationship between the components represented as PCK (Pedagogical Content Knowledge), TCK (Technological Content Knowledge), TPK (Technological Pedagogic) and TPCK (Technological Pedagogical and Content Knowledge) [9]. Material-oriented learning media and learning objectives that utilize technology must be designed within the TPACK framework [10].
The application of AR technology in education has the potential to increase the effectiveness of education and academic training by delivering real-time information enriched with 3D media [11]. In practicum activities, AR is packaged in the form of a 3-5 minute stimulus video related to practicum topics so that students can get an overview of the practicum that will be performed and can improve students' ability to work in the laboratory [12] [13]. The addition of AR media to the practicum module can be used as a learning medium with good quality and feasible as teaching material in physics learning. The use of AR media in the form of videos in experimental laboratory activities can improve the development of students' laboratory skills. In addition, AR videos can help students complete practical activities in a shorter time, thus providing more time to discuss experimental results [14]. AR videos are placed on the initial stage in the form of physical phenomena related to the concepts to be practiced, at the practical stage in the form of how to assemble and use tools. In addition, the AR video can help students complete lab activities in a shorter amount of time, giving them more time to discuss the results of the experiment [15].

Based on the above description, this article presented the results of research into the development of TPACK and augmented reality in the kinematics practicum module to forming HOTS physics education students.

2. Methods

2.1. Research design
This article is the result of research and development of TPACK and augmented reality in the kinematics practicum module using the Dick & Carey approach. In order that this book can forming HOTS physics education students, the R&D process is carried out in the following steps:

2.1.1. Identify learning goals
Identifying learning objectives that refer to the Course Learning Outcomes of the fundamental physics course module Jakarta State University.

2.1.2. Conduct a learning analysis
Identify skills, competencies, and concepts that must be formed in fundamental physics practicum. Learning analysis is carried out by formulating learning objectives in the affective, cognitive, and psychomotor fields.

2.1.3. Analyze learners and context
Analyzing the prerequisite abilities and affective, cognitive, and psychomotor abilities that will be formed in the fundamental physics practicum. Analyze the form of fundamental physics practicum based on the equipment available in the laboratory.

2.1.4. Write performance objective
Formulate learning objectives for each fundamental physics practicum topic based on the equipment available in the laboratory. The formulation of learning objectives describes the implementation of TPACK in practicum to form HOTS for physics education students.

2.1.5. Develop assessment instrument
Develop an instrument for measuring learning objectives for each developed practicum module.

2.1.6. Develop instructional strategy
Develop a practicum strategy that implements TPACK in forming HOTS for physics education students.

2.1.7. Develop and select instructional materials
Develop practical modules that are relevant to the learning objectives of fundamental physics and the equipment available in the laboratory. The module is prepared by implementing TPACK and the stages to form HOTS for Physics Education students.

2.1.8. Design and conduct formative evaluation
Develop a formative evaluation instrument for fundamental physics module products that implement TPACK with the stages of forming HOTS for physics education students. Formative evaluation was carried out for the feasibility of the material, the feasibility of the media, and the feasibility of learning. Formative evaluation instruments are arranged on a continuum scale of 4.
2.1.9. Revise module
Make improvements to the practicum module which, according to the expert is not feasible. Revisions are carried out until the expert states that the practicum module is suitable to be used to form HOTS for physics education students.

2.2. Instrumentation research
The instrument used was a questionnaire to test the feasibility of the research results on the development of the fundamental physics practicum module. The questionnaire used is a questionnaire for the feasibility test of the material, a questionnaire for the media feasibility test, a questionnaire for the pedagogical feasibility test.

2.2.1. Physics concept feasibility test
2.2.1.1. The suitability of the practicum material with the fundamental physics course syllabus, consisting of (a) the suitability of the practicum material with fundamental physics concepts; (b) the suitability of the practicum material with learning outcomes for fundamental physics courses; (c) the suitability of practicum activities with the description of fundamental physics courses.

2.2.1.2. The suitability of practicum activities with the learning outcomes of fundamental physics courses, consisting of (a) the suitability of the practicum objectives with the fundamental physics syllabus; (b) the suitability of the practicum objectives with the learning outcomes of fundamental physics courses; (c) the suitability of practicum activities with the established HOTS.

2.2.1.3. Feasibility of the preparation of the concept of physics, consisting of (a) the accuracy of the stages in the preparation of the concept of physics; (b) the relevance of the stages in the practicum module with the physics concepts learned by students; (c) the relevance of the practicum stages with the formation of student scientific literacy; (d) the relevance of the practicum stages with the established HOTS.

2.2.1.4. The feasibility of the language in the practicum module, consists of (a) the accuracy of the language used; (b) ease of understanding the language used; (c) the effectiveness of sentences in supporting scientific literacy.

2.2.2. Media feasibility test
2.2.2.1. Display of the practicum module, consisting of (a) proportional cover layout (text and image layout); (b) clarity of module title; (c) suitability of font type selection and cover font size (font type and numbers); (d) proportional layout of module content (layout of text and images); (e) the suitability of the selection of the font type and the font size of the content of the module (font type and numbers); (f) the relevance of the instructions for use with the contents of the practicum module; (g) the effectiveness of user-friendly instructions for use.

2.2.2.2. The practicum module media, consists of (a) the relevance of augmented reality-based media to the stages in the practicum module; (b) the quality of augmented reality-based media is clearly presented; (c) duration of augmented reality-based media; (d) interactive augmented reality-based media; (e) the completeness of augmented reality-based media to support independent study students.

2.2.3. Pedagogical feasibility test
2.2.3.1. The practicum stages, consist of (a) orientation students to problems; (b) organize students; (c) guide individual or group investigations; (c) develop and present the work; (d) analyze and evaluate the problem solving process.

2.2.3.2. Implementation of TPACK, consisting of (a) implementation of technological knowledge from the material practiced; (b) implementation of pedagogical knowledge for the practicum stage; (c) implementation of content knowledge for the practicum stage; (d) implementation of technological knowledge and pedagogy for the presented augmented reality media; (e) implementation of technology knowledge and content for stimulus videos and applications in each practicum module; (f) implementation of pedagogical knowledge and content for the formation of student HOTS at each stage of the practicum; (g) implementation of TPACK in the formation of HOTS in each practicum module;
(h) implementation of TPACK in the formation of scientific literacy in activities in the practicum module.

2.3. Data is analyzed

The expert assessment questionnaire on the practicum module produces research data. Experts provide an assessment using a continuum scale of 4 on each indicator of each aspect of the assessment.

**Table 1. Continuous Scale**

| No | Alternative Answer | Score |
|----|--------------------|-------|
| 1. | Very Good          | 4     |
| 2. | Good               | 3     |
| 3. | Bad                | 2     |
| 4. | Very Bad           | 1     |

The interpretation of the assessment results is calculated using the technique of determining the score range and score presentation.

\[
\text{IS} = \frac{\text{maximum scale} - \text{minimum scale}}{\text{number of scale}}
\]

\[
\text{Scor percentage} = \frac{\sum \text{earning score}}{\sum \text{maximum score}} \times 100\%
\]

The result of obtaining the percentage score is then measured using the interpretation of the score and the percentage score for the continuum scale, as shown in Table 2.

**Table 2. Score Interpretation**

| Scale      | Score Percentage | Interpretation     |
|------------|------------------|-------------------|
| 1 ≤ IS < 1,75 | 25% ≤ SP < 43,8% | Very Not Feasible |
| 1,75 ≤ IS < 2,50 | 43,8% ≤ SP < 62,5% | Not Feasible      |
| 2,50 ≤ IS < 3,25. | 62,5% ≤ SP < 81,3% | Feasible          |
| 3,25 ≤ IS < 4,00 | 81,3% ≤ SP < 100% | Very Feasible     |

3. Result and discussion

3.1. Product

3.1.1. The pre-stage of the practicum module

This section consists of cover, preface, laboratory rules, list of practicum activities, and initial questions in physical phenomena videos related to practical materials integrated with AR applications.

3.1.2. The main stage of the practicum module

This stage consists of practicum objectives that students must achieve, tools and materials needed for practicum activities, brief theoretical material related to practicum material, work steps equipped with video assembling tools and materials, observation tables, data processing, and concept analysis. Video assembly tools integrated with AR applications.

3.1.3. The post-stage of the practicum module

In this stage, there are post practicum assignments that students must do to measure student knowledge after doing a practicum.

3.1.4. AR application development

In the practicum module, several photos with unique markers are integrated with videos to support practicum activities, such as videos of physical phenomena at the beginning and videos of assembling tools and materials in the main section. The videos contained in this practicum module can be displayed using an augmented reality application. This augmented reality application was developed with the Unity software and installed on android with a minimum android version of 4.1 Jelly Bean. The kinematics practicum module has several menu sections in the augmented reality application, namely Scan, Hint, About, and Exit.
This kinematics practicum module develops HOTS, which consists of 3 categories, namely analyzing (C4), evaluating (C5), and creating (C6). These three categories can be seen in the following table.

| No. | HOTS indicators | Part of the module | Information |
|-----|----------------|-------------------|-------------|
| 1.  | Analyze (C4)   | **Main stage**    | Students can analyze the observation table into a meaningful graph.            |
|     |                | Observation table | Students can interpret graphs following physics concepts.                     |
|     |                | Data processing   | Through questions in data processing and concept analysis, students can evaluate a situation based on the graphs that have been obtained. |
| 2.  | Evaluate (C5)  | **Main stage**    | Students can develop concepts based on data observations and graphs.          |
|     |                | Pre-processing    | Students can create mathematical equations from the concepts and graphs they get from practical activities. |
| 3.  | Create (C6)    | **Main stage**    | Students can create problem-solving by combining concepts obtained through the practicum. |

3.2. Description of validation results

The development of this practicum module has passed the validation test by media experts, material experts, and pedagogical experts.

3.2.1. Physics concept feasibility test

As shown in Table 4, the results of material expert validation for this research product obtained an average value of 97%. These results indicate that the kinematics practicum module equipped with augmented reality technology to forming HOTS for physics students is considered very good and feasible to use.
3.2.2. Media feasibility test

As shown in Figure 3, the results of media expert validation for this research product obtained an average value of 94%. These results indicate that the kinematics practicum module equipped with augmented reality technology to forming HOTS for physics students is considered very good and feasible to use.

![Media feasibility test](image)

**Figure 3.** Graphics of formative evaluation results for media feasibility

3.2.3. Pedagogical feasibility test

As shown in Figure 4, the results of pedagogical expert validation for this research product obtained an average value of 94%. These results indicate that the kinematics practicum module equipped with augmented reality technology to forming HOTS for physics students is considered very good and feasible to use.

![Pedagogical feasibility test](image)

**Figure 4.** Graphics of formative evaluation results for pedagogical feasibility

3.3. Discussion

The development of the 21st century has brought education to be more advanced, as seen from the many learning media equipped with technology [1]. A kinematics practicum module has been produced by utilizing augmented reality to form HOTS for physics education students. This kinematics practicum module was developed using a problem-based learning model. The implementation of TPACK in collaborating between problem-based learning models and media-based augmented reality technology can form the stages of training HOTS through practical activities [9]. With the addition of videos about real-world phenomena, students identify and solve physics problems in everyday life [12]. The addition of videos on instructions for assembling tools and materials, helps students practicum more quickly and independently [15].

4. Conclusion

The implementation of TPACK and augmented reality-based media in the kinematics practicum module is declared feasible and can be used in learning to form HOTS for physics education students. The use of augmented reality technology-based media is very supportive of student independence in practicum activities.
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Reference

[1] Hilton M 2010 Exploring the Intersection of Science Education and 21st Century Skills: A Workshop Summary (Washington DC: The National Academies Press)

[2] Prihadi E 2018 Pengembangan Keterampilan 4C Melalui Metode Poster Comment pada Mata Pelajaran PAI a dan Budi Pekerti (Penelitian di SMA Negeri 26 Bandung) Jurnal Pendidikan Islam Rabbani

[3] Dosinaeng W B N Letson S I and Lakapu M 2019 Kemampuan Mahasiswa dalam Menyelesaikan Masalah Matematis Berorientasi HOTS JNPM (Jurnal Nasional Pendidikan Matematika) pp 250-264

[4] Malik A 2018 Pengembangan Higher Order Thinking Laboratory (Hot-Lab) Untuk Meningkatkan Transferable Skills Mahasiswa Calon Guru Fisika Doctoral dissertation Universitas Pendidikan Indonesia

[5] Subali B 2010 Penerapan Model Praktikum Problem Solving Laboratory Sebagai Upaya Untuk Memperbaiki Kualitas Pelaksanaan Praktikum Fisika Dasar Jurnal Pendidikan Fisika Indonesia 6, pp 90-97

[6] Choi S Y 2014 Effects of Problem-Based Learning vs. Traditional Lecture on Korean Nursing Students’ Critical Thinking, Problem-Solving, and Self-Directed Learning Nurse Education Today p. 52–56

[7] Sumarmi 2012 Model-model Pembelajaran Geografi (Yogyakarta: Aditya Media)

[8] Sholihah M and Yuliati L 2016 Peranan TPACK Terhadap Kemampuan Menyusun Perangkat Pembelajaran Calon Guru Fisika Dalam Pembelajaran Post-Pack Jurnal Pendidikan: Teori, Penelitian, dan Pengembangan pp 144-153

[9] Koehler M J and Mishra P 2014 What Is Technological Pedagogical Content Knowledge? Contemporary Issues in Technology and Teacher Education

[10] Nevrita N, Nasikin N and Amelia T 2020 Analisis Kompetensi TPACK Guru Melalui Media Pembelajaran Biologi SMA Jurnal Pendidikan Sains Indonesia (Indonesian Journal of Science Education) pp 203-217

[11] Kangon L 2012 Augmented reality in education and training TechTrends pp 13-20

[12] Bakri F, Wulandari S and Muliyati D 2020 Students Worksheet With Augmented Reality Media: Scaffolding Higher Order Thinking Skills Of High School Students On Uniform Accelerated Motion Topic Journal of Physics: Conference Series

[13] Nadelson L S, Scaggs J, Sheffield C and McDougal O M 2015 Integration of video-based demonstrations to prepare students for the organic chemistry laboratory Journal of Science Education and Technology 24(4) pp 476-483

[14] Bakri F, Pratiwi S and Muliyati D 2019 Video-enriched Worksheet Based on Augmented Reality Technology: The Heat Experiment is Easier AIP Conference Proceedings 2169 p 020010

[15] Bakri F, Ervina E and Muliyati D 2019 Practice The Higher-Order Thinking Skillsin Optic Topic Through Physics Worksheetequipped With Augmented Reality AIP Conference Proceedings