JIPF (JURNAL ILMU PENDIDIKAN FISIKA)
p-ISSN: 2477-5959 | e-ISSN: 2477-8451 *Vol. 9 No. 1, January 2024, Page 88-94*

The Development of Hydraulic Robotic Arm as a STEM-Based Physics Learning Media

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Received: September 2nd, 2023. Revised: October 10th, 2023. Accepted: November 3th, 2023

Keywords :
Hydraulic Robotic Arm;
Physics Learning Media;
STEM

ABSTRACT
The aim of this research is to develop, assess feasibility, and determine students responses of hydraulic robotic arm as a STEM-based physics learning media. The method used in this research is Research and Development (R&D) with the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) framework. Expert validation results show that the content's feasibility percentage is 95% (very good) and the media's feasibility is 94% (very good). The experiment was conducted involving 155 secondary school students in Garut, yielding a trial outcome of 84%. The results of the research indicate that the hydraulic robotic arm is suitable for use as a STEM-based physics learning media both in terms of content and the learning media. Additionally, students responses to the hydraulic robotic arm are categorized as good, particularly in terms of its benefits in learning.

INTRODUCTION

The rapid development of the 21st century, particularly in technology, competition, and challenges in every aspect of life, is undeniable. This progress is closely tied to the role of education in shaping a generation capable of facing the myriad challenges of the 21st century. Modern education recognizes the pivotal role of learning media. Learning media can aid students in understanding content and learning skills, while also creating their interest in a particular subject [1]. This applies to natural sciences like physics as well, where learning media is essential for enhancing students' interest, comprehension, and skills in addressing the challenges of the 21st century.

The results of the observation indicate that physics learning in schools often lacks the presentation of physical phenomena but tends to focus on complex formulas without applying these concepts to real-world problems. Students are not actively engaged in the learning process, leading to the perception that physics lacks practical relevance in everyday life. For instance, in the concept of pressure such as topic Pascal’s law, the material appears abstract and challenging for students to comprehend [2]. Therefore, there is a need for a learning media that can address students difficulties with abstract concepts in physics and enhance various 21st-century skills, in line with the expectations of the Kurikulum Merdeka. Previous findings that one of the limitations in delivering physics concepts can be addressed by using learning media that can help present concrete physical phenomena [3].

Based on the results of interviews with teachers and students, it was found that there is a need for a learning media that is easy to use in the classroom, portable, easy to assemble and rearrange by students, and encourages hands-on activities. However, the available school facilities and infrastructure are insufficient to support active student engagement in learning. Additionally, the relatively high cost of educational kits poses a challenge for schools in providing supportive learning media.

Several previous studies have developed physics learning media on the topic of Pascal’s law [4] [5]. Other findings have developed using various technologies, such as computer-based robots [6] [7], Augmented Reality [8], and Arduino [9]. Therefore, this study aims to develop a learning media in the form of a hydraulic robotic arm. While the development of a hydraulic robotic arm has been studied previously [10], that research used vulnerable materials, such as cardboard. Hence, this study will use stronger and more durable materials. Furthermore, previous research did not integrate their findings with a teaching approach that enhances various skills required in the 21st century.

One of the ways to enhance various 21st-century skills required by students is by implementing STEM (Science, Technology, Engineering, and Mathematics). STEM is an interdisciplinary approach to learning that applies the concepts of science, technology, engineering, and mathematics in real-life contexts [11]. The implementation of STEM learning in education can improve students critical thinking, creative thinking, self-efficacy, and problem-solving skills [12] [13] [14]. Therefore, the aim of this research is to develop a STEM-based physics learning media in the form of a hydraulic robotic arm.

METHOD

This research used the Research and Development (R&D) method with the ADDIE (Analysis, Design, Development, Implementation, and Evaluation) framework. This framework was used to produce the hydraulic robotic arm as a STEM-based physics learning media. The hydraulic robotic arm product was assessed for its feasibility by five physics content experts and five learning media experts. Furthermore, the product was pilot-tested with 15 students and field-tested with 155 students. The instruments used in the product development included validation sheets from physics content experts, learning media experts, and a student response questionnaire. The validation sheet from physics experts comprised 14 statements related to aspects of relevance, accuracy, basic material concepts, and STEM-based learning. The validation sheet from learning media experts consisted of 10 statements concerning general appearance, specific appearance, practicality, and media presentation. Additionally, the student response questionnaire consisted of 14 statements about media appearance, practicality, and its benefits in learning.

Qualitative data in this study included suggestions and conclusions that were analyzed and used as references for improving the hydraulic robotic arm product. Quantitative data consisted of the results from the validation by physics content experts, learning media experts, and the student response questionnaire, which used a Likert scale with a score range of 1-5. The obtained scores were summed, processed into percentages, and then interpreted into assessment criteria for the development product, as presented in Table 1. The developed learning media is considered suitable for use if the feasibility test results from both content and learning media experts achieve at least a good assessment category.

Table 1. Criteria for Feasibility Assessment

(%)	Criteria
91-100	very good
81-90	good
71-80	moderate
61-70	less
0-60	very less

RESULTS AND DISCUSSIONS

The result of this developmental research is a STEM-based physics learning media product in the form of a hydraulic robotic arm. The research phases align with the ADDIE research design, encompassing five stages: (1) analysis, (2) design, (3) development, (4) implementation, and (5) evaluation.

Analysis

During the analysis phase, problem analysis, needs analysis, and a literature review were conducted. Based on interviews with teachers and students, it was determined that there was a need for a learning media that was easy to use in the classroom, portable, easy to assemble and reassemble by students, and encouraged hands-on activities. Additionally, in line with findings from previous research [2], students expressed difficulties in understanding the concept of pressure, particularly the application of Pascals Law, due to its abstract nature. This was further supported by test results indicating low-level critical thinking skills among students. The findings from the analysis phase were subsequently followed by the creation of the initial design for the hydraulic robotic arm media, drawing upon various prior studies [15] [16].

Design

In this phase, the design process involved creating the blueprint for the hydraulic robotic arm. The hydraulic robotic arm product was designed following a STEM approach, incorporating both scientific and engineering processes. This design represents the preliminary concept for the product. The initial design of the hydraulic robotic arm is presented in Figure 1. The design includes details of the equipment and materials used in this research product, such as a 20 ml syringe, a 35 ml syringe, cable ties, hoses, plywood, wooden boards, nails, bolts, and nuts.

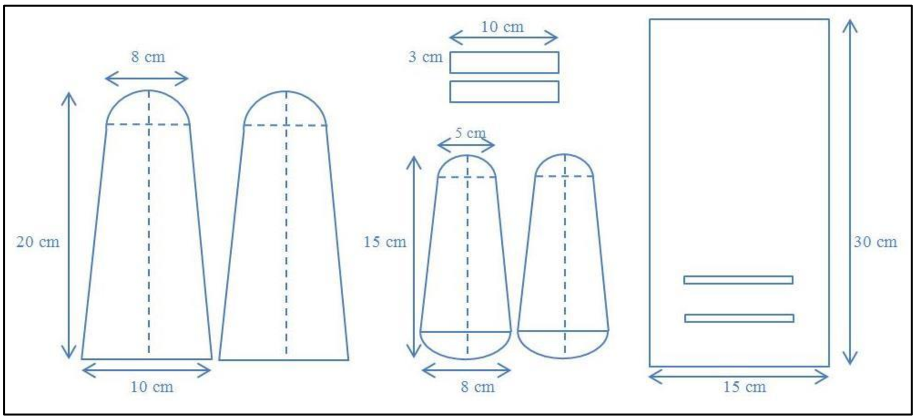

Fig 1. *Hydraulic robotic arm design*

Development

The development process of the hydraulic robotic arm product began with the construction of the hydraulic robotic arm based on the design from the previous phase. The hydraulic robotic arm product was modified from prior research [10], which used 10 and 20 ml syringes and a 10x10 cm arm base. In this research, the hydraulic arm was enlarged to 15 x 30 cm to enhance stability and provide space for control syringes, preventing easy tipping. Additionally, the primary materials used were plywood and wood to make the product more robust and sturdy [15].

Before implementation in the learning process, the developed hydraulic robotic arm product underwent a feasibility assessment by five physics conten experts and five learning media experts. The instruments used were validation sheets for content and learning media feasibility, assessed using a Likert scale. Aspects evaluated for content feasibility by physics content experts included relevance,

DOI: 10.26737/jipf.v9i1.4743

accuracy, basic concepts, and alignment with STEM-based learning. The results of the content feasibility assessment by physics content experts for the hydraulic robotic arm product are presented in Table 1.

Table 2. Content Expert Feasibility Assessment Results

Aspect Considered	Total Score	Maximum Score	Percentage (%)
Relevance	93	100	93
Accuracy	72	75	96
Basic concept	49	50	98
STEM learning	119	125	95
amount	**333**	**350**	**95**

Based on the assessment results of five physics content experts, a total score of 333 out of a maximum score of 350 was obtained. Consequently, the percentage of the assessment by physics subject matter experts regarding the hydraulic robotic arm product is 95%, which falls within the category of very good. Furthermore, feedback from all physics content experts indicates that in terms of content, the hydraulic robotic arm product is suitable for use as a STEM-based learning media.

Aspects evaluated for feasibility by learning media experts, these include general appearance, specific appearance, practicality, and media presentation. The results of the feasibility assessment by instructional media experts for the hydraulic robotic arm product are presented in Table 3.

Table 3. Media Expert Feasibility Assessment Results

Aspect Considered	Total Score	Maximum Score	Percentage (%)
General view	45	50	90
Special view	66	75	88
Practicality	73	75	98
Media presentation	50	50	100
amount	**234**	**250**	**94**

Based on the assessment results of five learning media experts, a total score of 234 out of a maximum score of 250 was obtained. Consequently, the percentage of the assessment by instructional media experts regarding the hydraulic robotic arm product is 94%, which falls within the category of very good. The lowest percentage rating was in the specific appearance aspect, particularly in terms of color to make it more appealing. This feedback led the researcher to make improvements, initially changing the product from being unpainted to being painted blue.

Feedback from all instructional media experts indicates that the hydraulic robotic arm is suitable for use as a STEM-based learning media, offering functional and operational ease. The product's final form, after receiving feedback and improvements from the experts, is presented in Figure 2.

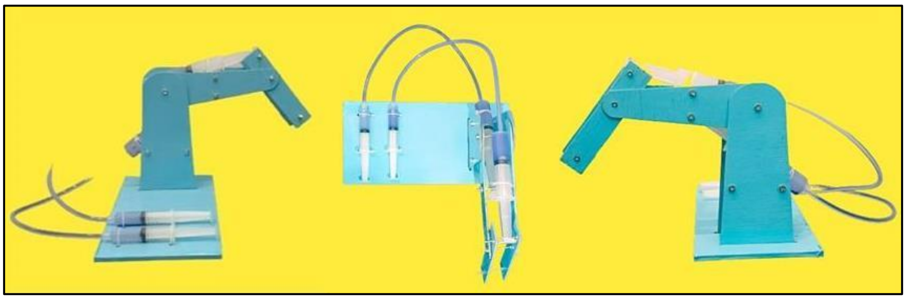

Fig 2. *Hydraulic robotic arm product*

The hydraulic robotic arm product, which has been deemed suitable for use, was tested on a limited basis with students to gauge their responses to its use. The limited trial respondents consisted of 15 students. The instrument used for this trial was a student response questionnaire.

Implementation

In this phase, the hydraulic robotic arm product was implemented in the learning process using the STEM approach. The learning began with the exploration of the concepts of pressure and the principles of Pascal's Law. Teachers encouraged students to test the effect of the volume of liquid on the arm's rotation angle [17]. Once students understood how the hydraulic robotic arm worked, they could assemble each component themselves to create their own hydraulic arm, which allowed them to produce different rotation angles.

The hydraulic robotic arm was implemented in the instruction of the topic of pressure, subtopic of the application of Pascal's Law, and was presented to 155 students. The instrument employed for this evaluation was a student response questionnaire, which encompassed three aspects: media appearance, media practicality, and the benefits in learning. The results of the student response questionnaire regarding the implementation of the hydraulic robotic arm in STEM-based learning are presented in Table 4.

Table 4. Student Response Results

Aspect	**Total Score**	**Maximum Score**	**Percentage (%)**
Presentation media	16.14	20	81
Practicality	12.62	15	84
Benefit in learning	30.51	35	87
Amount	**59.27**	**70**	**84**

Based on Table 4, it can be observed that the aspect with the highest percentage pertains to the benefits in learning. The aspect of benefits in learning in this study includes learning objectives, active engagement, motivation, interaction, comprehension, high order thinking skills, and awareness of STEM integration. Findings in this research indicate that students find it easier to understand the application of pressure concepts in Pascal's Law after using the hydraulic robotic arm as a learning media. This aligns with previous research stating that the use of media with a STEM approach can enhance students' understanding and learning outcomes because the learning is connected to everyday life, making it more meaningful [18] [19]. The implementation of STEM-based learning can also improve students' critical thinking skills [20], creative thinking, self-efficacy [21], and problem-solving abilities [22].

Evaluation

The final stage is evaluation. In this stage, the product is evaluated and revised based on the results of the implementation phase. The revised hydraulic robotic arm product is deemed suitable for widespread use as a STEM-based physics learning medium. Although the hydraulic arm product has been declared suitable as a STEM-based learning medium, it still has some limitations in its application and development. The hydraulic robotic arm product has not been fully maximized for training physics skills quantitatively. It can only demonstrate the effect of the volume of liquid on the arms rotation angle [1]. Therefore, in future research, it is suggested that this product can be used to show the quantitative relationship between force and cross-sectional area. Additionally, based on the findings from the implementation phase, this product has the potential to encourage students to engage in high-level thinking. Thus, future research is expected to investigate the impact of the STEM-based hydraulic robotic arm on the enhancement of high order thinking skills, such as problem solving, critical thinking, and creative thinking skills.

DOI: 10.26737/jipf.v9i1.4743

CONCLUSION AND SUGGESTION

This research has successfully developed a hydraulic robotic arm as a STEM-based physics learning media. Based on feasibility assessment results from physics content experts and learning media experts, it can be concluded that the hydraulic robotic arm is suitable for use as a STEM-based physics learning media, with very good category. Student responses to the implementation of the hydraulic robotic arm in STEM-based learning in good category, especially regarding its benefits in learning.

For future researchers, it is recommended that this product be used to demonstrate the quantitative relationship between force and cross-sectional area and the ability to move objects with a 360° rotation. Additionally, future research can investigate the impact of the STEM-based hydraulic robotic arm on the enhancement of high order thinking skills, such as problem-solving abilities, critical thinking skills, and creative thinking skills.

ACKNOWLEDGMENTS

Acknowledgments are addressed to Kementrian Pendidikan, Kebudayaan, Riset, dan Teknologi (Kemdikbudristek) for providing the research grant for this study. Also thanks to the LLDIKTI IV and Universitas Garut for their facilitation and support, which have enabled the successful completion of this research.

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DOI: 10.26737/jipf.v9i1.4743