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The Analysis of Pre-Service Student's Ability to Develop STEM-Based Learning Media Through Physics Learning Media Lectures

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Abstract: This study aims to analyze the ability of physics education teacher candidates to develop physics learning media in the form of teaching aids. The research method used is descriptive qualitative. This study was carried out a pre-service teacher in the 3rd semester who takes the physics learning media lectures at the physics education department. The sample of the study was code A class and code B class totaling 61 people using the saturated sampling technique. The instrument used is an observation sheet by the course lecturer. The indicators for assessing the instructional tool project in this research are 1) conceptual accuracy; 2) ease of use; 3) media aesthetics; 4) the emergence of STEM aspects; 5) environmentally friendly (Go-green) and the utilization of recycled materials. The study result showed that for class A, students' ability to create STEM-based teaching aids has an average value of 79.8, and using used materials is 79.8. Class B tends to understand the concepts of better teaching aids with an average score of 78.9, and the media used is easy to use at 78.7. Through this research, it can be concluded that students' abilities to develop STEM-based learning media have good criteria. In the implementation of the research, the lecture model was used through project-based learning with a STEM approach. The results of this study will provide implications for further research to measure student creativity and communication skills in the development of teaching aids such as physics learning media.

Keywords: Learning media, Pre-service student's ability, STEM

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INTRODUCTION

The function of national education is to develop abilities that shape the quality and civilization of the nation in the framework of education for the country's life. Meanwhile, the purpose of national education is to develop the potential of students to become human beings who are faithful, devoted to God Almighty, noble, healthy, knowledgeable, capable, creative, independent, democratic, and responsible citizens. The functions and objectives of national education are by UU No. 20/2003 on the National Education System. The law's mandate explains that education should produce intellectually intelligent people and develop their character. Professional teachers are needed and have a vital role in the success of national education goals (Parno et al., 2020). Education is an effort made so that children can have a happy life and their knowledge can be helpful for themselves and others. Education is an essential aspect because, in the 21st century, competition is increasingly fierce, requiring human resources to have good quality in various fields.

Physics is a discipline that investigates the characteristics of matter, energy, and phenomena that occur in objects in nature. Physics is one of the sciences that develops rapidly along with the development of science and technology. Technological advances facilitate the formation of creative and innovative elements in physics learning (Koponen & Nousiainen, 2019). In the physics learning process, students are expected to understand physics concepts theoretically and apply the scientific method to test and prove physics concepts derived from the theory (Khoshman et al., 2020; Irvani & Warliani, 2022). Physics learning rests on the specific realization of physics itself, which stems from efforts to get the truth cultured, namely systematic thinking through physics that remembers the nuances of humanity (Frågåt et al., 2021).

Physics Learning Media is a course that aims to equip students with knowledge and skills in designing and using effective learning media in the context of physics learning. Students will learn the basic concepts and principles in developing and using learning media in physics learning. They will understand the characteristics of effective learning media and how to choose media based on learning objectives. Students will learn various types of traditional learning media used in physics learning, such as textbooks, blackboards, graphs, diagrams, and teaching aids. They will learn how to design and use these media effectively to communicate physics concepts to students (An'nur et al., 2020).

Students will be introduced to digital learning media relevant to physics, such as computer simulations, learning videos, animations, and interactive software. They will learn about using and developing digital learning media that can improve students' understanding of abstract and complex physics concepts. In addition, students may also be given assignments or projects to design and develop creative and innovative physics learning media.

Creativity in choosing suitable learning media in physics learning is needed, including teaching aids (Wahyuni & Rosana, 2019). Media is a tool that has the function of conveying messages (Bovee, 1997). Learning media are physical means to convey learning content/materials such as books, movies, videos, etc. Learning media is a tool that functions and is used to convey learning messages. Students will obtain meaningful learning if all students get the same opportunity to gain manual and intellectual skills related to physics lessons. For this reason, adequate equipment and laboratory space are

needed to learn energy physics optimally. The reality is that the energy props in the laboratory still need to be completed. Implementing laboratory activities is still faced with various obstacles, such as incomplete sets of tools, tools, and materials that are not available, inadequate activity instructions, damaged laboratory equipment, and so on (Wahyuni & Rosana, 2019). Limited teaching aid facilities affect the physics learning process (Zulhelmi et al., 2023).

Simple Physics teaching aids/practices, also called homemade Physics tools, are tools that can be designed and made by yourself by utilizing tools/materials around the environment in a relatively short time and do not require special skills in the use of tools/materials/tools, can explain/show/prove the concepts or symptoms being studied, tools are more qualitative than quantitative provisions (Suprapto et al., 2019). One of the roles of props is to make abstract concepts more concrete (Parno et al., 2020).

Props are one of the learning media, which is a form of depiction of the mechanism of action of an object (Maghfiroh & Sucahyo, 2023). The definition of simple Physics teaching aids/practices, also called homemade Physics tools, is a tool that can be designed and made by yourself by utilizing tools/materials around our environment in a relatively short time and does not require special skills in the use of tools/materials/tools, can explain/show/prove the concepts or symptoms being studied, tools are more qualitative than quantitative provisions (Matsun et al., 2022).

Pro props will help make it easier for students to understand a concept. Props are tools or aids used to educate and convey material, either objects or behavior, to make it easier for students to understand (Espinosa et al., 2019; Hanif et al., 2019). Props are tools or aids used to educate and convey material, either objects or behavior, to make it easier for students to understand (Nousheen et al., 2020). Teaching aids in learning are one way to support the development of knowledge, skills, and basic needs for delivering material, concepts, and physics information (Sorge et al., 2019). Teaching aids can be used as learning media and channel messages that can stimulate students' thoughts, feelings, and desires to encourage the learning process in students (Varis et al., 2023).

Physics learning will be more meaningful if students actively observe, understand, and utilize natural phenomena in the surrounding environment. In the process, students are trained to have the ability to monitor and experiment, which is more emphasized on teaching the ability to think and scientific work. In addition, students are trained to conduct experiments by recognizing the equipment used in measurements in the laboratory and nature around students. With the support of their mathematical abilities, students are trained to develop the ability to think and reason by the principles, and this ability to think and reason is achieved through accurate data management, the truth of which is not in doubt (Dewantara et al., 2019).

Based on the facts in the previous lecture and the previous physics learning media course, there were several shortcomings in implementing and assessing the results of making student teaching aids. This was conveyed directly by students who had taken the course and responded to the lecture assessment through a questionnaire provided by SIMAK University. The results of the lecture evaluation were also carried out by the lecturer, who conducted a self-assessment of learning in the previous semester. The gaps in this study certainly provide helpful input for physics learning media courses further to improve the implementation and evaluation of student product results. This certainly offers continuous improvement to achieve the learning outcomes of physics learning media courses included in the semester learning plan (RPS). Based

on the RPS, one of the course outcomes is that students can design physics learning media tools as teaching aids that help students understand physics concepts.

Educational aids are organized based on the principle that the knowledge that exists in every human being is received or captured through the five senses (Khoshman et al., 2020). Teaching aids have a function to demonstrate events, activities, phenomena, or the mechanism of action of an object (Nurmiati, et al., 2021). The existence of teaching aids is intended to mobilize as many senses as possible to an object to facilitate perception.

In physics learning media lectures, students are directed to be able to make physics teaching aids on physics materials through Project Learning (PjBL) with the STEM (Science, Technology, Engineering, and Mathematics) approach. PjBL is a systematic learning model that engages students in learning essential knowledge and life skills through an extended inquiry process, authentic questioning, and careful design of products and activities. When learners are given projects in PjBL related to energy physics, they can improve their thinking skills. PjBL is based on thinking, imaging, and function, so it can train creative individuals who take responsibility for their learning (García-González et al., 2020). Meanwhile, STEM is applied through learning media teaching aids developed by students. The fundamental elements of science, technology, engineering, and mathematics (STEM) are the cornerstone for advancing cutting-edge technologies. While STEM-based education may initially focus solely on acquiring scientific knowledge within science, technology, engineering, and mathematics, it encompasses a broader scope (Haryadi & Pujiastuti, 2020). Students with a STEM education are anticipated to possess advanced technical skills and interpersonal qualities. Effective communication, collaboration, problem-solving, leadership, creativity, and various facets of the educational experience are all encompassed through engaging in active learning, as highlighted by (Parno et al., 2020).

Based on previous research, incorporating STEM education, especially the engineering component, into an elective technology course is valuable for students to develop essential skills for future endeavors, including design and collaboration (Nousheen et al., 2020). The adoption of STEM education has the potential to bring about innovation in the field of education, as indicated by (Sorge et al., 2019). The other research results show that both female and male students show a positive and happy response to the application of the STEM-based PjBL learning model in learning. Students feel so glad working in groups, so they desire that STEM-based PjBL learning can be reapplied to other materials in the future. Students argue that learning with this model is exciting and motivating and helps students understand the teaching material and form a creative attitude (Espinosa et al., 2019).

The physics material used in the development of teaching aids is limited to the material: 1) mechanics, 2) electricity and magnetism, 3) fluids, and 4) renewable energy. This material was chosen because, based on the results of the literature review, teaching aids that can be realized in the form of real media still have many innovations that can continue to be developed and selected based on the needs of students at school. Physics education students also interviewed physics teachers in their previous schools, so these four materials were chosen, which were limited in developing teaching aids. Based on the background above, the researchers analyzed students' ability to develop physics learning media in the form of teaching aids developed with the STEM approach through project-based learning.

METHOD

Research Design and Procedures

This study used an experiment method with descriptive qualitative. This research is intended to observe and obtain data and information on the ability of physics education students to develop physics learning media in the form of teaching aids. The learning model applied in lectures is project-based learning through the STEM (Science, Technology, and Engineering) approach. The learning steps through Project Based Learning through the STEM approach are carried out for six meetings with the following research procedures.

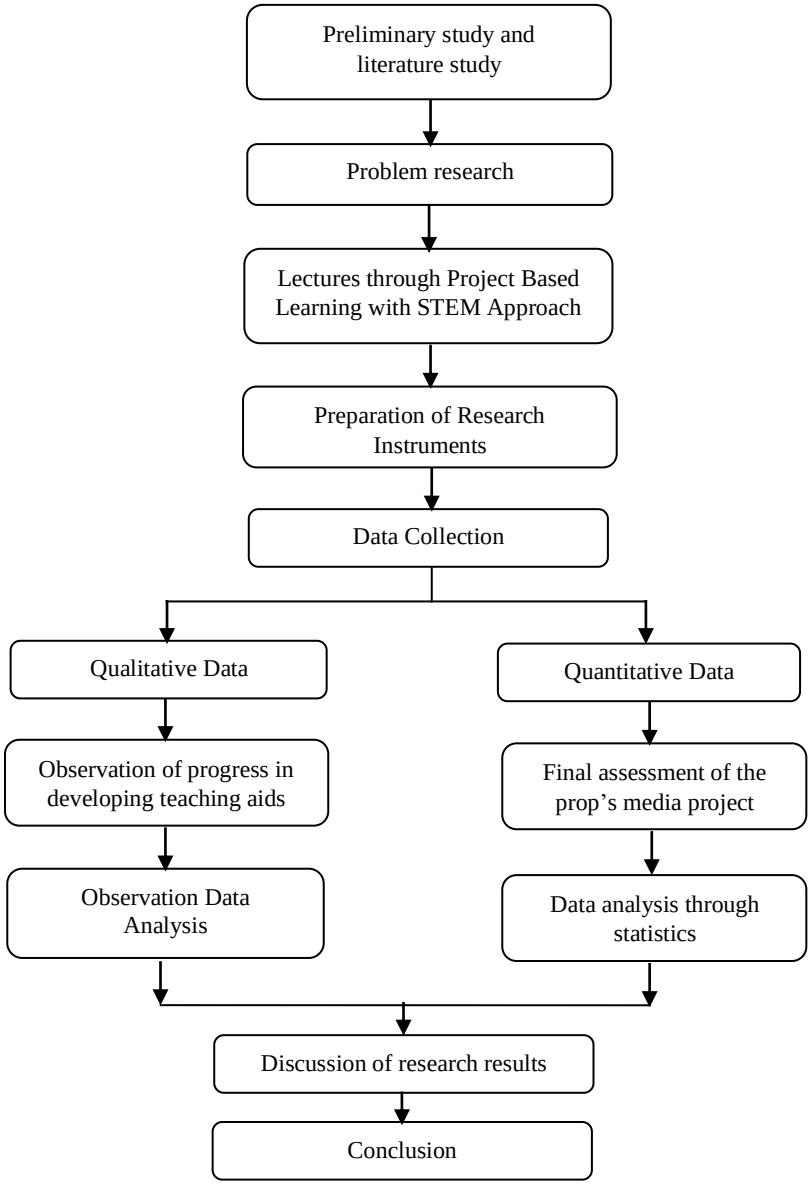

Figure 1. Research flowchart

Population and Sample

This study was carried out at pre-service teacher in the 3rd semester who takes the physics learning media lectures at physics education department. The sample of the study was code A class and code B class totaling 61 people using the saturated sampling technique. This sample was selected with the diversity of abilities possessed by each of individual.

Data Collection and Instrument

This study utilized project observation through the project assessment sheet. The indicators for assessing the instructional tool project in this research are 1) conceptual accuracy; 2) ease of use; 3) media aesthetics; 4) the emergence of STEM aspects; 5) environmentally friendly (Go-green) and the utilization of recycled materials. The assessment was conducted by the lecturer in charge of the course. Two expert validators have validated the instrument used. Based on the validation results, the device gets a validator I score of 89.84 and a validator II score of 91.34, which means that the device can be used for the benefit of physics learning media. Based on reliability, this instrument gets score 0.78 of which means interpretation high reliability degree. The percentage breakdown for each assessment indicator of students' instructional tool project is as follows:

Table 1. Percentage of project indicator evaluation

No.	Aspect or indicator	Percentage
1	Correctness of concept	30%
2	User-friendliness	15%
3	Media aesthetics	15%
4	Emergence of STEM aspects	20%
5	Go green and utilize used goods	20%
Total		100%

Data Analysis

The data analysis technique to process the score of the props project assessment through the observation sheet is carried out with the following steps:

a. Tabulation of all data obtained for each component of the assessment items available in the assessment instrument
b. Calculating the average total score of each component using the formula
c. Converting the average score into a score with criteria

Table 2. Category of score (Arikunto, 2010)

Final Score	Category
≥ 81	Very good
61-80	Good
41-60	Good Enough
21-40	Less
≤20	Not Good

RESULT AND DISCUSSION

Stage 1. Planning of learning media lectures through the implementation of project based learning with STEM approach

The implementation of learning is done face-to-face with six times the frequency of meetings to introduce the material on physics learning media. The early stages begin with delivering the learning plan, providing material on the basic concepts of physics learning media, and orienting the use of teaching aids to assist the existing physics learning process as a basis for developing and measuring students' abilities in developing physics learning media in the form of teaching aids.

Stage 2. Analysis of physics concepts at the high school level

Students are directed to analyze concepts in high school-level materials at this stage. This study's material is limited to 1) mechanics, 2) electricity and magnetism, 3) fluids, and 4) renewable energy. Each student also analyzes the existence of existing physics learning media at school by collecting information through interviews and literature reviews so that students can formulate problem-solving strategies

Stage 3. Planning a learning media project in the form of teaching aids

The next step is for students to individually solve the existing problems by making a model/design of physics learning media and analyzing the construction and calculation of materials up to writing the manufacturing procedures. At this stage, students also begin to work on making physics learning media products as previously designed. After the media becomes a natural product, students test the tool in their respective groups and end with a presentation in class.

At this stage, students make revisions if the trial simulation of teaching aids has not worked optimally. Students consult individually with the lecturer before the props are presented to the class. In this research, students have products in the form of physics learning media props, videos of making props, and PPT as a medium for students to make individual presentations.

Stage 4. Assessment of the teaching aids produced

At this stage, the lecturer assessed the teaching aids produced. Students are given 10 minutes each to present the teaching aids that have been made. After presenting, the lecturer asked each student verbally questions about the physics concepts applied to the learning media in the form of teaching aids, the manufacturing process, and the difficulty level in making teaching aids.

At this stage, the lecturer also reflects on the students. Reflection is carried out to assess the process that occurs and everything related to the actions taken. Reflection is carried out collaboratively, namely the discussion of various problems that arise in the classroom so that problem-solving strategies are found for improving the actions that must be taken.

To the research objectives, several instruments are used in this study: project assessment sheets and student progress observation sheets in developing learning media as teaching aids. The project assessment sheet assesses students' abilities and skills in designing projects, namely physics learning media. The assessment sheet is prepared

based on the indicators listed in Table 1. Through the assessment indicators, the average value of physics education students' ability in class A to develop learning media in the form of teaching aids is obtained through the diagram below.

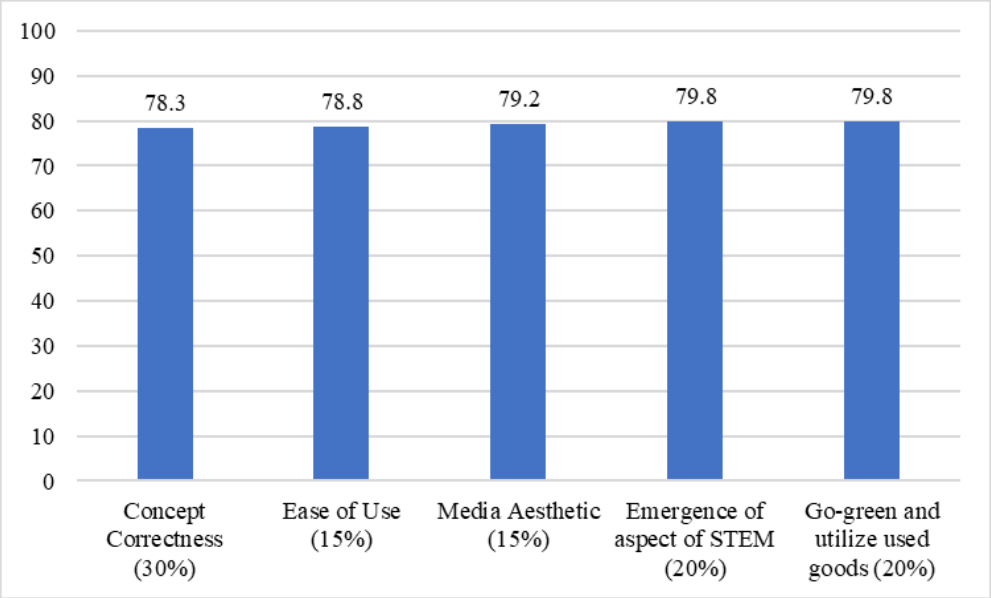

Figure 1. Average score of ability aspects of class A

The figure above represents the average student's ability to develop learning media through teaching aids. The emergence of aspect STEM and Go-green utilized use goods has the highest average value of 79.8 in the excellent category. Students develop learning media using the STEM (Science, Technology, Engineering, and Mathematics) approach. The science aspect assesses how students can use scientific knowledge and processes to understand and participate in making decisions. The technology aspect examines how students can utilize technology in the developed props (An'nur et al., 2020). In contrast, the engineering aspect assesses understanding of how technology can be developed through the engineering process using project-based physics materials and how to provide different innovations in the props developed from previous props. The mathematics aspect is the ability to analyze, reason, and communicate ideas effectively, formulate, solve, and interpret solutions to mathematical problems in the application of learning media in the form of teaching aids (Farwati et al., 2021; Zulhelmi et al., 2023).

The science aspect assesses how students can use scientific knowledge and processes to understand and participate in making decisions (Utami et al., 2020). The technology aspect examines how students can utilize technology in the developed props. In contrast, the engineering aspect assesses understanding how technology can be developed through the engineering process using project-based physics materials and how to provide different innovations in the props developed from previous props. The mathematics aspect is the ability to analyze, reason, and communicate ideas effectively, formulate, solve, and interpret solutions to mathematical problems in the application of learning media in the form of teaching aids (Rahmania, 2021).

Other data findings can be seen from the results of the concept correctness percentage, which is slightly lower than other indicators. The average score of 78.3 with

a good category shows that the correctness of the physics concepts presented through the presentation is still good. However, this is also based on several factors, such as the need for students' complete understanding of the concepts to be built through the tools presented. Although the teaching aids developed already have innovations, when students are asked to re-explain physics concepts related to teaching aids, some students still have a wrong understanding of concepts and are not fully understood. This is certainly a note in physics learning media lectures that students need to be given more concept deepening in other related courses such as materials in basic physics.

The development of learning media in the form of teaching aids respectively on the material 1) mechanics, 2) electricity and magnetism, 3) fluids, and 4) renewable energy. The media was developed for four weeks and reviewed the manufacturing process by the lecturer in charge of the physics learning media course. The following are the results of learning media tools produced by prospective teacher students in physics education.

Figure 2 (a). Electric waterwheels

Figure 2 (b). Excavator

Electric waterwheel props are learning media used to convey concepts about Bernoulli's Law. The working principle of the props is that it starts from the water entering through the hose and then entering the hole at the top of the electric pump; after the pressure and volume of the substance are complete, the water is pushed out through the hole at the top of the electric pump. Figure 2(b) is an excavator props. This prop can help in explaining the concept of Pascal's law. When viewed from a liquid in a container, the pressure of the liquid at the bottom of the container is, of course, more significant than the pressure at the top. The further down, the greater the pressure of the liquid. Conversely, the closer to the top surface of the container, the smaller the pressure of the liquid.

Figure 2 (a). Solar car

Figure 2 (b). Kinematics

Solar car is a teaching aid that implements the concept of renewable energy. This prop uses the principle of converting light energy into electrical energy. The following simple teaching aid is a learning media developed by students that implements motion kinematics material. This tool helps students understand the concept of regular straight motion (RSM) and regular changing straight motion (RCSM). Meanwhile, class B also applied a project-based learning model with a STEM approach. The application also took place for six meetings in face-to-face lectures. Through the assessment indicators, the average value of physics education students' ability in class B to develop learning media in the form of teaching aids is obtained through Figure 3.

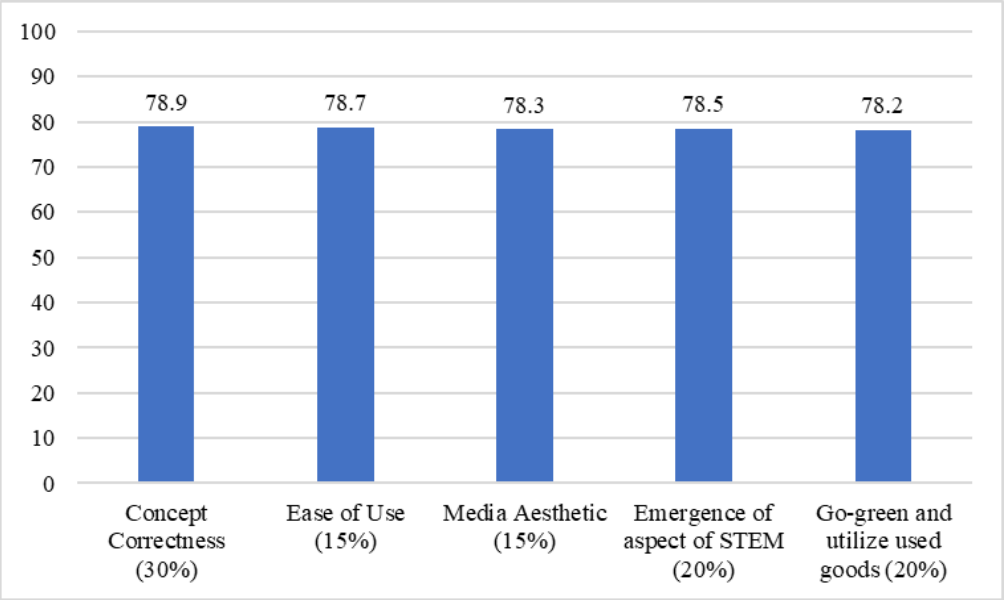

Figure 3. Average score of ability aspects of class B

Based on the diagram above, it represents data on class B students' ability to develop physics learning media in the form of teaching aids. The aspect of the most remarkable ability of students on the truth of the concept amounted to 78.9 with a good category. The ease of use of teaching aids gets an average value of 78.7 in the excellent category. The relevance of the application of STEM in teaching aids has an average value of 78.5 with a suitable category. In contrast, the aesthetics of the media have an average value of 78.3, and the use of used goods to support go-green is 78.2, with a good category. The following are the results of learning media tools produced by prospective teacher students in physics education.

The results of research conducted by Hussin et al., (2019) showed increased student creativity and learning achievement through project-based learning in Chemistry Education Workshop lectures at Yogyakarta State University. Research conducted by Harun (2020) in the final project course of the D-III Program concluded from the study's results that applying project-based learning can positively impact independence and the concept of learning.

STEM-based project-based learning is a learning model that forms students in a group to complete a project where the project integrates science, technology,

engineering, and mathematics. Project-based learning based on STEM has different steps from project-based learning. There are similarities between the characteristics of PjBL and STEM-integrated PjBL, but STEM-integrated PjBL emphasizes more on the design process or the process of making prototypes. The design process systematically solves a problem with a well-defined outcome (Capraro et al., 2013; Espinosa et al., 2019).

The data findings in the percentage results show that the result of 78.3 for aesthetic media is slightly lower than the other indicators. This is due to several factors, namely the appearance of the media in the form of teaching aids presented still has a simple display innovation and a somewhat lacking tidiness. This is certainly a note that students, in addition to emphasizing the ease of use of teaching aids, must also pay attention to the appearance of the media props themselves so that they are more attractive to present and attract students' attention when used in the classroom.

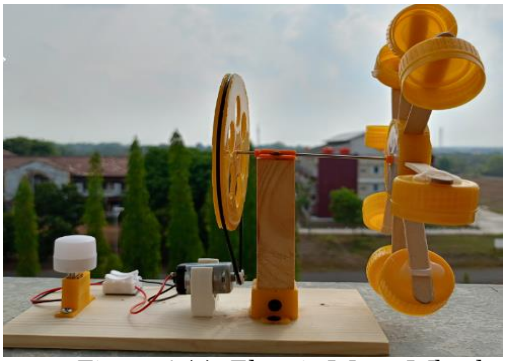

Figure 4 (a). Electric Water Wheel

Figure 4 (b). Conveyor Belt

Figure 4 (c). HCS-Project

Figure 4 (d). Simple electrical installation

In Figure 4(a) is a simple waterwheel that uses a dynamo to drive an LED lamp to generate electrical energy. The basic principle behind it is that the waterwheel converts the kinetic energy of the water into mechanical energy that is used to turn the dynamo. The dynamo then converts this mechanical energy into electrical energy. The generated electrical energy is then used to illuminate the LED lights. This trainer uses the principle of energy conversion. Figure 4(b) is the result of media development in the form of conveyor belt props. Conveyor Belt is a machine used to assist humans in transporting and moving large quantities of solid goods from one place to another. To drive this simple conveyor belt using a dynamo. This conveyor belt works based on the principles of physics, one of which is the law of conservation of mechanical energy.

Class B physics education students also produced teaching aids on the concept of measurement. In Figure 4(c) a distance measuring device based on the HCS-04 sensor and Arduino Uno R3 Series that can function as a digital ruler with optimal measurement capabilities up to 4 (four) meters. The use of ultrasonic sensors to simplify the measurement process of an object. While simple electrical installation props through Figure 4 (d) which explains the concept of series and parallel circuits. In this lesson, it is used for the scale of the miniature house, building height, building area and calculating the number of lights used and calculating the number of switches used.

The findings in this study are seen from the results of the assessment of the ability to develop physics learning media in class A and class B. Each has a different data trend. Each has a different data trend. Class A with a total of 31 students, the majority can develop better teaching aids by using used materials with an average value of 79.8 higher than class B. In addition, students are also able to relate STEM concepts to the development of teaching aids. In addition, students are also able to relate STEM concepts to the development of teaching aids. This shows that physics education students in class A are better able to show the STEM concept in teaching aids through the materials that have been determined. The aesthetics of the media produced is also an important assessment of student ability, a higher percentage of 20% than class B.

However, in the explanation of the truth of the concept and ease of use of learning media, physics education students in class B have a higher average score of 78.9 in the excellent category; this indicates that the truth and deepening of understanding of concepts traced through oral questions is much better than class A. Each physics education student in class A and class B has different characteristics so that for further research, students' creativity level as prospective teachers can be traced in developing physics learning media in the form of teaching aids. This research still has some shortcomings that become reflections for improvement and ideas for further research that can be outlined in the form of articles. Future research can evaluate other skills and abilities related to 21st-century skills, namely creative thinking, critical thinking, communication and collaboration.

CONCLUSION

Through this research, it can be concluded that students' ability to develop STEM-based learning media has a good-criteria. In class A, students' ability to create STEM-based teaching aids has an average value of 79.8 with good category, and using used materials is 79.8 with good category. Class B tends to understand the concepts of better teaching aids with an average score of 78.9 as good category, and the media used is easy to use at 78.7 with good category. In the implementation of the research, the lecture model was used through project-based learning with a STEM approach. The limitation of this study is that some students' skills in developing projects have not been measured as a whole. The results of this study will provide implications for further research to measure student creativity and communication skills in the development of teaching aids such as physics learning media.

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REFERENCES

An'nur, S., Sari, M., Wati, M., Misbah, M., & Dewantara, D. (2020). Developing of simple props using local materials to support natural sciences learning. Journal of Physics: Conference Series, 1422(1), 012011. https://doi.org/10.1088/1742-6596/1422/1/012011

Bovee, Courland. 1997. Business Communication Today. Prentice Hall : New York.

Capraro, R. M., M. M. Capraro. dan J. R. Morgan. 2013. STEM Project-Based Learning: an Integrated Science, Technology, Engineering, and Mathematics (STEM) Approach. Second Edition. Rotterdam: Sense Publisher.

Dewantara, D., Febrianti, Wati, M., & Mastuang. (2019). Development of simple machines props to train student's science process skills. Journal of Physics: Conference Series, 1171, 012017. https://doi.org/10.1088/1742-6596/1171/1/012017

Espinosa, T., Miller, K., Araujo, I., & Mazur, E. (2019). Reducing the gender gap in students' physics self-efficacy in a team- and project-based introductory physics class. Physical Review Physics Education Research, 15(1), 010132. https://doi.org/10.1103/PhysRevPhysEducRes.15.010132

Farwati, R., Metafisika, K., Sari, I., Sitinjak, D. S., Solikha, D. F., & Solfarina, S. (2021). STEM Education Implementation in Indonesia: A Scoping Review. International Journal of STEM Education for Sustainability, 1(1), 11–32. https://doi.org/10.53889/ijses.v1i1.2

Frågåt, T., Henriksen, E. K., & Tellefsen, C. W. (2021). Pre-service science teachers' and in-service physics teachers' views on the knowledge and skills of a good teacher. Nordic Studies in Science Education, 17(3), 277–292. https://doi.org/10.5617/nordina.7644

García-González, E., Jiménez-Fontana, R., & Azcárate, P. (2020). Education for Sustainability and the Sustainable Development Goals: Pre-Service Teachers' Perceptions and Knowledge. Sustainability, 12(18), 7741. https://doi.org/10.3390/su12187741

Hanif, S., Wijaya, A. F. C., & Winarno, N. (2019). Enhancing Students' Creativity through STEM Project-Based Learning. Journal of Science Learning, 2(2), 50. https://doi.org/10.17509/jsl.v2i2.13271

Harun, U. B. (2020). Project-Based Learning Integrated to STEM (STEM-PjBL) To Enhance Arabic Learning Hots-Based. Al-Bidayah: Jurnal Pendidikan Dasar Islam, 12(1), 139–150. https://doi.org/10.14421/al-bidayah.v12i1.230

Haryadi, R., & Pujiastuti, H. (2020). Use of bungee jumping with stem approach to improve science process skills. Journal of Physics: Conference Series, 1480(1), 012073. https://doi.org/10.1088/1742-6596/1480/1/012073

Hussin, H., Yee Jiea, P., Raja Rosly, R. N., & Omar, S. R. (2019). Integrated 21st Century Science, Technology, Engineering, Mathematics (Stem) Education Through Robotics Project-Based Learning. Humanities & Social Sciences Reviews, 7(2), 204–211. https://doi.org/10.18510/hssr.2019.7222

Irvani, A. I., & Warliani, R. (2022). Development of Physics Demonstration Videos on Youtube (PDVY) as Physics Learning Media. Jurnal Pendidikan Fisika Indonesia, 18(1), 1–12. https://doi.org/10.15294/jpfi.v18i1.26723

Khoshman, J. M., Abu Tayeh, K., & Al-Rsa'I, M. S. (2020). Jordanian Pre-Service Physics Teacher s Misconceptions about Force and Motion. Turkish Journal of Science Education, 17(4), 528–543. https://doi.org/10.36681/tused.2020.43

Koponen, I., & Nousiainen, M. (2019). Pre-Service Teachers' Knowledge of Relational Structure of Physics Concepts: Finding Key Concepts of Electricity and Magnetism. Education Sciences, 9(1), 18. https://doi.org/10.3390/educsci9010018

Maghfiroh, D. R., & Sucahyo, I. (2023). Development of Closed Organa Pipe Props as Learning Media to Determine the Speed of Sound Propagation in Air Assisted by Physics Toolbox Sensor Suite. International Journal of Research and Community Empowerment, 1(2), 33–38. https://doi.org/10.58706/ijorce.v1n2.p33-38

Matsun, M., Boisandi, B., Sari, I. N., Hadiati, S., & Zadrianus, M. T. (2022). Development of Arduino Uno-based real learning media for measuring density of objects. Jurnal Riset Dan Kajian Pendidikan Fisika, 9(1), 25–33. https://doi.org/10.12928/jrkpf.v9i1.27

Nousheen, A., Yousuf Zai, S. A., Waseem, M., & Khan, S. A. (2020). Education for sustainable development (ESD): Effects of sustainability education on pre-service teachers' attitude towards sustainable development (SD). Journal of Cleaner Production, 250, 119537. https://doi.org/10.1016/j.jclepro.2019.119537

Nurmiati, Safira, N., Saehana, S., & Wahyono, U. (2021). Development of Simple Teaching Aid on Resonance Topic Using Audacity Software as Learning Media. Journal of Physics: Conference Series, 2126(1), 012005. https://doi.org/10.1088/1742-6596/2126/1/012005

Parno, P., Yuliati, L., Hermanto, F. M., & Ali, M. (2020). A Case Study on Comparison of High School Students' Scientific Literacy Competencies Domain in Physics with Different Methods: Pbl-Stem Education, Pbl, and Conventional Learning. Jurnal Pendidikan IPA Indonesia, 9(2), 159–168. https://doi.org/10.15294/jpii.v9i2.23894

Rahmania, I. (2021). Project Based Learning (PjBL) Learning Model with STEM Approach in Natural Science Learning for the 21st Century. Budapest International Research and Critics Institute (BIRCI-Journal): Humanities and Social Sciences, 4(1), 1161–1167. https://doi.org/10.33258/birci.v4i1.1727

Sorge, S., Keller, M. M., Neumann, K., & Möller, J. (2019). Investigating the relationship between pre-service physics teachers' professional knowledge, self-concept, and interest. Journal of Research in Science Teaching, 56(7), 937–955. https://doi.org/10.1002/tea.21534

Suprapto, N., Mubarok, H., & Adam, A. S. (2019). Understanding the Nature of Science Through a Content Analysis of Dynamic Fluid: Voices of Pre-Service Physics Teachers. Journal of Physics: Conference Series, 1417(1), 012073. https://doi.org/10.1088/1742-6596/1417/1/012073

Utami, I. S., Vitasari, M., Langitasari, I., Sugihartono, I., & Rahmawati, Y. (2020). The Local Wisdom-Based STEM Worksheet to Enhance the Conceptual Understanding of Pre-service Physics Teacher. Jurnal Penelitian & Pengembangan Pendidikan Fisika, 6(1), 97–104. https://doi.org/10.21009/1.06111

Varis, S., Heikkilä, M., Metsäpelto, R.-L., & Mikkilä-Erdmann, M. (2023). Finnish pre-service teachers' identity development after a year of initial teacher education: Adding, transforming, and defending. Teaching and Teacher Education, 135, 104354. https://doi.org/10.1016/j.tate.2023.104354

Wahyuni, H. S., & Rosana, D. (2019). Physics Props Development based on Personal Desk Laboratory System to Improve Creative Thinking Ability and Students' Scientific Attitude. Journal of Physics: Conference Series, 1233(1), 012032. https://doi.org/10.1088/1742-6596/1233/1/012032

Zulhelmi, Z., Fauza, N., Syaflita, D., Pratiwi, J., Wijaya, T. T., & Hermita, N. (2023). Development of Learning Media to Improve Students' Higher Order Thinking Skills in Circular Motion Material. Jurnal Penelitian Pendidikan IPA, 9(4), 1734–1740. https://doi.org/10.29303/jppipa.v9i4.3536