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The Design of Modest Water Plan Building to Improve Scientific Process Skill

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Abstract

This research aims to: (1) create a design of a modest water plan for mathematics lessons with the material of fluid, (2) describe the improved psychomotor skills of the learners from the learning process with the created design, the modest water plan, for mathematics lesson with the material of fluid, and (3) describe the learners' responses toward the design of the water pump with the lesson of fluid mechanics. This Research & Development applied the ADDIE model with five stages. The first stage was analysis. The researchers reviewed the physics learning problems for Senior High School learner levels, specifically in the chapter on fluid mechanics. The second stage was the designing stage. The researchers designed the experiment tools. The third stage was the development stage. The researchers provided the materials to experiment. The fourth stage was the implementation stage. The researchers used the pre-created tool in a trial run test. Then, the fifth stage was the evaluation stage. This stage involved the reliability test based on the data validity of the experiment results. The results showed that: (1) the design of the modest water pump was applicable as the media of fluid mechanics learning, (2) the pretest-posttest results of the trial run test showed the improved aspect of the learners' scientific process skills; and (3) the learners' responses toward the design as the learning media for fluid mechanics was categorized "excellent."

Keywords: Water pump; scientific process skills

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Introduction

Learning activity is a process to make learners understand the basic concept of a science and an opportunity for learners to apply the concept in their daily life. Learning is strongly correlated to teaching-learning activity processes as a product of science assimilation to construct knowledge cognitively, affectively, in a psychomotor manner, and connate manner (Sanjaya, 2013; Sahim, 2013). The COVID-19 pandemic demands the teachers' creativity to manage productive learning for the learners. Educators must establish excellent relationships with the learners during online learning. One of the efforts to create effective learning is learning strategy, such as using experimental-based learning with a simple design about the relevant material, especially for a physics lesson.

The influential factor in lower education quality in Indonesia, especially in learning physics, is due to the ineffectiveness of the teachers in selecting the learning method. This matter can negatively influence various creativity and activity aspects of learners. These problems may also develop passive learners during the lesson. The philosophy of learning science in the 2013 curriculum indicates that science learning should not rely on cognition but also on innovation and psychomotor aspects (Trilling & Fade, 2012; Larson & Miller, 2011). The evidence should be the external factors to improve the education quality in Indonesia. The primary objective of learning is to establish the characters, attitudes, and civilization. Thus, education quality should be improved with cognitive, psychological, and social approaches so that learners could interact while learning and develop excellent attitudes and behaviors (Sanjaya, 2013).

Science is an intercorrelated process, product, and attitude. Physics is a part of science with a physical feature. Thus, learning physics needs a contextual-based approach to learning the physical phenomena. Physics learning is a designed teaching-learning activity to create interactions among teachers, learners, and learning sources within a learning environment. They interact to study the natural phenomenon and incident to achieve the targeted objectives, such as products and processes.

Science education at various educational levels has specific-contextual roles. Nurcahyani et al. (2021) explain that science education is based on nature. Thus, observation has an important role in developing the learners' cognitive aspects. Science education has various substantial and crucial features. Therefore, science education needs a Contextual Teaching and Learning, CTL, as an alternative to manage the problems during the learning process. CTL is a learning process that facilitates teachers to connect the teaching materials and the environmental situations of the learners. This process requires a scientific approach to facilitate the learners in implementing and connecting their knowledge to a real field (Khoiron & Sutadji, 2016; Susialita, 2016; Rusman, 2011). CTL-based learning refers to science learning, for example, with experimental activities.

The scope of contextual learning includes the learners' motivations; learning environment; individual, reasoning, learning approach and aptitude differences; interactions of teacher-learner and learner-to-learner; laboratory environment; affective dimension of science learning; cooperative learning; language; writing and interview of the learning; and social, political, and economic factors. Various learning method implementations could influence and develop the learners' characteristics. An excellent learning paradigm must perceive the learners as learning citizens. Thus, the educators must acknowledge the experience of their learning (Asrori, 2013). The popularity of contextual learning is based on the potential sub-topics, such as interest, motivation, attitude, and learning method implementation. Lin et al. (2014) explain that a problem could encourage the learners to carefully check certain categories. Then, they can develop meaningful answers, cognition, and insight into science education.

The understanding of physical learning is more effective and efficient within the essences of a physics lesson, such as product and process. Learners can find facts and develop concepts based on the promoted experience assimilation from theories and scientific nature. This assimilation positively influences the quality and the learning so the learners can master the physical concept excellently. The correct learning process of knowledge should integrate logical experience, mathematics, and self-efficacy within the scientific steps (Suparno, 2012; Schunk, 2012; Dahar, 2011). Learners must grow their scientific attitudes, especially while learning physics, such as observing, interpreting, clarifying, predicting, applying, and communicating the physics concepts excellently and effectively. Physics, as the primary science, has some basic science, such as facts, concepts, principles, laws, postulates, theories, and research methodologies (Mundilarto, 2010).

Experimental activities are the parts of a physics learning process to construct knowledge and establish an excellent understanding of the related physics concepts. Fluid mechanics is a primary discussed material in physics and engineering lessons.

The material of fluid mechanics deals with facts and actualizations of daily community life. The fact of learning physics at Senior High School showed that the lesson did not include experimental activity to support the learning and the learners' understandings.

The science process skill becomes a dependent factor in research because the process develops scientific literacy, especially scientific attitude development. In learning, learners must have excellent imagination power and provide daily life evidence to support Physics learning with an integrated experimental method with the guided-inquiry learning model that could improve the cognitive and psychomotor aspects of the learners (Subekti & Ariswan, 2016). Chebi et al. (2012) explain that effective science learning activities should include experiments, demonstrations, discussion, and relevant experience sharing about the material. The process skill includes the skill to find and develop relevant facts and concepts, and develop the believed attitudes and values. Process skills should include exercising to improve the effective and efficient values in the learning process (Tezcan et al, 2013; Abungu et al, 2014; Turiman, 2012). The instruments could be useful to measure the psychomotor aspects. The instruments can be observation, experiment activity, and written tests (Shahali et al., 2010).

In this research, the researchers limited the psychomotor aspects with some primary skill and integrated skill indicators. The primary skill indicators were observing, hypothesizing, calculating, and concluding. The integrated skill indicators were identifying variables, tabulating the data, presenting the data in graphs, drawing the inter-variable correlation, collecting and processing the data, analyzing the research, arranging the hypothesize, defining the operational variables, designing the research, and promoting experiment.

The scientific process skill test was deemed effective if the percentage of classical minimum standard mastery was 80%. If the criterion had not been achieved, the researchers had to review the test. The minimum standard mastery score in this research was adjusted with the applied minimum standard mastery score on the research site. Here is the formula to determine the learners' scores.

$$Studen\ Scores = \frac{Total\ score\ obtained\ by\ students}{maximum\ score}\ x\ scoring\ scale \quad \dots\dots\dots\dots (1)$$

From the experts' arguments, the process skill refers to a learning approach that allows learners to have opportunities to interact with concrete objects to construct their concepts.

Physics learning, with the material of dynamic fluid for XI Science Class in the second semester, is strongly correlated to the learning with science skill process orientation. Thus, the learning process should apply to a laboratory-based learning environment. This learning is a strategy to teach physics concepts excellently. In this research, the primary focus is the experiment activity by using the design of a modest water pump to learn dynamic fluids and to improve the scientific process skill of the learners.

The design of the modest water pump had some continuity principles. Yana et al. (2017) explain the development of a water pump engine with a recharging system is to facilitate the water distribution in areas with an energy crisis. The concept of the water pump design had some benefits for the water pump controlling system around a flooded area. Thus, this area can manage and prevent flooding water and minimize the cost by applying solar cells (Molle et al., 2020). Sugiyanto et al. (2014) explain that a wind-milled water pump with a rubber-seal rope could facilitate rice field irrigation. The water pump scheme indicated that the water pump had a turbine. One of them was the wind-milled turbine with better performance because it had low power capacity, for example, the Vertical Axis Wind Turbine, VAWT, typed Savonius VAWT (Jha, 2011). Studies about the Savonius turbine proved a better power coefficient than the modified-rotor configuration (Hussain, 2011). The Savonius-Typed VAWT could produce a maximum power of about 6.2KW only from the wind-milled turbine with a wind velocity of 5m/s (Vinay, 2012). Sanjay et al. (2012) explain that the strong point of a wind-milled pump with VAWT type is - the pump can be operated with lower wind speed.

From the explanations, the underlying concept of the modest water pump design is to moderate the scientific knowledge and the scientific concept into contextual science matter. Thus, the learning will be more useful in the future. Sulistya (2013) also explains that the centrifugal pump model could demonstrate the characteristics of water flow and the mechanical system for pumphouses. The pumps are important to alter the mechanics of the driving source into speed-related kinetics that could flow the fluid along the streams (Sucipriadi, 2016). Principally, two important components should appear in a water pump design. They are the impeller and the rotor as the rotating element; and the casing as the stationary element. In this research, the researchers focused on the principles of the centrifugal water pump design. The researchers assumed the centrifugal pump had more qualities, such as smaller dimension, lower wearing and tearing levels, adjustable, and easy to couple with high-speed rotation from the driving rotor.

In this research, the physics concept to learn about the water pump design experiment was about the fluid flow inside of a pipe. The fluid moves from high pressure into lower pressure. These pressure differences occur due to tot eh external air pressure and hydrostatic pressure. Thus, in this research, the minimum requirement to make a modest water pump should include a minimum height of 10.3m. The researchers took the derivative formula of hydrostatic pressure from this formula (2).

$$P_h = \rho \ x \ g \ x \ h \quad \text{...(2)}$$

The flow inside of a pipe consists of two flows: laminar and turbulent flows. The laminar flow refers to a fluid movement in the form of water lines without intercepting each other. This laminar flow has a lower speed and does not cause any turbulent flow. The second flow is turbulent. This flow refers to random and unstable moving particles with various speeds. From the flows inside of a pipe, the researchers determined the resulted power by a pump with this formula (3).

$$P_{pompa} = \rho \ x \ g \ x \ Q \ x \ (H + \frac{v^2}{2g}) \quad \text{...,(3)}$$

The speed of fluid flow inside of a pipe applies this formula (4).

$$v = \frac{Q}{A} \quad \text{..(4)}$$

From the fourth formula (4), the researchers elaborated the continuity principles of fluid dynamics, from the inlet and the outlet of a pipe. The water flows from different areas are the same $(A_1 > A_2, \ so \ (v_2 > v_1)$. The applied physics concept is the Bernoulli law, as explained in the fifth formula (5):

$$P_1 + \frac{1}{2}\rho v_1^2 + \rho g h_1 = Konstan \quad \ldots(5)$$

(Tipler & Mosca, 2008)

The Bernoulli principle indicates that high-speed flows have lower pressures and vice versa. Many applicable phenomena from this Bernoulli principle, for example, a flying plane, a torn pipe, and many more.

This research designed the design of modest water pumps, both electric and non-electric water pumps, based on the material of fluid mechanics to improve the scientific process skills of the learners. The scientific process skill aspects of the learners include observing, predicting, hypothesizing, calculating, interpreting, and drawing a conclusion. The researchers used a test with some test guidelines to measure the process skill aspects. The test design was based on the science process skill indicators. Besides that, the researchers identified the learners' responses toward the objectives to describe the design of the modest water pump as the learning media for fluid mechanics. The novelty of this research dealt with the implementation of Contextual Teaching Learning, CTL. The researchers integrated the concept with the design of a modest water pump for physics lessons, specifically on the dynamic fluid material, to improve the scientific process skills of the learners.

METHODS

This Research & Development study produced a certain product. Sugiyono (2013) also explains that Research & Development should also examine the effectiveness of the developed product. In this Research & Development, the researchers applied the ADDIE stages: *analysis, design, development, implementation,* and *evaluation* (Mulyatiningsih, 2011). Figure 1 shows the structure of the ADDIE model.

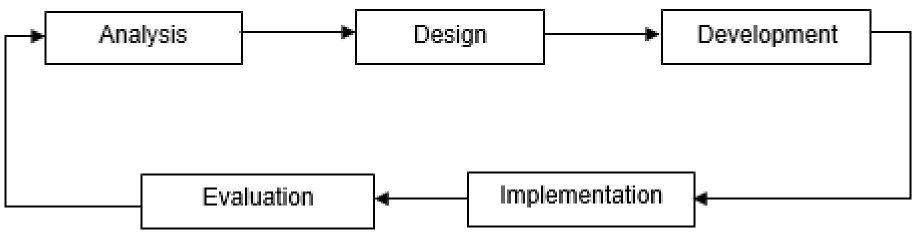

Figure 1. The ADDIE Model

The researchers conducted this R&D in the second semester of the Academic Year of 2020/2021. The researchers grouped the research promotion periods into three phases. The researchers the first two hours as the pretest session for the participants. Then, the researchers used the subsequent 6 hours of the lesson to do experiments with the design of modest water pumps to teach fluid mechanics. Then, the researchers used the last two hours to conduct a posttest. The researchers conducted the research at Public SHS 7 Semarang. The subjects were the learners of XI Mathematics & Science Program 3. The total of the sample that joined the pretest and posttest was 24 learners.

The collected data types in this research were quantitative and qualitative data. The researchers obtained the quantitative data from the scientific process skill test while the qualitative data from the experts and the learners' responses. The applied instruments were tests and questionnaires. Then, the researchers collected the data with a science process skill test sheet in the form of an essay and questionnaire for the learners' responses.

The researchers used the general equation of the Gain score as the data analysis technique to determine the improvement of the learners' scientific process skill achievement (Hake, cited in Ariesta & Supartono, 2011). The researchers applied this formula (6).

$$g = \frac{(S_{posttest}) - (S_{pretest})}{Smax - (S_{pretest})} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

Remarks:
Sposttest : posttest score;
Smax : maximum score;
Spretest : pretest score;
g : gain score.

Table 1 provides the criteria for the Gain score. In this step, the researchers calculated the Gain score with the sixth formula (6).

Table 1. The Gain Score criteria

Number	***Gain Score***	**Criteria**
1	g ≥ 0.7	High
2	0.3 ≤ g ≤ 0.7	Moderate
3	g < 0,3	Low

Table 1 shows the guideline to analyze the obtained Gain score criteria from the calculated differences between the pretest and post-test scores. The difference indicated the Gain score result. Then, the researchers interpreted the result descriptively based on the criteria in Table 1. After interpreting the Gain score, the researchers categorized to measure the effectiveness, of the N-Gain, by determining the interpretation criteria as shown in Table 2.

Table 2. The Interpreted Categories of N-Gain Effectiveness

Number	**Percentages**	**Interpretations**
1	< 40	Ineffective
2	40 – 55	Less Effective
3	56 – 75	Fairly Effective
4	> 76	Effective

Table 3 shows the analysis of the learners' responses based on the data conversion from quantitative to qualitative data with the four-scale instrument.

Table 3 The Quantitative-Qualitative Data Conversion of the Learners' Responses with the Four-Scale Instrument

Number	**The score of the Learners**	**Criteria**

1	*R ≥ x + 1.SBx*	Extremely High
2	*x + 1.SBx > R ≥ x*	High
3	*x > R > x – 1.*	Low
4	*R < x – 1.SBx*	Very Low

Remarks:
R = score of the learners' responses
SBx = the standard of deviation from all learners' responses;
X = the average score of all learners' responses.

The design of the modest water pump required some materials and tools, such as a 5-volt dynamo, USB cable, super-sticky glue, wall glue, tenol, solder, injector, straw, and a small diameter pipe (d=0,6 cm), and two bottles. The researchers divided the design into two experiments. They were electric and non-electric water pump designs. The researchers made the non-electric water pump with some bottles. The design was simple with the principle of the inlet water to fill the bottle. Then, the water was sucked at the other tip of the pipe. This process was done by flowing the air to trigger the fluid flow inside of the bottle. This principle applied to aquarium water pumps and they did not need an electrical source. Figure 2 shows the non-electric water pump design.

Figure 2. The Design for Non-Electronic Water Pump

The experiment of the modest water pump was done by:

a) Assembling the parts as shown in Figure 2 (connecting the bottles with a pipe); creating the inlet and outlet water holes;
b) sucking the water with a small pipe from the upper part of the bottle; and
c) calculating the water flow, continuity, and Bernoulli from the water pump design design.

The connections with the physics lesson were the types of water pumps for the experiment. The electrical water pump implementation had the purpose to allow the learners to compare and analyze the types of water pumps. The primary principle of this experiment was to use an electrical source as the primary power in an air-sucking system. Thus, the water could be flown out of the system. The output of this experiment was expected to improve the learners' scientific process skills. Figure 3 shows the concept of the design.

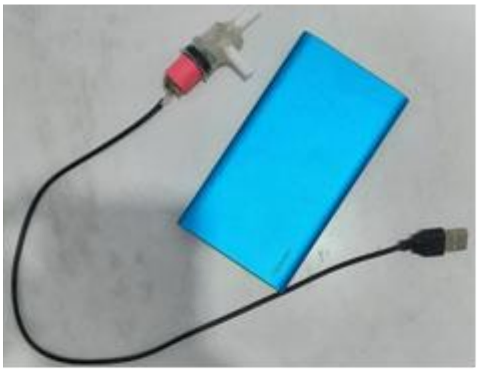

Figure 3. The Design Electronic Water Pump

The experiment procedure of the design was done by:

a) Assembling the dynamo from some unused propellers; connecting the dynamos with USB cables;
b) Creating a valve and a propeller from the injection interception;
c) Creating the inlet and outlet holes for the water;
d) Assembling the parts as shown in Figure 3 by connecting the dynamos with the USB cables as the input;
e) Putting the pump under the water to check the mechanism;
f) Calculating the flow, continuity, and the Bernoulli

RESULTS AND DISCUSSION

1. The Experimental Media Development of the Modest Water Pump Design for Fluid Mechanics

From the practice, the learners could construct their physics concepts and know the physics law from the experiment of a modest water pump design. They could many things from the experiment, including the water flow principle, continuity, and Bernoulli. The researchers began the process of developing the non-electric water pump design with some bottles combined as shown in Figure 2. When the researchers combined these two bottles, the researchers carefully created the inlet and outlet holes for the water. The researchers connected the two bottles with a small pipe to allow the continuous water flow from the pump process mechanism. The efforts to produce smooth flows of inlet-outlet water from the non-electric pump required a sucking process via a small pipe, put on the bottle cap. Thus, the water would leak out continuously.

The experimental media development with the electric modest water pump design required the use of a dynamo and a power bank as the energy source. The researchers started by making the propeller from injection materials. Then, the researchers connected these materials with the dynamo. After that, the researchers made a valve as the holder between the propeller and the internal space of the pump. This position would make the space between the propeller and the inlet-outlet holes vacuum. This situation triggers the mechanism of the electric water pump principle maximally.

In this experiment, the researchers also calculated the impermeability of the internal room of the pump as an unobserved variable to influence the performance of the measurement. Thus, the researchers had to carefully design the modest water pumps, both the electric and non-electric water pumps to be free from leakages. These leakages could stop the mechanism of the pump and even could draw the water upward.

2. The Analysis of Learners' Scientific Process Skills

From the test data of learners' scientific process skills, such as pretest and posttest scores, and the minimum standard mastery score (75), the learners could achieve a minimum standard mastery category with an increased percentage of 87.5%. Figure 4 shows the data analysis percentage of scientific process skills.

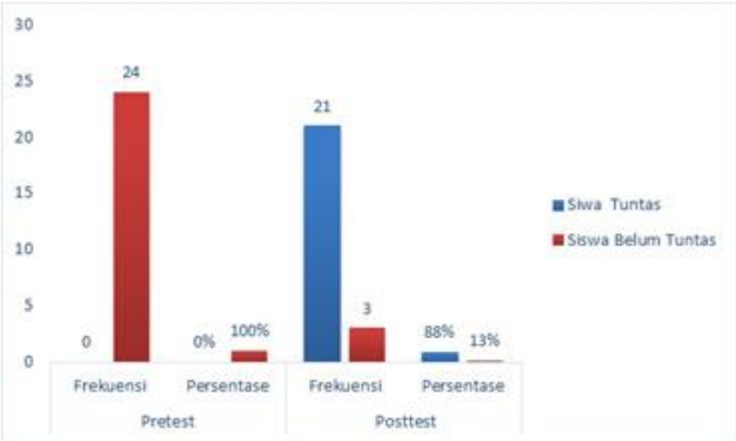

Figure 4. The Analyses of Pretest and Posttests based on the Scientific Process Skill Aspect

Figure 4 shows the successful objective achievement of the design development to teach the mechanics of fluid from the aspect of learners' scientific process skills. The N-Gain score of the learners' scientific process skills shows a "high category." Table 4 shows the detailed results.

Table 4. The Descriptive Analysis of Learners' Scientific Process Skill Gain Scores

Group	N	Minimum	Maximum	Mean
The Gain Score of Scientific Process Skill	24	0.53	0.92	0.71

Table 4 shows the average N-gain score on the learners' scientific process skills is high. The table shows that 17 learners are categorized with high N-gain scores. Then, only seven learners with moderate n-gain score category. The table also shows that the experimental learning activity with a modest water pump design for fluid mechanics could improve the learners' scientific process skills aspect.

The researchers interpreted the N-gain score analysis of learning effectiveness with the design for the scientific process skills. The result showed an average percentage of 72%. Table 2 also shows that the experimental learning activity with a modest water pump design for a fluid mechanic was effective to improve the learners' scientific process skills aspect.

The researchers interpreted the N-gain score analysis of learning effectiveness with the design for the scientific process skills. The result showed an average percentage of 72%. Table 2 also shows that the experimental learning activity with a modest water pump design for a fluid mechanic was effective to improve the learners' scientific process skills aspect.

Based on the analysis results from various studies, the researchers also found a test development to develop learners' scientific process skills. The scientific process skill refers to a set of mental, physical, and competence skills as the instruments in scientific learning, the problem solution fining, and the individual and social development (Akinbobola, 2010; Agustina et al, 2016; Nurlela et al, 2016). The scientific process skill is applicable to get information about the scientific method as the underlying principle in the reasoning process and analysis, to find the facts and concepts. Thus, learners will be more ready to encounter the globalization era (Budiyono et al, 2016; Manu et al, 2018; Hutagalung et al, 2013; Wulaningsih et al, 2012; Maison et al, 2018; Hirça, 2013; Özgelen, 2012; Darmaji et al, 2018; Rahmawati et al, 2018; Hartono et al, 2014; Nworgu et al, 2013).

The constructed instrument in this research was useful to measure the learners' scientific process skills, especially on dynamic fluid material. The primary material, dynamic fluid, became the context for the constructed scientific process skills. In this research, the primary focus was the experiment activity by using the design of a modest water pump to learn dynamic fluids and to improve the scientific process skill of the learners. The applied instruments for the constructed scientific process skills are a four-question item essay to measure the five aspects of scientific process skills. This essay was designed based on seven scientific process skills indicators proposed (Hamalik, 2014). Here are the specifications of the scientific process skill test in this research.

Table 5. The Specification of Scientific Process Skill Test

The Aspects of the Skill	The Indicators of the Skills	The Item Numbers
Observing	- The learners could observe the questions in real-world situations. Thus, they could find the temporal answers or hypotheses from the questions, such as the materials, the applied sources, the variable determination, the measurement determination, and the actions to take.	4
Predicting	- The learners could express the answers about an observed or an unobserved phenomenon. - The learners could find the temporal answer patterns as consideration to determine the initial answers.	4
Hypothesizing	- The learners assumed the temporal answers as the hypotheses.	4
Calculating	- The learners could construct and analyze the answers based on the question arguments in the form of correlation.	4
Drawing conclusion	- The learners could read the graphics, tables, and diagrams. - The learners could describe the empirical data from the observation, experiment, and question analysis. - The learners could transform the presentation.	4

3. The Analysis of Learners' Responses

The implementation of the questionnaire was to obtain the reliability information during the product implementation and the procedure of the product implementation based on the learners' responses. The researchers analyzed the learners' responses related to the experiment result data of the product implementation. The researchers analyzed the data descriptively to explain the calculated results as the guideline to analyze the learners' response categories, as shown in Table 6.

Table 6. The Descriptive Statistics Analysis

	N	Minimum	Maximum	Mean	Std. Deviation	Variance
Scores	24	28	37	31.25	2.069	4.283

Table 6 shows that the mean score is 31.25. The score indicates all learners perceived the product as excellent. The researchers explained the descriptive results into graphics to show the percentage average of the learners' responses. The highest response category consisted of 2 learners, the high category with 8 learners, the fairly high category with 8 learners, and the lowest category with 6 learners. Figure 5 shows the frequency of the learners' responses.

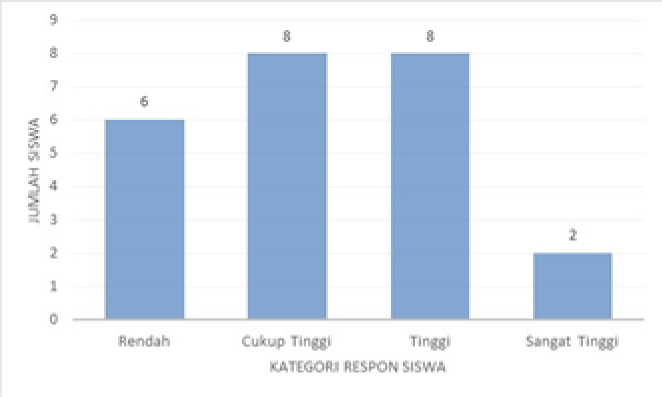

Figure 5. The Analysis of Learners' Response Frequencies

Figure 5 shows the average score percentage of the learners is 31.25%. Thus, the learners' responses are categorized as high. Table 7 provides the calculation results and the learners' responses.

Table 7. The Data Analysis of Learners' Response Categories

Number	Scores of the Learners	Categories	Category
1	R ≥ 33,32	8.34	Extremely High
2	33,32 > R ≥ 31,25	33.33	High
3	31,25 > R ≥ 29,18	33.33	Fairly high
4	R < 29,18	25	Low

Table 7 shows the average percentage of the learners' responses is categorized as 'high.' Based on the applied criteria, the learners' responses indicated the effectiveness of the media. The minimum average score of the learners' responses toward the learning activities component reached the criterion of fairly high while the analysis of the learners' responses was categorized as high. Thus, the developed product was effective to improve the scientific process skill based on the learners' responses.

CONCLUSION

From the results and discussion, the researchers concluded that the developed product with the ADDIE model, the modest water pump design experiment, could improve the scientific process skills of the learners. The product received "excellent category" responses from the learners while learning about fluid mechanics. The experiment result of a modest water pump could be used as an alternative in physics learning media, especially in fluid mechanics.

The researchers suggested further researchers apply the design of the modest water pump on a broader scale. These researchers must apply quasi-experimental research to analyze the differences between the control and experimental groups. Further researchers should consider the efforts to improve STEM literacy. These efforts could be the dependent variable since they are the trend of current research and have implications for learners' technological literacy.

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