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Musschenbroek Learning Media with Arduino Based with Relay and Max6675 Sensor to Increase HOTS and Creativity

Soka Hadiati[1], Adi Pramuda[1], Matsun[1*]

[1] Department of Physics Education, IKIP PGRI Pontianak, Pontianak, Indonesia.

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Corresponding Author:
Matsun
matsunzaidan@gmail.com

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Abstract: This study aims to obtain a proper and effective form of Arduino-based Musschenbroek learning media with MAX6675 relays and sensors in increasing HOTS and student creativity, as well as knowing student responses to the developed Arduino-based Musschenbroek learning media with MAX6675 relays and sensors. This research is a development research with ten stages, including: information gathering research, planning, initial development, initial testing, main product revision, main testing, operational product revision, operational field testing, final product revision, and dissemination. The research subjects involved in the research, namely: experts, lecturers, colleagues, and students were selected by cluster random sampling technique. Analysis of the feasibility of learning media and student responses is determined qualitatively. The results showed that Arduino-based Musschenbroek learning media with relays and MAX6675 sensors in increasing HOTS and valid creativity with very good criteria. Students gave a very good response to learning media.

Keywords: Arduino; Creativity; HOTS; Musschenbroek learning media

Introduction

Presidential Regulation number 59 of 2017 has been released as a legal umbrella to reach agreements with various countries called Sustainable Development Goals (SDGs). The realization of Sustainable Development Goals (SDGs) through education is called Education for Sustainable Development (ESD). In this regard, the government of the Republic of Indonesia has launched a learning and assessment system that is oriented towards HOTS (Higher Order Thinking Skills) to address the problem of Indonesia's position in reviewing the results of the Program for International Student Assessment (PISA). This policy is still being implemented with various optimizations because simultaneously it has not shown the expected results (Siregar et al., 2020). The government is also trying to change the education paradigm related to the emergence of problems with employment along with the industrial revolution 4.0. Learning must begin to shift to placing creativity as a target for optimizing intelligence based on the fact that the creativity of students in Indonesia at various levels is still low (Irhamsyah, 2020). ESD can be integrated into science learning (science, especially physics) in various ways, such as learning tools, learning media, and learning models (Purnamasari et al., 2021).

Science learning media in particular is an important problem. Various studies have shown that various variables that describe students' abilities in the field of science (physics) such as HOTS and creativity can be improved by developing learning media (Fakhri et al., 2018; Latifah et al., 2020; Zahro et al., 2019). The urgency of developing learning media refers to this research generally being motivated by the problem of the lack of opportunity for students to interact with various learning media in terms of the limited ability of educators as well as from the limited side of the tools in the school science laboratory. The consequence of not making any effort to overcome these limitations is that HOTS, creativity, and science (physics) learning outcomes of students at various levels are low.

HOTS, creativity, and students' science (physics) learning outcomes in the concept of expansion in schools and colleges were found to be low (Melissa et al., 2015; Sitinjak, 2020). There are not a few schools and even tertiary educational institutions that produce prospective science (physics) teacher students who are still constrained by the limited learning media in the

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form of the main practicum tools on expansion concepts such as Musschehenbroek. The existing Musscehenbroek tools are not in line with efforts to develop HOTS and student creativity to be responsive to technological developments in welcoming the industrial revolution era 4.0 (Diatri, 2020; Rohmah et al., 2017). On the other hand, Arduino-based technology and sensors are available which are proven to be able to increase HOTS, creativity, and students' understanding of concepts (Matsun et al., 2021). There is potential for using the MAX6675 sensor module sensor and its relay to form an automated Musscehenbroek technology that is more practical and effective (Evalina et al., 2022).Thus, it is necessary to study Arduino-based Musschenbroek learning media with relays and MAX6675 sensors to increase HOTS and creativity. The development of this as a research scheme is in line with the research and community service strategic plan of IKIP PGRI Pontianak on the leading topic of developing instructional media and specifically on basic studies and development of study-based learning media. This in the long term context is expected to form a comprehensive sensor-based physics learning tool in West Kalimantan, so that it can become a new and concrete reference for teachers, LPTKs, and the West Kalimantan Physics Education Association. Figure 1. presents the Gap Research Obtained and Research Urgency.

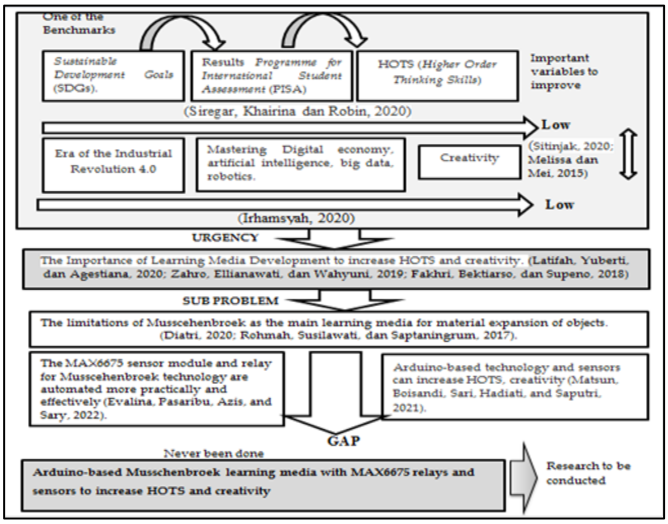

Figure 1. Obtained research gap and research urgency

Method

This research is development research, referring to Borg and Gall (1983) with ten stages, including: research and information gathering, planning, initial development, initial testing, main product revision, main testing, operational product revision, operational field testing, revision final product, and dissemination. The flow of research activities is presented in Figure 2.

Stage	Activity	Product
Information gathering	• Identification and verification of problems regarding the academic atmosphere. • Study of learning theory and media	Information on media development needs.
Research planning	• Identification of media characteristics to increase HOTS and creativity. • Exploration of learning media.	Initial draft of media.
Initial product development	• Preparation of learning media, learning tools and test instruments. • Expert judgment and revision of media and learning tools as well as test instruments.Pengujian validitas dan reliabilitas tes.	Learning media and test instruments are valid and reliable.
Initial field testing	Limited media trials.	Preliminary field test results.
Major product revisions	Evaluation and improvement of learning media and test instruments.	Preliminary field test results that have been
Main field testing	Testing the revised media and tools with the addition of the number of learning meetings.	Main field test results.
Operational product revision	Improvement of learning media and test instruments.	Revised primary field test results.
Operational field testing	Test media and devices on a larger class.	Operational field test results.
Final product revision	Improvement of learning media and test instruments.	Final Learning Media
Final product	Dissemination of articles in accredited national journals and international seminars.	Articles published in journals (Sinta 2), Proceedings and HAKI

Figure 2. Research flow

Information gathering is done to identify problems and needs analysis. Identification of the problem examines aspects of the problem regarding the academic atmosphere in the Physics Education Study Program, IKIP PGRI Pontianak. This is examined from the point of view of curriculum implementation and materials, the condition of educational facilities and infrastructure. The results obtained are verified by the lecturer. The next process is to identify the characteristics of students and related problems.

Research planning by identifying the characteristics of learning media to increase HOTS and student creativity based on all the information obtained. The next process as part of the planning is the construction of the media by combining the arduino device with the max6675 relay and sensor for the Musschenbroek experiment.

The main activities at the initial product development stage were the preparation of learning media and HOTS and creativity test instruments. Content analysis is used in this stage. Research instruments and learning media were content validated by 3 experts. The experts involved were 2 material experts and 1 learning media expert. This aims to obtain a feasibility assessment of the media and instruments developed.

Media trials were conducted within a limited scope at this initial testing stage. Revisions were carried out and continued with the main and operational field tests to obtain the final media. Initial field testing was carried out on a limited basis in semester 1 of the Physics Education Study Program, IKIP PGRI Pontianak. The responses of students and educators after learning became a consideration for revising the main product.

Evaluation and improvement of learning media and test instruments is carried out at this stage. The results of this revision were then tested at the main field testing stage. In the main field testing stage, learning is carried out using the developed media. Improvement of learning media and test instruments is also carried out at the main product revision stage, the next process is product testing produced in operational field testing.

Operational field testing is carried out in semester 4 of the Physics Education Study Program. The final product revision was carried out based on the results of field testing and observer suggestions regarding the learning process. Technical aspects related to learning media and test instruments were perfected. The results of the revision of the final product are in the form of Arduino-based Musschenbroek learning media with relays and MAX6675 sensors that can increase HOTS and creativity. These results are used as material for dissemination. Dissemination in the form of article publication in Sinta 2 accredited national journals and national seminars as well as Intellectual Property Rights from learning media.

The independent variable in this study is the Arduino-based Musschenbroek learning media with the max6675 relay and sensor. The dependent variables in this study are HOTS and creativity. Arduino-based Musschenbroek learning media with relays and MAX6675 sensors is a technological tool used to show differences in the coefficients of long expansion of various metals that can be programmed at certain temperatures based on Arduino with MAX6675 relays and sensors. HOTS in this study is the ability to think logically by using reasoning and associating with the knowledge possessed to solve problems through analyzing, evaluating and creating activities. Creativity in this study is thinking divergently based on knowledge in terms of fluency, flexibility, originality, elaboration, and redefinition.

Research subjects involved in research, namely: experts, lecturers, colleagues, and students. Experts and lecturers as research subjects to obtain the feasibility of the developed learning media. Students as subjects were selected by cluster random sampling technique referring to Babbie (2016). Students as subjects involved are students in semesters 2 and 4 to obtain response data.

Data collection techniques in this study consisted of test and non-test techniques. The test technique is used to measure the effectiveness of the median with data collection tools in the form of HOTS tests and creativity tests. Non-test data collection techniques are in the form of questionnaires on student responses to the media and validation sheets for the eligibility of the media.

Expert validation data is made in the form of validation sheets. The sheet contains statements related to the product development of SMP Student Worksheets based on STEM (Science Technology Engineering Mathematics) with an inquiry approach to the material temperature and its changes. Expert validation sheets are made using positive statements with a range of score scales with answer choices: Very Good (SB), Good (B), Enough (C), Less (K). Each answer is related to the score (SB=4), (B=3), (C=2), (K=1). To calculate the results of expert validation, Equation (1) is used as follows:

$$\text{Questionnaire score} = \sum((L_1\ x\ N)) \tag{1}$$

Information:
L_1 = Skala Score
N = Velue validation

Calculating the percentage of expert responses to calculate the validation percentage, equation (2) is used as follows:

$$\%X_{\text{in}} = \frac{\text{Expert Validation Score}}{\text{Maximum score}}\ X\ 100\% \tag{2}$$

Student responses were obtained from a questionnaire in the form of a Likert scale and calculated by the equation:

$$\%X_{\text{in}} = \frac{\sum S}{S_{\max}} x100\% \tag{3}$$

Then the data is concluded based on the percentage value of 0.0 - 20 with very low criteria, 20.1 - 40 low criteria, 40.1 -60 moderate criteria, 60.1 - 80 high criteria, and 80.1 - 100 very high criteria.

Result and Discussion

The development model used in this study is the Borg & Gall model. The stages in its development are information gathering, planning, product development, product testing, revision and dissemination. The details of the research results are based on the stages of the research as follows:

Information Collection

This research begins by looking at the potential of students who are accustomed to using microcontrollers and sensors, but practicum in the Physics Education study program still uses manual tools and is not entirely microcontroller-based. Observation activities are carried out to find out the process of learning and teaching activities that occur, learning using manual experimental tools does not maximize students' creativity and HOTS. One of the compulsory subjects in the Physics Education study program is Basic Physics 2.

Planning

In the planning stage, there are several things that are done, including adjusting learning outcomes with product designs. An illustration of the initial design of Musschenbroek technology which will be developed using Arduino, MAX6675 sensors, and relays is presented in Figure 3.

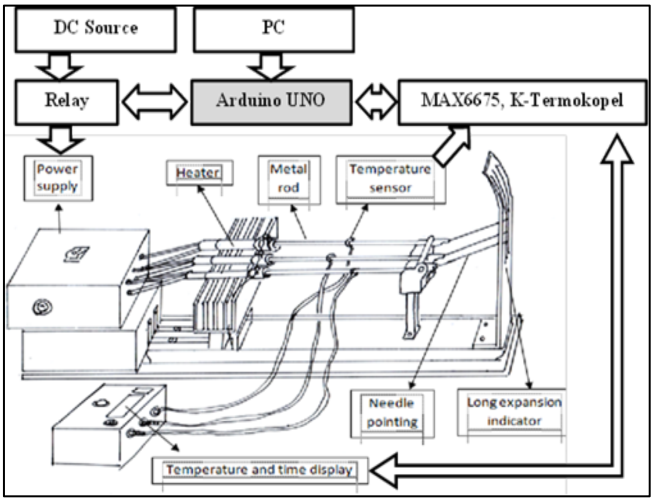

Figure 3. The initial design of musschenbroek technology which will be developed using Arduino, MAX6675 sensors, and relays

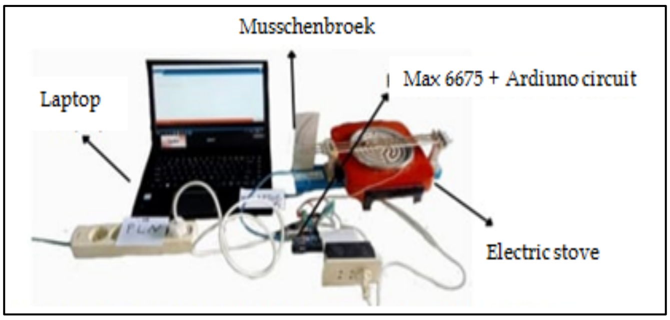

Figure 4. Designed tools that are ready to be validated

Initial Testing

Material expert validation

Assessment of student worksheet products by material experts. The results of the material expert trial validation are as follows:

Table 1. Material Expert Recapitulation Results

Aspect	Criteria score	Gain Score	Percentage (%)
Material eligibility	28	23	82.14
Presentation eligibility	52	42	80.77
Total	116	65	81.45

After knowing the results of the average material expert validation value, it is interpreted using references such as Figure 5.

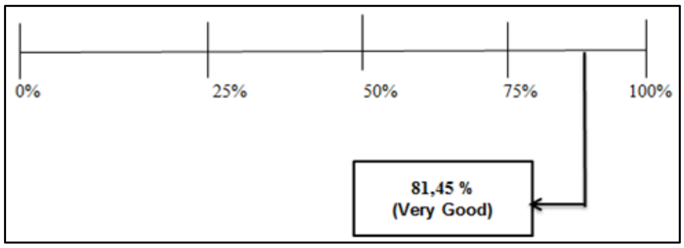

Figure 5. Range of material validation values

Media expert validation

Assessment of student worksheet products by media experts. The results of the media expert test validation are shown in table 2.

Table 2. Media Expert Recapitulation Results

Aspect	Criteria score	Gain Score	Percentage (%)
Size	8	8	100
Tool design	32	29	87
Interesting	20	16	80
Total	60	53	89

After knowing the results of the average material expert validation value, it is interpreted using references such as Figure 6.

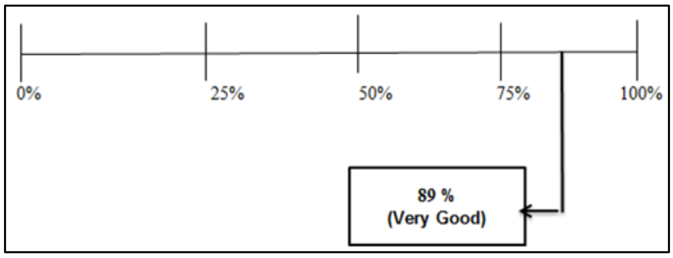

Figure 6. Range of media validation values

Product Trials

The product trial phase is carried out after going through the validation stage by material experts and media experts. In the trial phase, the researcher involved 2nd and 4th semester students to obtain response data. Students will be given a questionnaire to assess the feasibility of the product. The results of student responses to the product are shown in Figure 7.

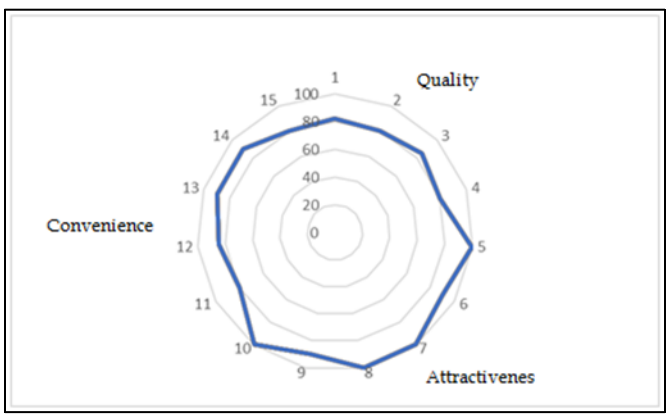

Figure 7. Product trial results

The radar diagram above shows the average value of the values obtained, so the product is categorized as very feasible to be used as a learning medium. After testing the product to determine feasibility. The product is said to have very high feasibility. A series of experiments using the Musschenbroek tool were able to increase HOTS and student creativity when viewed from each stage of the experiment. When students design tools and materials for experiments, conduct experiments, and analyze results (compare, evaluate, and revise) they can practice analysis, evaluation, and create skills and train creativity. In the experimental stage, measurements were carried out with arduino and sensors so that creativity was needed in running the program code. The results of the assessment by experts regarding the feasibility of the product indicate that the product is suitable for increasing HOTS and creativity. Heinich et al. (1993) which shows that measurement devices are used more as a vehicle for honing laboratory work skills. This finding is supported by Fauziyah (2018), and Zohar et al. (2018) which show that experiments will stimulate reasoning so that students can develop HOTS. This is in line with the research Raiyn (2016) and Walid et al. (2019) who found the importance of collaboration, collaboration and communication activities that encourage increased HOTS and creativity.

Conclusion

It has been found that Arduino-based Musschenbroek learning media with relays and MAX6675 sensors in increasing valid HOTS and creativity with very good criteria. Students gave an excellent response to the Arduino-based Musschenbroek learning media with relays and MAX6675 sensors in increasing HOTS and creativity.

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