The implementation of project-based learning to enhance the technological-content-knowledge for pre-service physics teacher in ICT courses

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Abstract. The pre-service teachers must be prepared to integrate technology into classroom learning. This technical capability must be adapted to the material to be taught. Material for physics has a different character, especially in the selection of media. Media on one material is not necessarily suitable for other materials. The pre-service physics teacher must have the ability to analyze content and find appropriate technology in making media. This study was aimed to implement project learning for ICT based learning in physics courses for a pre-service physics teacher. This research can be used to see how significant Technological-Content-Knowledge (TCK) pre-service physics teacher is through Project-Based Learning (PjBL). This PjBL is applied to the undergraduate pre-service physics teacher level. All students participated in full lectures for 16 meetings, which were combined between the explanation of topic matter guidance and progress report. The lecturer will give feedback to all students. The data taken is the initial ability of students, evaluation of progress reports, and project output of each student. The results obtained were students' pre-service physics teacher had a portfolio and an increase in TCK pre-service physics teachers were initially students were still having difficulties in applying technology with physics content.

1. Introduction

The ICT (Information and Communication Technology) integration in various aspects of education can improve a variety of student achievements. Research on increasing digital literacy shows that using ICT can contribute to increasing the performance of learning outcomes [1]. This increase comes from fast access to information, so students easily search for all things related to learning topics, including problems and solutions. The use of technology can provide self-directed learning [2-3]. Elearning, as a technology product, can increase the effectiveness of student learning [4]. The main thing so that we achieve the goal of integrating various forms of ICT products is to improve the skill of teachers to apply technology in every learning activity.

Training of teachers' abilities in improving skills using various technology products needs to be designed in stages. It needs to be started when pre-service teacher education. This implementation is a responsibility and cooperation between universities that provide teacher education, schools, government, and related institutions so that professional teachers with the ability to apply technology in learning can be realized. Many forms of training, whether related to technology or related to pedagogical concepts, are all summarized in the framework concept of the TPACK (Technological...
Pedagogical Content Knowledge). TPACK is the basis that can be used to integrate technology into science lessons [5]. One of the reviews recommends design thinking and technological pedagogical engineering knowledge for training for increasing TPACK science teachers [6]. The types and skills on the part of TPACK are carried out according to their needs and indeed must be based on indicator analysis.

The need analysis and objective indicators can be summarized well through the design and syntax of the right learning. If technology is available, there is a need to provide professional development to deepen teacher knowledge and pedagogical content to teach with technology. This paper describes how to enhance Technological-Content-Knowledge (TCK) specifically for prospective physics teachers by using project-based learning (PjBL) design. The PjBL can increase motivation [7] and student performance to prepare the pre-service physics teacher graduates for professional practice [8].

In this era of Industry 4.0, physics education researchers and teachers must be made, with professional development and research-based teaching resources that are easily accessible. The goal is, of course, to make technology as a means to provide better physics teaching. The experience of physics learning can be made possible through the virtual environment [9], online learning [10], or new software to visualizing physics concept [11], or special-purpose applets, e.g., PhET [12]. In the previous step of this study, we develop the model and media learning to enhance the technological-knowledge of pre-service teachers. This paper describes how to condition pre-service physics teachers to choose technology-based media that is following the character of physics learning material designed in class. After being able to choose the right media, the next step is to make and use it. These abilities are trained in courses with a PjBL approach.

2. Methods

The entire set of studies was carried out using the ADDIE approach stage using the ADDIE (Analyze, Design, Develop, Implement, and Evaluate) approach [13]. In the analysis phase, a preliminary study was conducted regarding the possibilities and needs of a PjBL curriculum in ICT-based Physics Learning courses. These results are then used in designing applications for physics education students with output in the form of ICT products to explain related physics concepts. It is delivered in the form of a teaching plan. It was developed into a learning device equipped with various supporting media.

Furthermore, in the development stage, this learning device is assessed by peers to be then improved. After going through a cycle between assessment-revisions, learning devices are tested on students. The implementation phase was held for 16 meetings. Evaluation is carried out for each stage of ADDIE activities.

Previous research has described how to increase part of TPACK through delivering thermodynamics concepts [14], didactical reconstructions [15], and organizing subject contents [16-17]. In this paper, we enhanced TCK through a specific course about multimedia ICT-based. The main point in the ICT-based Physics Learning curriculum analysis stage is the ability of physics education students to design innovative, creative learning models and strategies, and present the active participation of all students during teaching practice. Physics education students as future Physics teachers need the right learning environment to be able to achieve this. Today's students, on average, are born Generation-Z with the characteristics of caring for technology and have very high self-confidence to participate in studying ICT developments. With this assumption, the problem that remains is how to condition the learning environment that supports professionally the improvement of ICT integration capabilities in physics learning.

These ICT improvements are also accompanied by content knowledge enhancement. At the beginning of the lectures, students are required to choose the topic of high school physics material. Furthermore, they must develop a matrix related to the needs and types of ICT integration. They attended the lecture according to the PjBL design. Next, they create media that is by the character of the topic of physics. They must be able to show the academic arguments as the answer to why the chosen media and software are appropriate for a specific topic. The argument must be based on related studies. Each student must report progress regularly, product development and performance, and end
of the article as a final report. This implementation has included elements of improving technology and content knowledge from pre-service physics teachers simultaneously and interrelated.

3. Results and Discussions

3.1. The Peer Evaluation Results
Table 1 shows the results of the assessment by peers in this PjBL design. The assessment was carried out in the form of suggestions as to the basis for improvement.

| Learning Syntax | Media Support | Revisions |
|-----------------|---------------|-----------|
| **Peer 1** | The preparation of indicator matrices and material is grouped and sorted by pedagogical topics. | During training and product manufacturing practices, more choices were given. | 1. The modifications to grouping ICT for planning, teaching, and assessment.  
2. More software choices are given. |
| **Peer 2** | Examples of material that are highly related to specific software are given. | A tutorial is given when using the software. | 1. Examples of highly related material topics accompany each software usage training.  
2. Tutorials are provided in written and video forms. |

Based on the assessment questionnaire, it was found that the revised learning device had reached 88% of the maximum value so that it could be used to carry out learning trials. Assessments based on questionnaires are in Table 2. It shows that the PjBL devices produced are in the excellent category.

| Aspect       | Peer 1 | Peer 2 | Average |
|--------------|--------|--------|---------|
| Learning Syntax | 85%    | 87%    | 86%     |
| Media Support  | 92%    | 88%    | 90%     |
| **Average**  |        |        | 88%     |

3.2. Results of Class Implementation
Figure 1 shows the pattern of pre-service physics teacher interest in developing media based on the topic of the material chosen. Every student has the freedom to choose their research topic to do.
The next step after choosing a research topic, students then group according to their interests. Each group then drafted an ICT media created and used in the design of high school physics learning, followed by software selection, shown in Table 3. The selection of topics and software must be based on previous research. The final report on the manufacture and use of media is packaged in the form of scientific articles.

In the final report, the pre-service physics teacher must be able to write the analysis of the selected material. Every media produced must also be equipped with a student worksheet. The aim is that pre-service physics teachers are accustomed to designing learning that is student-oriented.

| Group | Title of ICT-based Media Learning | Topic | Software and Media Support |
|-------|-----------------------------------|-------|---------------------------|
| 1     | The development of Evaluation of Physics Learning at the Concept of Temperature and Heat of Middle School with Quizmaker Media | Thermodynamics | Quizmaker, Ms. Word. |
| 2     | The Use of VR in Solar System Material on Student Learning Outcomes | Astrophysics | Unity, VR app. |
| 3     | Development of Powerpoint, iSpring, and Tracker Software-based Material Modules | Mechanics | Ms. PowerPoint, iSpring, Tracker, Ms. Word. |
| 4     | E-Learning with Problem Based Learning assisted by Moodle on Straight Motion Material | Mechanics | Moodle, iSpring, Ms. Word. |
| 5     | Interactive Video on Material For Rigid Equilibrium and Rotational Dynamics | Mechanics | VSDC, Ms. PowerPoint, Youtube. |
| 6     | The development of Momentum Material and Impulse Module based on Macromedia Flash | Mechanics | Macromedia Flash. |
| 7     | Joyful-Based Interactive Learning Video in Circular Motion Material by Utilizing Youtube Media | Mechanics | VSDC, Ms. PowerPoint, Youtube. |
| 8     | The development of Mobile Learning on Stationary Waves Material | Mechanics | Unity, Ms. PowerPoint. |
| 9     | Learning Development Based on Schoology on Rigid Equilibrium Material | Mechanics | Schoology, Ms. Word, Ms. PowerPoint. |
| 10    | The development of Science Books with Augmented Reality Technology to Enhance Critical Thinking Skills | Mechanics | 3D Pageflip, VSDC, Unity, AR app. |

Based on Table 3, there is a pattern of software selection based on the choice of ICT-based media development titles. In the selection of media to evaluate students can directly choose the test maker software specifically. Titles, with the purpose of a complete device such as e-learning, selected some software for each part.

The process of making media, pre-service physics teachers must analyze each component that appears. This component can be in the form of images, animations, videos, simulations, tests, augmented reality, virtual environments, and others. The lecturer checks the inputted content. This step is by the theoretical framework for improving TCK, namely (a) digital technology, (b) prospects for curricular reform, and (c) cognitive processes [18].
The use of ICT can improve teacher skills and increase learning resources that can be accessed by students. The use of ICT allows students to learn independently and encourage students to broaden their horizons. Precious interactive capabilities from ICT-mediated learning resources also motivate and involve weaker students and enable them to adjust learning speed. The use of ICT can train the competencies needed in this Industry 4.0 era, namely communication, collaborative, critical thinking, and innovation and creativity, so as not to close the possibility of project-based curriculum implementation can be mediated by ICT.

The use of other ICT, such as learning physics, is helping to convey concepts and explain physical phenomena. For this reason, physics teachers are required to have the ability to integrate ICT in the learning process because it becomes a primary need. Not only that, by integrating ICT in project-based learning, students are expected to be able to develop other skills, such as solving problems, thinking high-level, working together, and interactively. This goal can be achieved by implementing a project-based curriculum implementation for ICT-based physics learning. During the implementation, the researcher will evaluate to find out how much impact it has on the implementation of the applied curriculum and makes improvements so that the resulting curriculum remains by the expected learning objectives. Long-term research after the implementation of a project-based curriculum for ICT-based physics learning during prospective teacher education, followed by the implementation of Continuing Professional Development for in-service physics teachers.

4. Conclusions
Implementation of project-based learning in this study has been able to make students have increased knowledge both on technology and content simultaneously and accordingly. The pre-service physics teacher became to enhance the understanding in designing classroom learning with the integration of ICT-based media in it. The results of the physics teacher and its improvement are the results of the pre-service physics teacher. It can also be used to consider the training model within the TPACK framework during the in-service physics teacher.

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