



Development of Internet of Things Based Learning Media Through STEM Investigative Science Learning Environment Approach to Improve Student Learning Outcomes

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Abstract: This study aims to design and implement IoT-based media using the STEM-based ISLE model to improve student learning outcomes. This type of research uses Research and Development with the Dick & Carrey development model. The products produced are teaching aids based on the Internet of Things (IoT), student worksheet, and lesson plan. The IoT-based teaching aids were developed using Long Range Area (LoRa) SX1276, Raspberry Pi 3 Model B+, Arduino Uno, and DHT11 sensors, the data is displayed on the ThingSpeak web which has been integrated with the TTN (The Things Network) web for analysis by students. The results of the validation of teaching aids by media experts showed an average value of 4.20, material experts got an average value of 4.16, and observer teachers 4.83 which showed that the teaching aids were feasible to be applied. Validation was also carried out on student worksheets and lesson plans, the average value of student worksheets validation by media experts showed a value of 4.75, while by material experts 3.99 and by teacher observers 5, therefore student worksheets were feasible to be applied in the learning process, as well as with lesson plans with a validation value of 4.33. The results of the pre and post-test student learning outcomes showed an increase in the completeness of 70%. These results indicate that IoT-based media and products developed are feasible to be applied and can improve student learning outcomes in the learning process.

Keywords: Learning media; IoT; STEM approach; ISLE; Learning outcomes

Introduction

Based on the latest research conducted by TIMSS (Trend in International Mathematics and Science Study), the average ability of Indonesian students in the field of science is at the bottom. Indonesia got a score of 397 for Mathematics and placed Indonesia at 45th out of 50 countries, while in the field of science, Indonesia was 45th out of 48 countries, where only 4% of the answers were correct (TIMSS, 2015). Therefore, many methods, approaches, and learning media have been developed to improve the average ability of students in physics or science, one of which is through the Science, Technology, Engineering, Mathematics (STEM) approach.

STEM is known as an applied learning method that uses an inter-science approach. The STEM approach is

applied in learning the fields of study of chemistry, physics, biology, and mathematics. STEM applications are accompanied by active and problem-solving-based learning to train students to think critically, analytically, and focus on solutions. With the existence of STEM education, each individual can compete globally to face various changes or progress that is more complex. In addition, individuals are not fixated on one field only, so apart from being capable in the field they are involved in, they are also able to utilize technology according to the field they are engaged in.

Along with the rapid development of technology that is happening today, jobs that were originally done by humans may be replaced by robots someday, just as when the first-generation industrial revolution occurred, where human work was replaced by steam engines, it is not impossible, in the revolution era. In this

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fourth-generation industry, more technical jobs will be replaced by robots or machines. Currently, many routine and daily jobs have been taken over by machines, some jobs cannot be taken over by machines or robots in *kompasiana* (Harusilo, 2018) including the ability to solve problems (problem-solving), adapt (adaptability), collaborate (collaboration), leadership (leadership), creativity and innovation (creativity and innovation), these abilities are contained in the objectives of the 2013 curriculum. Therefore, it is necessary to improve the ability of human resources in the ability to solve problems, collaboration, creativity, innovation, etc.

At this time, there have been many innovations in the field of education to increase student motivation and improve student abilities needed to face the industrial era including, Sunyoung Han researched the STEM approach with Project-Based Learning (PBL) on student achievement, and the results of the research he got showed increasing student achievement using the STEM approach with PBL (Han et al., 2015). Widya Nessa also did the same thing, the results of her research show that book products based on the STEM PBL (Project Based Learning) approach can increase the percentage of student graduation on the KKM score. However, the two researchers above did not apply the use of technology in their research (Nessa et al., 2017). Moreover, in the current era, technology is very close to everyday life there are almost no middle school students who do not understand technology, so, according to the author, integrating technology into learning can increase students' interest in studying physics or science and later can also improve student achievement.

To be able to develop students' critical thinking skills, collaboration, etc., depends on the teacher knowing how these abilities are explored or developed (Bayindir & Inan, 2008). Most teachers still apply conventional learning, where the learning process in general only trains convergent thinking processes, so that when faced with a problem, students will have difficulty solving the problem creatively and innovatively (Munandar, 2001). Students' creative thinking skills are still relatively low because students have not been able to think flexibly in solving a problem (Wahyuni et al, 2021). A teacher needs to use a learning approach that can train students' creative thinking skills. One of the learning approaches that can be used to train creative thinking skills is the STEM learning approach (Beers, 2011). In addition to using the right learning approach, appropriate learning media and teaching materials are needed to improve students' ability to solve problems, be creative, and think critically. Teaching materials are important in improving students' abilities, one of which is student worksheets (Kaymakci, 2012). In applying learning media that have been designed in the learning process, guidelines are needed for students in carrying out the learning process, one of

which is using student worksheets. A student worksheet is teaching material that is packaged in an integrated manner so that it allows students to study the material independently (Suyanto et al., 2011). However, most of the student worksheets used today do not facilitate students to develop problem-solving, creative, and independent skills in the learning process. The student worksheet contains brief material and questions that students have to work on, although it can support students in learning, it is still not effective as seen from the low level of student activity and students have not demonstrated the skills required in the 2013 curriculum (Putri, 2015). Whereas worksheets should contain work that makes students more active in taking meaning from the learning process (Ozmen & Yildirim, 2005).

Pertiwi in her article made observations about the use of teaching materials. The results of the observations revealed that 68% of teachers had provided opportunities for students to ask various questions, answers, and ideas. However, students still find it difficult to convey various, different, and detailed questions, answers, and ideas. For the use of a worksheet, 60% of teachers stated that they had used a worksheet, where they worksheet used did not present contextual materials related to science, technology, engineering, and mathematics which had implications for improving students' creative thinking skills. All teachers stated that they did not know what the STEM approach was in learning, so it can be said that the teacher had never applied the STEM approach in learning (Pertiwi, 2017).

This study aims to develop media and student worksheets to see the environmental temperature, this material is related to the topic of thermodynamics and the effects of global warming. Global warming is one of the environmental problems caused by the increase in the average temperature of the earth's surface due to the increase in greenhouse gas emissions in the atmosphere. The impact caused by global warming can be reduced by understanding the impact of global warming so that the topic of global warming is included in the material at the junior and senior secondary levels since the implementation of the 2013 curriculum, this is done to require students to use critical thinking skills to meet the achievements of the 2013 curriculum. conducted by Shepardson et al in 2011 explained that there are still middle-level students from the Midwest who do not understand the greenhouse effect and the types of radiation included in the greenhouse effect (Shepardson et al., 2011). Bahroni in his research also explains that the main problem at SMP Negeri 21 Surabaya is the lack of innovation that teachers have to support learning activities, especially on climate change and global warming material, this material requires a lot of reading activities, making students bored so that the material being studied is difficult for students to understand

(Bahroin, 2017). Likewise, the initial observations made by researchers on 18 physics teachers in Banda Aceh and Aceh Besar regarding the implementation of the learning process on global warming material, where 88.9% answered that global warming material was not effective because the material at the end of the semester and 9 of 18 teachers only just give assignments on this material (Personal communication, November 2019). Therefore, researchers consider it important to take the topic of global warming for the development of IoT-based media. The developed IoT-based media is to study the environmental temperature. The variables studied are displayed on the cloud for analysis by students, visualization can help students in the learning process such as Pike's research written in Melvin Active Learning book, by adding visual media in the learning process, will improve memory from 14% to 23% (Melvin, 2007), therefore technology plays an important role in improving students' memory and understanding.

Therefore, the integration of technology that can answer the challenges of the fourth-generation industrial era in the learning process needs to be done, the STEM approach can train the abilities and skills of students required in the 2013 curriculum and is appropriate to use in compiling student worksheet for the developed media.

Method

The type of research and research approach used in this research is Research and Development (R&D). The development carried out is developing an Investigative Science Learning Environment (ISLE) learning media with a STEM approach. The student worksheet development model used in this study is the Dick and Carey model.

This study develops Student Worksheet using the STEM-based ISLE learning model and learning media in the form of IoT products/props that are connected to sensors to read air temperature and humidity. The feasibility level of the developed learning media was assessed based on validation by material experts, media experts, validation by field teachers, and student trials.

The material chosen in this study is related to the effects of global warming. Based on the physical variables, namely temperature, and humidity (T), the device used in this experiment is a series of temperature and humidity sensors connected to Arduino which is integrated with IoT. The sensor is assembled on an IoT-based Arduino which is then connected to LoRa (Long Range Area), this LoRa is then connected to the LoRaWAN Gateway. The product developed in this research is Low-Cost LORAWAN technology with components that are easy to obtain and low cost. The components used are Raspberry Pi 3 B+, Arduino Uno, and several LoRa RFM96 or SX1276 transceivers. The

software uses `single_chan_pkt_fwd` as a gateway and the Arduino-LMIC (LoRaMAC-in-C) library as a node.

After designing the experiment and analyzing the data, then the worksheet is designed, the student worksheet to be designed is the global warming effect worksheet, the worksheet is designed based on the Investigative Science Learning Environment (ISLE) pedagogic element, then the worksheet is tested, in this case, whether the worksheet is appropriate based on ISLE syntax or not, this test will be carried out by experts, if it is not appropriate then repairs will be made, if appropriate, the student worksheet will be tested at Class XI Senior High School, in this case, the Unsyiah Laboratory High School.

This research was conducted at the Unsyiah Laboratory High School, especially in class XI IPA, there are three classes and the research target is only 1 class consisting of 35 students. The research subjects included experts/experts, high school physics teachers, and one class of senior high school students in the student readability test, in this case, the Unsyiah Laboratory High School.

The data in this development research were obtained through a questionnaire/questionnaire instrument. Analysis of research data was carried out using qualitative and quantitative approaches. The data in the form of suggestions and criticisms from experts/experts and students were analyzed with a qualitative approach, while the data on the feasibility of the module and opinions regarding the suitability of the module were processed using a quantitative descriptive approach.

The maximum score on the rating scale is 5 and the minimum score is 1, teaching aids, student worksheets, and lesson plans can be used if the results of the validation analysis are in the good or very good category (4 or 5). The guideline for the assessment student worksheet category is shown in Table 1.

Table 1. Guidelines for the average category of student worksheet validation scores

Interval Skor	Criteria
$\bar{x} > 4,20$	Very Good
$3,4 < \bar{x} \leq 4,20$	Good
$2,6 < \bar{x} \leq 3,4$	Enough
$1,8 < \bar{x} \leq 2,6$	Less
$\bar{x} \leq 1,8$	Very Less

(Widoyoko, 2015)

Analysis of student learning outcomes was done by looking at and comparing the pretest and posttest data. Data about student learning outcomes were analyzed descriptively by using the terms of completeness of learning outcomes. Completeness of learning outcomes according to the Ministry of Education and Culture (Trianto, 2009) is achieved if 85% of students reach the

set score of 75. Then calculate the percentage of classical completeness using the following Formula 1.

$$P = \frac{T}{n} \times 100\% \tag{1}$$

Information:

P = classic completion percentage

T = many students have completed

n = many students

Then the percentage of completeness is converted into qualitative data based on Table 2.

Table 2. Classical completeness percentage category

Score Interval	Criteria
$P > 80$	Very Good
$70 < P \leq 80$	Good
$60 < P \leq 70$	Enough
$50 < P \leq 60$	Less
$P \leq 50$	Very Less

Result and Discussion

Based on the validation data for teaching aids, lesson plans, and student worksheets that have been done to media experts, material experts, and teacher assessments, it can be analyzed that the average total validation is in the very good category, which means that the developed media is feasible to be applied in the learning process with little revision.

Table 3. Props Validation Result Data

No	Validator	Assessment Aspect	Score
1	Media Expert	Tool resistance	4.17
		Tool accuracy	3.92
		Tool efficiency	4.50
		Aesthetics	4.50
		Security	4.13
		Kit box	4.00
Average			4.20
2	Materi Expert	Linkage with teaching materials	4.00
		Educational value	4.50
		Tool efficiency	4.00
Average			4.17
3	Teacher Assessment	Linkage with teaching materials	4.80
		Tool resistance	4.80
		Tool accuracy	4.30
		Tool efficiency	5.00
		Security	5.00
		Estetika	5.00
		Technical	4.70
		Kit Kbox	5.00
		Average	

Table 4. Student Worksheet Validation Results

No	Validator	Assessment Aspect	Score
1	Media Expert	Design Quality	4.39
		Communicative	4.89
		Conformity to the level of development of students	5.00
		Average	4.76
2	Media Expert	Content eligibility	3.89
		Serving eligibility	3.58
		Language eligibility	4.50
Average			3.99
3	Teacher Assessment	Content eligibility	5.00
		Serving eligibility	5.00
		Language eligibility	5.00
Average			4.52

Table 5. Lesson PLAN Validation Results

Assessment Aspect	Assessment Criteria	Average Per Criteria	
Design Quality	Completeness of lesson plan identity	4.33	
	Completeness of Core Competencies, Basic Competencies, and Competency Achievement Indicators and Learning Objectives	4.33	
	Efficient and effective time allocation	4.00	
	There are aspects of science, technology, engineering, and mathematics	4.67	
	Learning activities are following the ISLE-based STEM approach	4.00	
	Media, tools and learning resources used	4.67	
	Average		4.33

After the teaching aids, student worksheets, and lesson plans are valid, student worksheets and lesson plans are valid so that a trial is carried out in schools to observe the learning outcomes obtained by students on global warming material after applying IOT-based learning media (internet of things) through the STEM ISLE approach. (Investigative Science Learning Environment), this is done by giving pretest and post-test questions regarding the material on the effects of global warming. The pretest was conducted before starting the learning process, the pretest consisted of 6 questions about the material on the effects of global warming. The pretest is said to be complete if students get a minimum score of 75, if below 75 the pretest is incomplete, as well as the posttest, the percentage of students' completeness in the pretest and posttest is presented in Table 6.

Table 6. Percentage of students' completeness on pretest and posttest

Description	Pretest Percentage (%)	Posttest Percentage (%)
Complete	20	90
Not Complete	80	10

The Table 6 shows the data on the percentage of completeness of students who meet the KKM score (75) before the learning process is carried out and after the learning process, there is a significant increase from pretest to post-test, at the time of pretest only 20% of students completed and 80% of students who incomplete, and posttest was carried out, the percentage of completeness increased to 90% and only 10% of students did not complete.

Based on the results of the analysis, the data on student learning outcomes increased significantly, as explained in the previous subchapter, the student's level of completeness increased by 70%, but when viewed from the average pretest and post-test scores, the increase in scores from pretest to posttest was 28%, students are said to be complete if it gets a score of more than or equal to 75, the increase in the value in the posttest is dominated by questions about the notion of global warming and questions about the notion of the greenhouse effect, at the time of the pretest 8 out of 10 students could not answer the question, while on the question of the temperature relationship and humidity and the relationship between temperature and air quality, 4 out of 10 students still did not answer the question correctly, after the learning process the student's test scores increased to meet the minimum completeness score, this shows the learning process can improve students' understanding.

Following the theory put forward by Bruner (Tung, 2015) that the learning process will run well and creatively if the teacher allows students to find their own rules through concepts, theories, definitions, and so on. The STEM-based ISLE student worksheet leads students to find their concepts about the effects of global warming. In addition to being valid for use by students, STEM-based ISLE worksheets also guide the development of students' ideas, including (1) observing phenomena and looking for patterns, (2) developing explanations for patterns, (3) using these explanations to make predictions about the results of experimental testing, (4) decide whether the results of the test experiment are following the predictions, and (5) revise the explanation if necessary, to encourage students to learn in a fun and effective ways used in learning because they can make students construct (build) their knowledge about the global warming phenomenon. Researchers also hope that carrying out the learning process on this material, will make students more curious about the latest technology and more aware of the importance of protecting the environment.

In the teaching and learning process, the researchers observed, that students preferred to study outdoors, and were excited when using IoT-based teaching aids, but students still had difficulty finding their own without any direction from the teacher, this happened because students were not used to doing this. the process of investigation, the process of curiosity, and critical thinking are needed in the learning process with the ISLE model. The learning process by self-discovery can increase students' understanding in finding new concepts in the learning process (Persada, 2016), therefore, the investigation process is considered important by researchers to be honed for students.

In the learning process, the researchers found that students were more enthusiastic about learning physics if the teacher could make the learning process fun and not be too fixated on formulas. The ISLE model leads students not to introduce the formula first, but the process of getting the relationship between variables, so that they get the expected equation.

The ISLE model takes a long time to be used in the learning process to be able to lead students to find their patterns and relationships between variables in learning, especially if it is applied to students who rarely use the investigative process in the learning process.

Learning media in the form of teaching aids and products in the form of learning process instruments are considered feasible to be applied, this is based on the validity of teaching aids, student worksheets, and lesson-learning which is classified as very good, and based on student responses after the learning process which shows the learning process using IoT-based media with an IoT-based approach. ISLE-based STEM with very good implementation, as well as student activities during the learning process, the ISLE learning model makes students think critically, innovatively, and collaboratively in the learning process. Thus, the learning media developed is very feasible to be applied in the learning process.

Research conducted by Rahmayani on the development of ISLE-based STEM learning media on the topic of a simple pendulum using the ADDIE development model (Analysis-Design-Develop-Implement-Evaluate) showed the percentage of student responses to learning reached 85% which showed positive student responses to learning using developed learning media. These results indicate that ISLE Based STEM learning media can improve student learning outcomes (Rahmayani, 2019). Physics learning in the 21st century, prioritizes skills, creativity, problem-solving abilities, interacting and making students continue to develop from time to time as well as how physics should be taught in the future. To meet these learning objectives, one of them needs to be researched with the ISLE and STEM learning models initiated by Etkina (Bao & Koenig, 2019). Another study conducted

by Alphonsus on the effect of applying the ISLE model to the topic of electrical circuits showed a significant increase in learning outcomes when using the ISLE learning model compared to the use of other learning models in the daily learning process. Learning with the STEM approach integrates several aspects, namely aspects of science, technology, engineering, and mathematics in a learning process. In this study on the topic of global warming, several aspects can be integrated including the scientific aspect in the form of pollution which is a chemical compound where the increase in pollution causes an increase in the earth's surface temperature. The technological aspect is using IoT technology with LoRa. The mathematical aspect of the learning process invites students to find the relationship between temperature and humidity, the relationship between temperature and air quality, and analyze the resulting graph of the relationship between the two. Students discuss these aspects in the learning process.

Conclusion

To apply media in the learning process on the topic of global warming effects, products such as student worksheets and lesson plans were developed, and student worksheets and lesson plans were developed using the Dick & Carrey model. In the development process, the product is validated by a media and material validator, based on the validation results, the media in the form of teaching aids is feasible to be applied in the learning process with a media expert validation value of 4.2 and material expert validation 4.17, as well as student worksheet, getting a validation value by media experts 4.75 and by material experts 3.99, which indicate that this student worksheet is feasible to use, as is the case with lesson plans which get a validation value of 4.33. The assessment by the physics teacher also received a very good category with an average of 5. The Internet of Things and student worksheet teaching aids developed using the STEM approach with the ISLE learning model can improve student learning outcomes on the topic of global warming, this is indicated by the increasing pretest and post-test results. There is a difference in the percentage of completeness during the pretest and posttest, at the time of the pretest only 20% of students were completed, while at the posttest, which was conducted after the learning process, the percentage of completeness was 90%.

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