Science activity for gifted young scientist: thermodynamics law experiment media based IoT

by Sulhadi 71

Submission date: 02-Aug-2022 01:59PM (UTC+0700)
Submission ID: 1878014617
File name: 2020_Jegys_Yeni_dkk.pdf (943.42K)
Word count: 7939
Character count: 42962

Journal for the Education of Gifted Young Scientists, 8(2), 757-770, June 2020
e-ISSN: 2149- 360X
jegys.org

Young Wise Publishing
youngwisepub.com

Research Article

Science activity for gifted young scientist: thermodynamics law experiment media based IoT

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Article Info

Received: 16 December 2019
Revised: 17 April 2020
Accepted: 08 May 2020
Available online: 15 June 2020

Keywords:
Experiment media
IoT
Thermodynamics law
Science activity for gifted young scientists

Abstract

In this research, thermodynamics law experiments media based IoT was developed and tested. The purpose of this research was to assess the effectiveness of media through a problem-based learning laboratory for gifted young scientists. This research is Research and Development with ADDIE (Analysis, Design, Development, Implementation, and Evaluation) models. The research subjects consisted of four expert validators, two teachers and one groups of 108 students in Senior High School in Batang City, Indonesia. Data were gathered by using questionnaires, observation, and written test. The results of the Normalized-gain test were 0.79 for the experiment class and 0.41 and 0.30 for the control class. This media is easily assembled, based on digital, equipped with manuals and student worksheets. The validation results from the media experts 3.81 (Very Good), the results of the validation from the material experts 3.54 (Very Good) and the results of the physics teacher's responses covering all aspects of the material and multimedia 3.68 (Very Good). The results of the validation show that thermodynamic law experiment media based IoT is appropriate to be used as a medium for learning thermodynamics law.

To cite this article:
Liana, Y.R., Linuwih, S., & Sulhadi. (2020). Science activity for gifted young scientist: thermodynamics law experiment media based IoT. *Journal for the Education of Gifted Young Scientists, 8*(2), 757-770. DOI: http://dx.doi.org/10.17478/jegys.657429

Introduction

Physics is one of main subject in 2013 curriculum Science and Mathematics interest group in Indonesia. Physics Learning applies learning based on concept understanding through the construction of science with active and fun learning through experiments or activities in the laboratory (Alfiyah, Bakri & Raihanati, 2016). Learning physics is not only transferring information but learning physics must provide direct learning experience for students (Kemdikbud, 2019). Direct learning experience can be taught with experiment activity using learning media (Rusydi, 2017). Referring to the cone of Edgar Dale experience, direct experience which has been thought could give more effective understanding and make meaningful learning (Docktor, Strand, Mestre, & Ross, 2015). Success parameter of learning is students can well understand the fundamental theory (Helen Georgiou, Sharma, & Khachan, 2014).

Physics learning provides ability to someone regardless of gender in order to have knowledge and problem solving in the era of globalization in the 21st century (Baran, 2016). The 21st century learning paradigm demands students' ability to think critically, creatively, master information technology, be able to collaborate, and be communicative (Trisdiono & Muda, 2013). One of the purposes of learning physics is to understand the development of science and technology that progress rapidly. This demands good quality in the physics learning process because a good learning process helps students to deal with technology developments. Learning physics plays an important role

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in the development of technology (Abubakar, 2012). The development of information and communication technology can be observed in its application in the learning process, especially in physics learning.

Learning media innovation become an integral part of school learning process (Goovaerts, De Cock, Struyven, & Dehaene, 2019). Learning media as an experimental tool can be used as an alternative to present physics learning to be more interesting (Religia & Achmadi, 2017). Experimentation is a learning method where students are invited to conduct a series of experiments by experiencing and proving subject that is taught in theory. Experiments in the laboratory are expected to create scientific and social behavior, and also develop students curiosity in problem solving (Dostál, 2015). Problem Solving Laboratory (PSL) model facilitates students to carry out practical activities that enable them to practice of becoming gifted young scientists in making decisions based on the physics problems presented (Argaw, Haile, Ayalew & Kuma, 2017). The physics problems can be solved in the laboratory, so that requires students to make decisions based on their physics knowledge (Malik, Novita & Nuryantini, 2019).

The purpose of global education states that 21st-century learning needs to integrate aspects of learning and innovation skills (Erlin Eveline, Suparno, Ardiyati & Dasilva, 2019). Information and Technology development in the era of globalization has entered the era of Internet of Things (IoT) (Muchlis, Sulisworo & Toifur, 2017). IoT is a network that connects various objects that have an IP that enable them to communicate with each other and exchange information about themselves or the environment they perceive (J. He, Lo, Xie & Lartigue, 2016). The idea of IoT is to integrate all these devices into the network, which can be managed from the web and in turn, provide information in real time (we can know their status and features on line) and also allowing the interaction with people who use it (Gómez, Huete, Hoyos, Perez & Grigori, 2013). The presence of IoT provides a new color in the development of learning media innovation (Saputra & Hertanto, 2018). Limitations such as the lack of experimental learning media or visual media can be handled by IoT facility. Opportunities for IoT need to be used more broadly in learning in schools (Muchlis, Sulisworo & Toifur, 2015). Physics learning media that utilize IoT can increase student interest and learning motivation and strengthen knowledge in its entirety (Charmonman, Mongkhonvanit, Ngoc Dieu, & van der Linden, 2020). Agreeing with this, Mohamed, Abdeslam & Lahcen, (2018) stated that IoT has the ability to improve the quality of the learning experience that enables real time insight and can be followed up through performance. This explanation concludes that the use of media in learning is very helpful for students in learning about difficult and abstract physics material.

Based on the results of observations and interviews with XII grade students of senior high school in Batang the most difficult physics material in the Computer-Based National Examination (UNBK) is thermodynamics. Thermodynamics is a branch of physics that studies the relationship between energy and work of a system. Thermodynamics has various concepts and some of them are very abstract, such as the concepts of heat and entropy (Hakim, Liliasari, Setiawan & Saptawati, 2017). Sari, Surantoro and Ekawati (2013) research results states that most students have difficulty understanding the concept of entropy (the second law of thermodynamics). This causes difficulties in the learning process. The application of android-based technology in collaboration with experimental learning can help teachers to overcome difficulties in visualizing abstract concepts (Gunawan, Harjono & Herayanti, 2019).

Observations at several secondary schools in Batang indicate the unavailability of thermodynamic law experiment media and learning media that utilize IoT. One foundational technology of IoT is the Radio-Frequency Identification (RFID) technology, which allows microchips transmit the identification number of the objects to a reader through wireless communication. Through RFID technology, the physical objects can be identified, tracked, and monitored automatically (Dasilva et al. 2019). Students say that the law of thermodynamics is a theory that is difficult to learn and it requires media to understand it (Azizah, Zulaikah & Siti, 2017). Most physics teachers in secondary schools only use informative learning methods that emphasize cognitive skills, whereas the 2013 curriculum requires students to play an active role in the learning process through a scientific approach (Cahyo, Saputro & Admoko, 2019). The obstacle that is often encountered by teachers is the problem of teaching time. The lack of time to do practical work is the main obstacle for teachers. Because, most of the teachers' time is used to pursue teaching materials. Judging from the conditions or facts on the ground, it does not fulfill the expected competencies and learning objectives. In addition, the lack of opportunities for students to have real experience and active learning through experiment activities especially thermodynamic law (Layali & Kartika, 2015). Based on these problems, this research aims to develop experiment media to explain the law of thermodynamics by utilizing the IoT facility which is expected to provide a more concrete learning experience for students and increase the activeness of students in learning.

Problem of Study

Based on these expectations and facts, it is necessary to conduct research aimed at testing (1) the feasibility of thermodynamics law experiment media based IoT through problem-based learning approaches, (2) the practicality and effectiveness of thermodynamics law experiment media based IoT through problem- based learning approaches.

Method

Research Approach

This research uses Research and Development with ADDIE models can be seen in Figure 1 bellow. Mulyatiningsih (2012:34) describes the design stages of the development of ADDIE as follows.

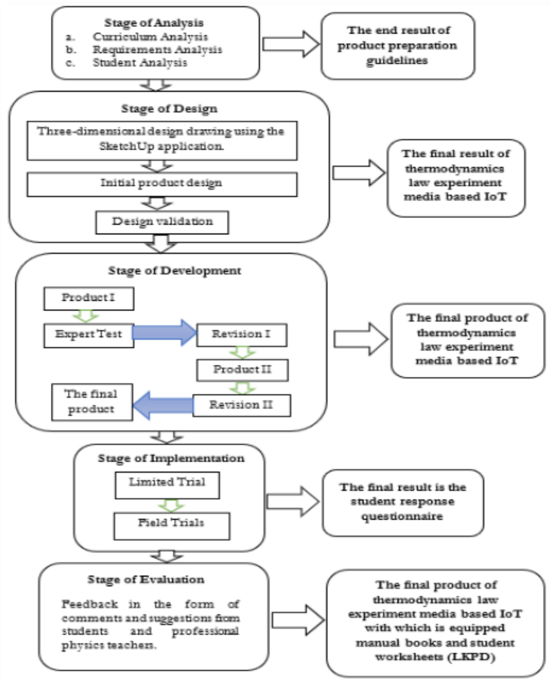


Figure 1.

Development Stages of ADDIE Mode

Participants

The subjects of this study were four lecturers as expert validators, two physics teachers, and three groups in Science 11th grade students in Senior High School 2 Batang, Indonesia. The number of students involved was 108, with 72 students in the control group and 36 people in the experimental group selected using cluster random sampling.

Data Collection

Data collection is done by using interviews, observation and questionnaires. Interviews were conducted with physics teachers and students in the form of questions and answers with the aim of identifying school needs related to experimental learning media and students' obstacles in learning physics. The results of this interview are then used as a reference in developing learning media. Before a limited trial was conducted, the experiment media of thermodynamic law were validated by two expert judgment including the newness of the media, the durability of the experimental instrument components, practicality, precision measurement results, safety for students, efficiency of media and aesthetics utilization. After the revision, limited trials and field trials were carried out. The validation sheet is used to determine the feasibility of the products developed, while the questionnaire sheet is used to determine the response of students to products that have previously been assessed by expert judgment. In addition, the observation sheet is used to determine the implementation of learning using the products that have been developed.

Data Analysis

Analysis of the results of the assessment of the feasibility of thermodynamics law experimental based IoT media, practicality and effectiveness is based on student responses in the form of an assessment in the range of scores from

1 to 4. The average score of each item for all aspects of product assessment is calculated based on the total score of all aspects of the assessment divided by the number of evaluators.

$$\bar{X} = \frac{\sum X}{n}$$

information:

$\bar{X}$ = Average score

$\sum X$ = Total score

n = number of evaluators

Comparing and converting the average score with criteria refers to the category proposed by Widoyoko (2014), as shown in Table 1,

Table 1.

Scale Conversion Intervals of Average Quality Criteria Questionnaire

Score Range	Categories	Indeks
$\bar{X} \geq X_i + 1{,}8\,Sbi$	Excellent	5
$X_i + 0{,}6\,Sbi < \bar{X} \leq X_i + 1{,}8\,Sbi$	Good	4
$X_i - 0{,}6\,Sbi < \bar{X} \leq X_i + 0{,}6\,Sbi$	Fair good	3
$X_i - 1{,}8\,Sbi < \bar{X} \leq X_i - 0{,}6\,Sbi$	Less	2
$\bar{X} \leq X_i - 1{,}8\,Sbi$	Very Less	1

Information:

$\bar{X}$: *Mean* Score

X_i : *Mean* Ideal Score

$$X_i = {}^{1}\!/_{2}\,(maximum\ score + minimum\ score)$$

Sbi : Ideal Standard Deviation of Scores

$$Sbi = {}^{1}\!/_{6}\,(maximum\ score - minimum\ score)$$

Data analysis on the effectiveness of the thermodynamic law experimental media based IoT to student learning outcomes is determined based on the normalized average gain score. N-gain is obtained using the equation by Meltzer (2005).

$$N_{gain} = \frac{S_{Post-test} - S_{Pretest}}{S_{max} - S_{Pretest}} \times 100\%$$

Where N-gain is a normalized gain, S_{max} is the maximum score from the initial test and the final test, S_{post} is the final test score, while S_{pre} is the initial test score. The *N-Gain* scores can be classified as follows: (1) if g > 70, then the *N-Gain* is in the high category, (2) if 30 ≤ g ≤ 70, then the *N-Gain* is in the medium category, and (3) if g < 30, then the *N-Gain* is in the low category. The independent sample test calculation was calculated using the SPSS 21 program for Windows, aimed to differentiate two groups of samples that do not influence each other. The independent sample test calculation was calculated using the SPSS 21 program for Windows, aimed to differentiate two groups of samples that do not influence each other.

Results and Discussion

Stage of Analysis

Analysis stage is a stage that identifies what teachers and students need in learning physics and to identify problems that on the field are directly complained by teachers and senior high school students. This stage consists of three aspects, needs analysis, curriculum analysis and subject of theory analysis (Yono, Marpaung, & Desnita, 2016). Based on the results of a needs analysis for 20 senior high school physics teachers in Batang Regency, we know that learning methods that are often applied in schools still use the discussion model and question and answer models. In addition, there is no teaching model or experiment media of thermodynamic law, so physics learning in high school on thermodynamic law theory still have not applied the basic five learning approach (Observing, Asking, Trying, Reasoning, Communicating).

The 2013 curriculum demands teachers to able to become facilitators, motivators and inspirators for students in the process of finding their own knowledge including the transfer process, level of understanding, ability to predict, problem solving, and translating process (Holme, Luxford & Brandriet, 2015). Implementation of the 2013 curriculum uses three learning models which expected to advance scientific and social behavior also develop a sense of curiosity. The three models are: (1) Discovery/Inquiry Learning Model, (2) Problem-Based Learning Model (3) Project-Based Learning Model (Subali, Lu & Sumpono, 2019).

Based on the high school physics curriculum analysis, Basic Competence 4.7 in thermodynamic law theory is supposed to make a work/model of the first and second law of thermodynamics application and their physical meaning. This requires teachers to be creative and innovative in creating learning media so they can guide students in observing the phenomenon of thermodynamic law through real experiments. The results of high school physics subject analysis based on the Computer Based National Examination (UNBK) average score in 2019, showed that Nationally, students ability to answer thermodynamic subject was 42.51% (Puspendik, 2019). The percentage of indicators related to thermodynamic law material is the lowest among other physical subject achievements, therefore to required learning media which provides real experiments in order to enable students can observe thermodynamic laws directly (Tatar & Oktay, 2011).

Stage of Design

The initial design was made in the form of three-dimensional drawings that were developed using the SketchUp application. Hot and cold water reservoirs are made of acrylic with dimensions of 30 cm × 15 cm × 20 cm which are equipped with a water circulation pipe in the cold water reservoir. The two reservoirs are separated by a thermal wall made of Aluminum Composite Panel (ACP) with 8 Peltier TEG SP1848. Electrical boxes and microcontrollers made of multiplex boards with dimensions of 30 cm × 15 cm × 10 cm are placed under the water reservoir which is equipped with an LCD display and lamp holder. The data displayed on the LCD display are temperature, electric current strength and electric voltage. The product developed is an IoT-based thermodynamic legal experiment media using ATmega328 microcontroller, so that the data generated can be communicated wirelessly using radio to the receiver, by connecting it to the Internet via wifi and sending data to open source sites (Thingspeak.com) as shown in Figure 2.

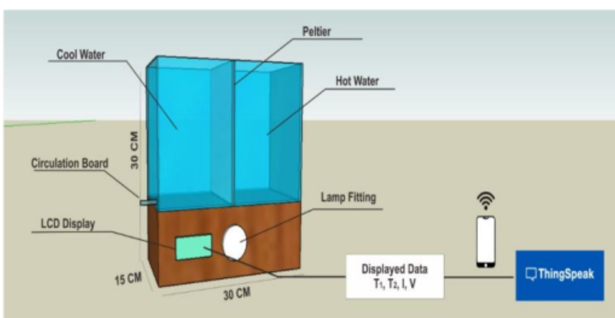


Figure 2.
Thermodynamic Law Experiment Based IoT Media Design

The advantages of thermodynamics law experiment media based IoT which is getting automatic result of measurement done, high temperature (T_1), low temperature (T_2), electric voltage (V) also electric current (I) results can be observed directly in real time through the ThingSpeak website.com on smartphone by typing https://thingspeak.com/channels/channel ID in accordance with the experimental group, shown in Figure 3.

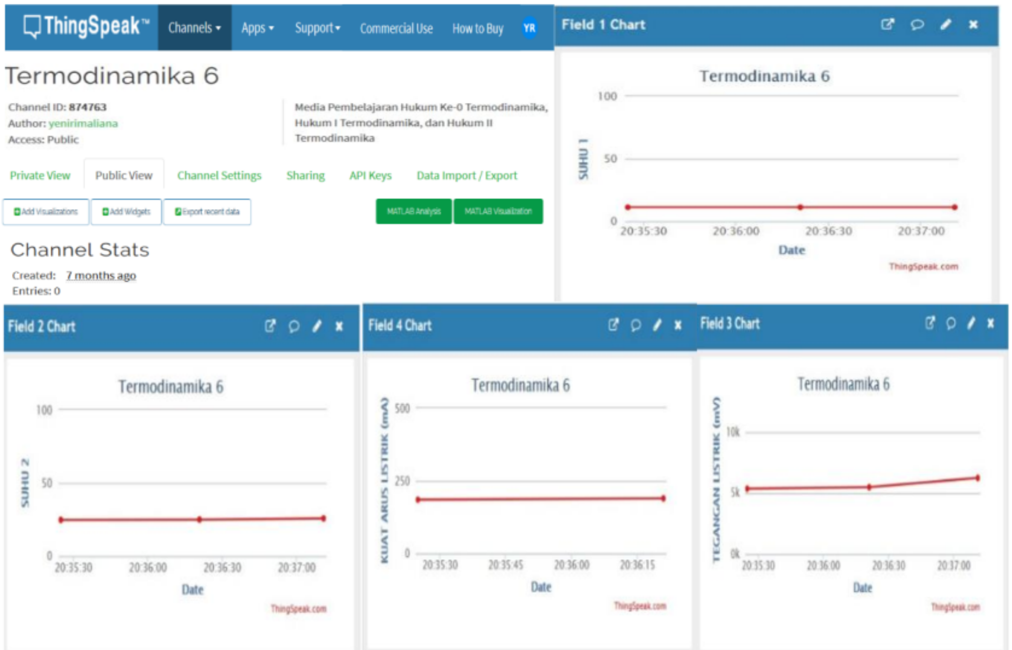


Figure 3.
Public View ThingSpeak Graph on Smartphone

Stage of Development

Hot and Cold Body Reservoir Components (Top)

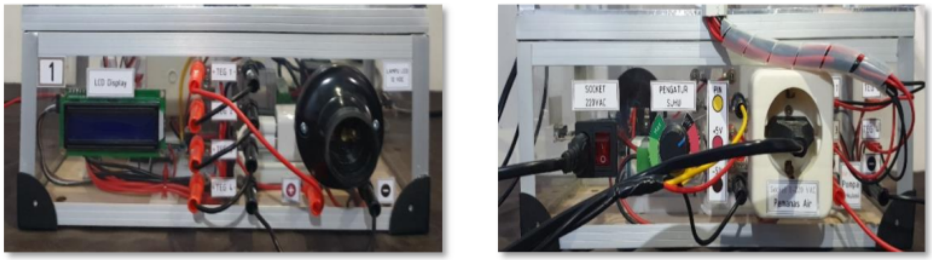
Hot and cold reservoir components are made of acrylic with a thickness of 5 mm. In the boundary plane between the hot and cold reservoirs is given a diatermal seal of ACP with dimensions of 20 cm long, 15 cm wide and 2.5 mm thickness connected in series with eight TEG SP1848 peltiers. The function of the TEG SP1848 peltier is converting heat energy into electrical energy due to the temperature difference between the two reservoirs. The top of both reservoirs are closed with ACP which is equipped with a hole to put the heater and insert two temperature sensors DS18B20, shown in Figure 4.

(a) (b)

Figure 4.
Thermodynamic Law Experiment Media Based IoT (a) Front View and (b) Top View

Electrical Body Components (Bottom)

The electrical components of the front consist of LCD displays, TEG sockets, Jumper cables for TEG 1, TEG 2, TEG 3, and TEG 4, sockets lamp sockets, 12 V DC LED lamp fittings, Jumper cables for light sockets. Whereas the rear electrical component consists of 220 V AC sockets, on / off buttons, temperature control buttons, temperature sensor sockets that are colored yellow, red and black, water heater sockets, TEG sockets, JST Port TEG 1, TEG 2, TEG 3 dan TEG 4, and 5 V DC output terminals for circulating water pumps as shown in Figure 5.



(a) (b)

Figure 5.
Electrical Components of Thermodynamic Law Experiment based IoT Media (a) Front View and (b) Rear View

At this stage, the electrical body component is revised from multiplex to acrylic material based on criticism from media experts and material experts. The goal is that the internal components of the body in the form of a microcontroller and sensor can be seen clearly and add aesthetic factors. In addition, the electronic components inside can be seen and facilitate identification in the event of a failure to read the thermodynamic law experiment data. An electric body was also added an information label that made it easy for students to insert sockets into the thermodynamics experimental media based IoT, such as Figure 6.

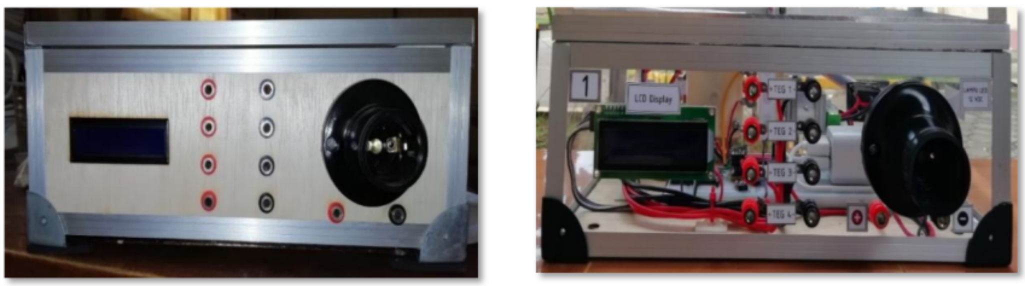


Figure 6. (a) (b)
Electrical Components of Body Thermodynamic Law Experiment Based IoT Media (a) Before Revision and (b) After Revision

Microcontroller Components

The microcontroller components consist of: (1) 830-point breadboard, (2) Arduino Nano version 3.0, (3) ESP8266-01 wifi module, (4) 3.3 Volt AMS, (5) voltage sensor, (6) 5V adapter; 3A, (7) USB cable, (8) NYAF 2.5 mm cable, male to female jumper cable, resistor as shown in Figure 7.

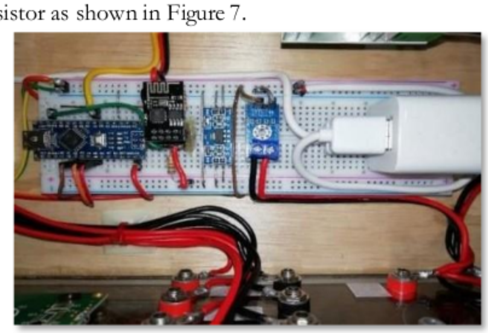


Figure 7.
Microcontroller Components

At this stage the media is tested to find out whether the data obtained is in accordance with the theory or not before validation. The media trials also help find out whether the media is suitable or not. The selection of accurate sensors becomes an obstacle at this stage. The temperature sensor has changed twice, first using the LM35 temperature sensor but because of the medium of water, the sensor does not detect the temperature accurately. The temperature sensor is replaced with a DS18B20 sensor that is resistant to high humidity. This also has an effect on the coding program for the microcontroller. Then the product design is realized, which is to create an IoT-based thermodynamic law experiment media to study the laws of thermodynamics, as shown in Figure 8.

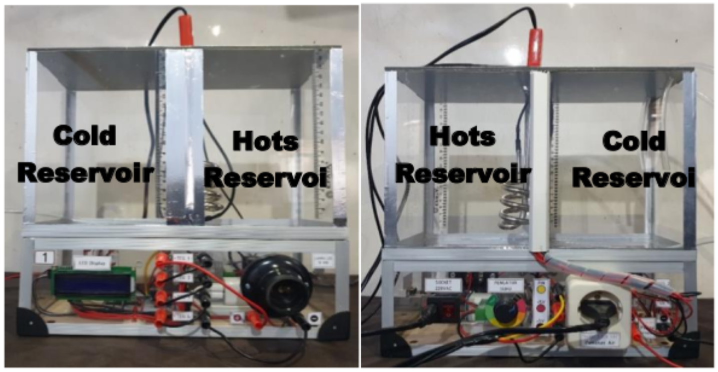


Figure 8.
The Front and Rear of Thermodynamic Experimental Media Based IoT

The process of developing IoT-based thermodynamic legal experiment media is based on the feasibility characteristics of a learning media, which is durable (made of strong enough material), attractive shapes and colors, simple and easy to use (not complicated), can clarify concepts, in accordance with the objectives learning, and can be the basis for the growth of cognitive abilities and 4Cs competency skills (Creativity, Critical thinking, Collaboration, Communication) of students.

Experiments Guide Section

This media is equipped with a thermodynamic law experiment based IoT guide and a Student Worksheet (LKPD) which contain instructions for the use, procedures and practicum for the zero-law thermodynamics law, the first law of thermodynamics, and the second law of thermodynamics as Figure 9. I thermodynamics, and law II thermodynamics as Figure 9.

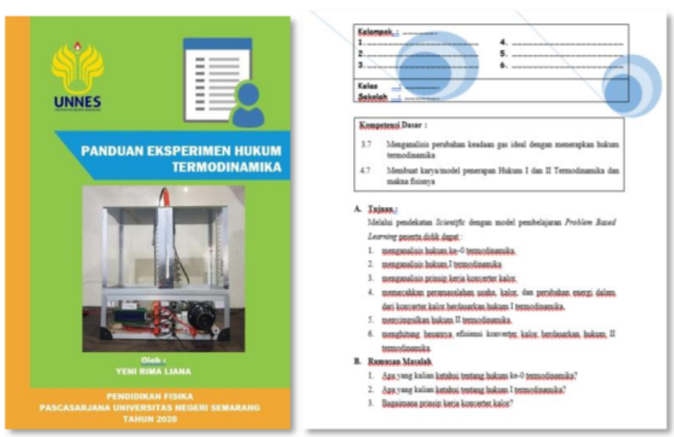


Figure 9.
Thermodynamic Experiment Media Based IoT Guide

Product Validation Results

Thermodynamic law experiment media based IoT that has been revised, then validated by 4 expert judgment (2 material experts and 2 media experts) and 2 professional physics teachers. Each expert was given a questionnaire sheet containing statements relating to the suitability of the media, reviewed from the aspect of the media and material aspects. Data obtained from the assessment of thermodynamic law experiment media based IoT in the form of an assessment in the range of scores from 1 to 4. The average score of each item for all aspects of product evaluation is calculated based on the total score of all aspects of assessment divided by the number of judgments. After that the average score to the criteria converted into categories by using the five-scale grading criteria technique.

The results of the product evaluation based on the media aspect and material aspect were analyzed using a standard five-scale assessment category and categorized according to Table 2.

Table 2.
Feasibility Criteria for Assessment Standard Five- Scale

Range of Scores	Category
$\bar{X} > 3,4$	Very good
$2,8 < \bar{X} \leq 3,4$	Good
$2,2 < \bar{X} \leq 2,8$	Fair
$1,6 < \bar{X} \leq 2,2$	Less good
$\bar{X} \leq 1,6$	Not good

Analysis of the results of the assessment of the feasibility of the media aspects of thermodynamic law experiment based IoT media that have been categorized are presented in Table 3.

Table 3.
Media Expert Validation Results

Aspect	No	Indicators	Rater Rating Score				Average per Item	Categories per Item	Average per aspect	Categories per aspect
			1	2	3	4				
Resilience of Media Components	1	Body Media Resilience	4	4	4	4	4.00	Very good	4.00	Very good
Ease of Conducting Experiments	2	Ease of socket installation	4	4	4	4	4.00	Very good	4.00	Very good
	3	Ease of operation	4	4	4	4	4.00	Very good		
Sensor accuracy	4	Accurate temperature sensor	3	4	4	3	3.50	Very good	3.50	Very good
	5	Accurate voltage sensor	4	3	4	3	3.50	Very good		
Aspect	**No**	**Indicators**	**Rater Rating Score**				**Average per Item**	**Categories per Item**	**Average per aspect**	**Categories per aspect**
			1	**2**	**3**	**4**				
Ease of reading experiment result data	6	Ease of reading experiment results	4	4	4	4	4.00	Very good	3.88	Very good
	7	Ease of reading ThingSpeak Application data	4	3	4	4	3.75	Very good		
Ease of Care	8	Ease of cleaning body media	4	4	4	4	4.00	Very good	3.75	Very good
	9	Ease of detecting reservoir leaks	4	3	4	4	3.75	Very good		
Safety for students	10	Construction of experiment media is safe for students	4	4	4	4	4.00	Very good	4.00	Very good
Aesthetics	11	Experimental media design	4	4	4	4	4.00	Very good	4.00	Very good
	12	Neatness of experiment media	4	4	4	4	4.00	Very good		
Efficient	13	Time efficiency of data retrieval	4	3	3	4	3.50	Very good	3.50	Very good
Average of all aspects									3.84	Very good

The assessment results obtained are quantitative data with a score of 1 to 4. This data is then converted and analyzed using a five-scale rating category as in Table 2. Product evaluation based on sub-aspects of sensor accuracy and experimental time efficiency in Table 3 using a scale 5 rating category gets a value average of 3.50 which is classified as very good category. Ratings provided by the validator are included with suggestions for improvement. Suggestions for improvement given by the validator include the socket is designed more friendly so that it is easily installed and removed by students, so that the experimental time is more efficient and does not affect the sensitivity of the sensor.

The aspect of reading ease of experimental results on ThingSpeak obtained a mean value of 3.75 and was classified as a very good category. Suggestions for improvement given by the validator is that when conducting internet network experiments, it must be stable. Overall analysis of all aspects obtained a mean value of 3.81 and showed that thermodynamics law experiment media based IoT developed were included in the excellent category. These results prove that thermodynamics law experiment media based IoT developed are suitable for use in physics learning activities.

Analysis of the results of the assessment of the feasibility of the material aspects of thermodynamic law experiment based IoT media that have been categorized are presented in Table 4.

Table 4.

Material Expert Validation Results

Aspect	No	Indicator	Rater Rating Score				Average per Item	Categories per Item	Average per aspect	Categories per aspect
			1	2	3	4				
Media suitability with curriculum analysis and requre ment analysis	1	Media conformity and basic competence	4	3	4	4	3.75	Very good	3.81	Very good
	2	Conformity with learning objectives	4	4	4	4	4.00	Very good		
	3	Conformity of student competencies	3	4	4	4	3.75	Very good		
	4	Conformity to media needs in schools	3	4	4	4	3.75	Very good		
Media and material	5	Conformity of media and material	4	4	4	4	4.00	Very good	3.75	Very good
	6	Conformity of thermo dynamics in everyday life	4	2	4	4	3.50	Very good		
Media update on Student problem solving	7	21st century problem solving	3	4	4	4	3.75	Very good	3.69	Very good
	8	the stage of the investigation of the problem is clear	4	4	4	4	4.00	Very good		
	9	Problem solving based experiment guide	3	4	4	4	3.75	Very good		
	10	Problem based questions	3	3	4	3	3.25	Very good		
Average of all aspects									3.75	Very good

Assessment of thermodynamics law experiment media based IoT based on aspects of curriculum analysis and needs analysis in Table 4 using a scale 5 assessment category obtained a mean value of $\bar{X}$= 3.81, which is classified as a very good category. Ratings provided by the validator are included with suggestions for improvement. Suggestions for improvement provided by the validator include researchers adding basic competency skills. Aspects of the suitability of the media with learning material obtained an average value of $\bar{X}$=3.75 and classified as very good category. Suggestions for improvement given by the validator that need to be explained that water can represent the ideal gas system. In the problem-solving aspect, the mean score was $\bar{X}$= 3.69 and classified as very good category. Suggestions for improvement given by the validator are that researchers are asked to improve the steps of the experiment in detail so that it is easy for students to understand. Overall analysis of all aspects obtained a mean value of $\bar{X}$= 3.75 and showed that thermodynamics law experiment media based IoT developed were included in the excellent category. These results prove that thermodynamics law experiment media based IoT developed are suitable for use in physics learning activities.

Stage of Implementation

Limited Trials of Experiment Media

The limited trial of media experiment was carried out into two stages. The first stage One to One Trying Out conducted to 6 students from science grade XI student in Senior High School 1 Pekalongan, Indonesia. While the second stage was Small Group Tryout conducted science grade XI student in Senior High School 2 Batang, Indonesia. On the first stage, the trial was conducted by demonstrating the media to each student individually with the guidance of researchers. After that, the students were interviewed related to the thermodynamic law experiment media that is being developed. In the second stage, the trial was carried out by carrying out experimental activities by six students who were divided into two groups with the guidance of researchers, then students processed the data obtained, conducted interviews, and filled out the questionnaire given.

Field Trials of Experiment Media

The implementation of field trials was carried out at sma negeri 2 batang with a population of 36 students from science grade 11th student in Senior High School 2 Batang, Indonesia. Field trials were carried out through thermodynamic law experiment activities with a problem-solving approach. Stages of problem solving skills: (1) preparing lesson plan in accordance with the syntax of the Problem Based Learning model, (2) students were divided into 6 experiment's groups by the name of the thermodynamics 1 to thermodynamics 6, (3) guide each group into the ThingSpeak.com website using channel ID namely: **https://thingspeak.com/channels/** 924020, 924021, 924024, 944777, 944778, and 874763, (4) each group monitor the results of experiments on the ThingSpeak.com application then select the channel settings, and public view (heat vs. time, cold vs. time, voltage vs. time, and electric current vs. time), (5) students process data to calculate heat the heat reservoir is released, the heat received by the cold reservoir, the electrical energy produced by the heat converter, the energy change in the system, and the efficiency of the converter, (6) students concluded the results of experiments on the zero the zero law of thermodynamics, the first law of thermodynamics and the second law of thermodynamics, the principle of work of a heat converter, and the efficiency of the converter. After completing the experimental activities, conducted interviews and filling out of student response sheets related to the media were developed in the form of comments and suggestions from students about the strengths and weaknesses of this media.

Students' Responses

This limited trial aims to determine the effectiveness of the use of the product based on the students' responses to the thermodynamics law experimental media based on IoT which were previously revised based on the results of expert validation. Student responses used as a basis for product improvement before it is applied to field trials in physics learning. The limited trial subjects were 6 students from XI grade Science students in Senior High School 1 Pekalongan, Indonesia. This assessment includes aspects of learning process, aspects of experimental guidelines, and experimental data obtained from ThingSpeak. During the learning process, students use experimental media to learn thermodynamics. Researchers observe students' attitudes toward the product being developed and provide guidance if problems arise in the use of media. After completing the experimental activities, students fill out a questionnaire about the use of thermodynamics law experiment media based IoT. Assessment is done using students' responses to the questionnaire and assessment of the media. The assessment results obtained are quantitative data with a score of 1 to 4. This data is then converted and analyzed using a five-scale assessment category are presented in Table 5. After that, the students were interviewed related to the thermodynamic law experiment media that is being developed.

Table 5.

Students Responses to Limited Trials

Aspect	Number of participants	Average per aspect	Categories
Learning		3.76	
Experimental guidelines	6	3.50	Very Good
ThingSpeak data		3.24	

Table 5 shows the average value of the learning aspect of 3.76 which is included in very good category, the experimental guidance aspect obtained an average per aspect of 3.50 with a very good category, and the ThingSpeak data aspect of 3.24 with a good category. Suggestions from students regarding IoT-based experimental media is to improve the TEG socket so that it is easier to insert the jumper cable. Overall student assessment of thermodynamics law experiment media based IoT is included in the very good category, so the product is suitable for use in physics learning activities.

Field Trial Results

Field trials aim to determine the effectiveness of IoT-based thermodynamic experimental media in improving students learning outcomes. Field testing is done by applying three steps, namely pretest, treatment and posttest. The test to see an increase in student learning outcomes after using media is done by giving essay questions to the experiment class and the control class. This stage is carried out to see the effectiveness of thermodynamic law experiment media based IoT developed to improving student learning outcomes. The results are presented in Table 6.

Table 6.
Student Learning Outcomes Test Results

Class	Average		N-Gain	Categories
	Pretest	Posttest		
Experimental	31,33	85,77	0.79	High
Control 1	49,99	65,21	0.30	Low
Control 2	49,11	70,22	0.41	Medium

The results showed an increase in student learning outcomes from the experimental group with an average n-gain value of 0.79 included in the high category while the control group's average N-Gain value was 0.30 and 0.41 which were in the low categories and medium categories. Based on the N-Gain score, it shows that the experimental class that uses thermodynamic experimental media based IoT provides improved scores in improving student learning outcomes compared to the control class that uses interactive multimedia based on android and the teacher's general module.

The hypothesis was tested using an independent sample T-test. Based on the results of the independent sample T-test for the experimental and control class, the sig value is 0.018. for decision making criteria for two-sided decisions if the value of sig <0.05, this indicates a significant change in student learning outcomes before and after using thermodynamics law experimental media based IoT between the control and the experiment class.

Stage of Evaluation

The fifth stage is evaluation. At this stage, thermodynamics laws experiment media based IoT trial media that have been applied to students get feedback in the form of comments and suggestions from students about the advantages and disadvantages of this media. The assessment of students' questionnaire responses to the use of thermodynamics law experiment media based IoT using a standardized five-scale rating category that has been categorized are presented in Table 7.

Table 7.
Students Responses to Thermodynamics Law Experiment Media Based IoT

Aspect	Number of participants	Average per aspect	Categories
Learning		3.68	
Experimental guidelines	36	3.14	Good
ThingSpeak data		3.26	

Table 7 shows the average value of the learning aspects of 3.68 included in the very good category, the experimental guidance aspect obtained an average of 3.14 in the good category, and the ThingSpeak data aspect of 3.26 in the good category. The response given by students is included with suggestions for improvement, namely adding a water pump so that the reservoir does not need to be removed from the electricity section to dispose of water after experiment activities are finished and the experiment guide is made more detailed. Overall student assessment of the IoT-based thermodynamic law trial media is included in both categories. Based on the criteria of the five scale aspects are considered positive. Overall student assessment of the thermodynamics law media based IoT is included in either category. So this product is feasible and effective for use in learning physics.

Conclusion and Recommendations

Based on the results of the validation by judgment expert and professional physics teachers, we conclude that the development of thermodynamics law experiment media based IoT for Science grade XI student in Senior High School has a good interpretation and can be applied to learning physics in thermodynamic materials. The advantages of this thermodynamics law experimental media based IoT are digital measurements of temperature, electric current and electric voltage. The advantages of this thermodynamics law experiment media based IoT are temperature measurements, electric current strength and electric voltage are digitally displayed on the LCD display. Experimental data can be accessed directly through the ThingSpeak website on smartphones with the link https://thingspeak.com/channels/ID. Student learning outcomes are emphasized on cognitive and skills competencies. The effectiveness of thermodynamics experimental media based IoT when learning can be seen from the results of student competency, it can be categorized that the use of thermodynamics law experiment media based IoT as a physics learning media on thermodynamic materials is very effective.

The effectiveness of the media can be seen from the results of the N-Gain shows that the experimental class that uses thermodynamics law experiment media based provides improved scores in improving student learning outcomes so that it can be stated that the media is practical as a medium of physics learning on thermodynamic material. The clarity of the learning process can be stated that learning using thermodynamics law experiment media based IoT has been done very well. Student responses were very interested in the use of thermodynamics law experiment media based IoT as a media for learning physics on thermodynamics law material.The author provides suggestions for further research that can develop thermodynamic experimental media that are not only limited to the laws of thermodynamics, but students are involved in creating thermodynamic experimental media from used materials with the STEM approach. Thermodynamic experimental media must be adapted to 21st century skills that are relevant to student learning needs. Finally, the authors also suggest further research to develop thermodynamic learning media that can be combined with HOTS-oriented learning models, to get more in-depth and broader data.

Acknowledgement

Thanks giving for Batang 2 Senior High School headmaster and all participant who help on making media until this research done.

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References

Abubakar, S. (2012). *Role of Physics Education for Technological Development for Employment and Self Productivity in Nigeria*. *2*(November), 166–170. https://doi.org/10.5901/jesr.2012.v2n10p166

Alfiyah, S., Bakri, F., & Raihanati, R. (2016). Pengembangan Set Praktikum Fluida Dinamis untuk Sekolah Menengah Atas (SMA) Kelas XI. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, *02*(2), 47–56. https://doi.org/10.21009/1.02207

Argaw, A.S., Haile, B.B., Ayalew, B.T., & Kuma, S. G. (2017). The effect of problem based learning (PBL) instruction on students' motivation and problem solving skills of physics. *Eurasia Journal of Mathematics, Science and Technology Education*, *13*(3), 857–871.

Azizah, D. N., & Zulaikah, Siti, S. (2017). *Identifikasi Pemahaman Konsep Siswa SMA Pada Materi Termodinamika*. *2*(2015), 134–142.

Baran, M. (2016). An Analysis on High School Students' Perceptions of Physics Courses in Terms of Gender (A Sample from Turkey). *Journal of Education and Training Studies*, *4*(3), 150–160. https://doi.org/10.11114/jets.v4i3.1243

Cahyo, V., Saputro, E., & Admoko, S. (2019). Pengembangan ALat Peraga Mesin Carnot sebagai Media Pembelajaran dengan Model Pembelajaran Inkuiry Terbimbing. *IPF : Inovasi Pendidikan Fisika*, *08*(02), 716–721.

Charmonman, S., Mongkhonvanit, P., Ngoc Dieu, V., & van der Linden, N. (2020). Applications of Internet of Things in E-Learning. *International Journal of the Computer, the Internet and Management*, *23*(3), 1–4.

Christensen, W. M., Meltzer, D. E., & Ogilvie, C. A. (2009). Student ideas regarding entropy and the second law of thermodynamics in an introductory physics course. *American Journal of Physics*, *77*(10), 907–917.

Dasilva, B. E., Ardiyati, T. K., Suparno, Sukardiyono, Eveline, E., Utami, T., & Ferty, Z. N. (2019). Development of Android-based Interactive Physics Mobile Learning Media (IPMLM) with scaffolding learning approach to improve HOTS of high school students. *Journal for the Education of Gifted Young Scientists*, *7*(3), 659–681. https://doi.org/10.17478/jegys.610377

Docktor, J. L., Strand, N. E., Mestre, J. P., & Ross, B. H. (2015). Conceptual problem solving in high school physics. *Physical Review Special Topics - Physics Education Research*, *11*(2), 1–13. https://doi.org/10.1103/PhysRevSTPER.11.020106

Dostál, J. (2015). Theory of Problem Solving. *Procedia - Social and Behavioral Sciences*, *174*, 2798–2805.

Erlin Eveline, Suparno, S., Ardiyati, T. K., & Dasilva, B. E. (2019). Development of Interactive Physics Mobile Learning Media for Enhancing Students' HOTS in Impulse and Momentum with Scaffolding Learning Approach. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, *5*(2), 123–132. https://doi.org/10.21009/1.05207

Georgiou, H., & Sharma, M. D. (2015). Does using active learning in thermodynamics lectures improve students' conceptual understanding and learning experiences? *European Journal of Physics*, *36*(1). https://doi.org/10.1088/0143-0807/36/1/015020

Georgiou, Helen, Sharma, M., & Khachan, J. (2014). Doing Positive Work: On student understanding of thermodynamics.

Gómez, J., Huete, J. F., Hoyos, O., Perez, L., & Grigori, D. (2013). Interaction system based on Internet of things as support for education. *Procedia Computer Science*, *21*, 132–139. https://doi.org/10.1016/j.procs.2013.09.019

Goovaerts, L., De Cock, M., Struyven, K., & Dehaene, W. (2019). Developing a Module to Teach Thermodynamics in an Integrated Way to 16 Year Old Pupils. *European Journal of STEM Education*, *4*(1), 1–11. https://doi.org/10.20897/ejsteme/3964

Gunawan, G., Harjono, A., & Herayanti, L. (2019). *Problem - Based Learning Approach with Supported Interactive Multimedia in Physics Course : Its Effects on Critical Thinking Disposition*. *7*(December), 1075–1089.

Hakim, A., Liliasari, L., Setiawan, A., & Saptawati, G. A. P. (2017). Interactive Multimedia Thermodynamics To Improve Creative Thinking Skill of Physics Prospective Teachers. *Jurnal Pendidikan Fisika Indonesia*, *13*(1), 33–40.

He, J. (Selena), Chia, D., Lo, T., Xie, Y., & Lartigue, J. (2016). Integrating Internet of things (IoT) into STEM undergraduate education: Case study of a modern technology infused courseware for embedded system course. *Proceedings - Frontiers in Education Conference, FIE*, *2016-Novem*. https://doi.org/10.1109/FIE.2016.7757458

He, J., Lo, D. C. T., Xie, Y., & Lartigue, J. (2016). Integrating Internet of things (IoT) into STEM undergraduate education: Case study of a modern technology infused courseware for embedded system course. *Proceedings - Frontiers in Education Conference, FIE*, *2016-Novem*. https://doi.org/10.1109/FIE.2016.7757458

Holme, T. A., Luxford, C. J., & Brandriet, A. (2015). Defining Conceptual Understanding in General Chemistry. *Journal of Chemical Education*, *92*(9), 1477–1483. https://doi.org/10.1021/acs.jchemed.5b00218

Kemdikbud. (2019). Buku Pegangan Pembelajaran Berorientasi pada Keteramplan Berpikir Tingkat Tinggi. In *Direktorat Jenderal Guru dan Tenaga Kependidikan Kementrian Pendidikan dan Kebudayaan*. https://doi.org/10.1017/CBO9781107415324.004

Layali, S., & Kartika, I. (2015). Pengembangan Alat Praktikum Termodinamika Berbasis Problem Based Learning. *Kaunia*, *XI*(2), 136–143.

Malik, A., Novita, Y., & Nuryantini, A. Y. (2019). Enhancing Critical Thinking Skills of Students Related to Temperature and Heat Topics Through Problem Solving- Laboratory Model. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, *5*(1), 9–20.

Meltzer, D. E. (2005). Relation between students' problem-solving performance and representational format. *American Journal of Physics*, *73*(5), 463–478. https://doi.org/10.1119/1.1862636

Mohamed, F., Abdeslam, J., & Lahcen, E. B. (2018). Towards new approach to enhance learning based on internet of things and virtual reality. *ACM International Conference Proceeding Series*. https://doi.org/10.1145/3230905.3230955

Muchlis, F., Sulisworo, D., & Toifur, M. (2015). *Pengembangan Alat Peraga Fisika Berbasis Internet of Things untuk Praktikum Hukum II Newton*. *6*(1), 1–8.

Muchlis, F., Sulisworo, D., & Toifur, M. (2017). Pengembangan Alat Peraga Fisika Berbasis Internet of Things. *Jurnal Pendidikan Fisika Unversitas Muhammadiyah Makasar*, *6*, 13–20.

Mulyatiningsih, E. (2020). *Research and development*. Yogyakarta: Universitas Negeri Yogyakarta.

Prihatmoko, D. (2016). Penerapan Internet of Things (IoT) dalam Pembelajaran di UNISNU Jepara. *Simetris : Jurnal Teknik Mesin, Elektro Dan Ilmu Komputer*, *7*(2), 567. https://doi.org/10.24176/simet.v7i2.769

Puspendik. (2019). Ringkasan Eksekutif Hasil UN SMA/MA dan SMK Tahun 2019. In *Kementerian Pendidikan dan Kecudayaan*.

Religia, R., & Achmadi, H. R. (2017). Pengembangan KIT Sederhana Stirling Engine pada Materi Termodinamika sebagai Media Pembelajaran Fisika SMA. *Inovasi Pendidikan Fisika*, *6*(3), 113–119.

Rusydi, R. (2017). Pembelajaran Berbasis Masalah (Pbm) Pada Materi Termodinamika Untuk Meningkatkan Kemampuan Kognitif Dan Kemampuan Kreatif (Kreativitas) Mahasiswa Ftk Uin Ar-Raniry Banda Aceh. *Jurnal IPA & Pembelajaran IPA*, *1*(2), 192–202. https://doi.org/10.24815/jipi.v1i2.9694

Saputra, R. H., & Hertanto, D. B. (2018). Media Berbasis Teknologi Internet of Things (Iot) Mata Pelajaran Teknik Mikroprosesor Di Kelas X Audio Video Smk N 3 Yogyakarta. *E-Journal Universitas Negeri Yogyakarta*, (3), 131–138.

Siti Aminah, N. (2013). Jurnal Materi dan Pembelajaran Fisika (JMPF). *Jurnal Materi Dan Pembelajaran Fisika (JMPF)*, *3*(2), 33–39.

Subali, B., Lu, Z., & Sumpono, I. (2019). Development of Ultrasonic Sensors Based Mechanical Energy Experiments. *Jurnal Pendidikan Fisika Indonesia*, *15*(1), 29–38. https://doi.org/10.15294/jpfi.v15i1.19308

Tatar, E., & Oktay, M. (2011). The effectiveness of problem-based learning on teaching the first law of thermodynamics. *Research in Science and Technological Education*, *29*(3), 315–332. https://doi.org/10.1080/02635143.2011.599318

Trisdiono, H., & Muda, W. (2013).Strategi Pembelajaran Abad 21. *Jurnal Lembaga Penjaminan Mutu Pendidikan Prov.DIYogyakarta*, p.4.

Widyoko, S. E. P. (2017). *Teknik Penyusunan Instrumen Penelitian*. (6th ed). Yogyakarta: Pustaka Belajar.

Yono, N. T., Marpaung, M. A., & Desnita, D. (2016). Pengembangan Media Pembelajaran Termoelektrik Generator sebagai Sumber Energi. *Jurnal Penelitian & Pengembangan Pendidikan Fisika*, *02*(2), 65–70. https://doi.org/10.21009/1.02209

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