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# Developing worksheets through ISLE-based STEM approach and implementing them on senior high school students

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**Abstract.** The Indonesian 2013 curriculum demands that a learning process emphasize three domains, namely attitude, knowledge, and skills. One learning environment that supports the curriculum is the *Investigative Science Learning Environment* (ISLE), which is based on Science, Technology, Engineering, and Mathematics (STEM). The ISLE-based STEM approach is a learning approach that encourages students to be active, creative and innovative in conducting observations and experiments on a project. The ISLE-based STEM method can help students solve actual scientific problems through collaborative group activities. The development of worksheets lays an important role in ISLE-based STEM approach. The purpose of this study was to develop worksheets of the ISLE-based STEM by gathering feedback and learning outcomes from grade 10 high-school students in Banda Aceh. This research employed the ADDIE (*Analysis-Design-Develop-Implement-Evaluate*) development model. The result of the analysis of worksheet validation by experts reached 3.91, indicating a valid criterion for a worksheet to be used in a learning process. The percentage of students' responses to learning was 85%, indicating positive students' responses to learning using worksheets developed, while the test of learning outcomes after the implementation of ISLE-based STEM approach reached 86%. These results indicate that ISLE-based STEM worksheets can be used for grade 10 high-school students.

## 1. Introduction

Physics is a branch of science that is expected to contribute to the development of the quality of human resources because of its importance in the advancement of science and technology. Due to the great role of physics in responding to global challenges and supporting technological advances, it is necessary to improve the process of learning physics so as to improve the quality of education. In fact, the quality of physics learning in schools is currently still low [11]. This fact is evident from the substantial number of learning materials that are not suitable for the teaching time and the learning process in the classroom, thus causing ineffective learning activities. In addition, the process of physics learning in Indonesia is mostly still largely based on "traditional" education system in which educators and students regularly meet face to face at a certain time in the classroom [7].

The Indonesian 2013 curriculum (K-13) requires that a learning process, including physics learning, be focused on three domains, namely attitude, knowledge, and skills [6]. K-13 emphasizes the modern pedagogic dimension in learning and students are expected to be able to dig, process, and present the information through observation, inquiry, and experiment before analysis, reasoning, conclusion, and creation are performed. The development of science and technology in the world has resulted in a thorough change in the world of education. The change is to improve the quality of education. Today there are evolving thoughts about a collaborative discipline known as STEM



education, which focuses on the educational process of solving problems in everyday life by integrating into science, technology, engineering and mathematics [9].

Students in Indonesia need a learning process that can help them develop their identity and ability as a scientist. One approach to learning that can support the 2013 curriculum is the ISLE-based STEM. ISLE (*Investigative Science Learning Environment*) is an environmental science investigation approach. According to Etkina, ISLE is an educational framework that can guide instructional design and student learning [4]. It engages students in processes that reflect scientific practice in order to help them learn physics.

Thus, the core of ISLE's approach is to link any learning subject or topic with real life. Drawing the connection can be done in many ways. The material that is being studied can be linked directly to factual conditions or accompanied by illustrations or examples, learning resources, media, etc., which are either directly or indirectly pursued related or their relationships with real-life experiences.

Thus, learning will be more interesting since students can directly feel the direct benefits of what is learned. Most students often complain that the system of teaching and learning in schools is still focused on solving the problems in the books. This concern was expressed by some high school students in Banda Aceh when the researchers made observations in their school. If this condition continues to happen, the reasoning ability of some Indonesian students especially Acehese is going to decrease. Whereas in order to apply the acquired knowledge, one must have a basic scientific whole where one must be able to apply the knowledge they have in solving everyday problems. In addition, the students do not understand the basic concepts of the topics being studied.

According to Arsyad [1], the use of learning media in teaching and learning process can produce new desires and interests, generate motivation and learning stimuli, and even bring influence to the psychological development of students. Interesting teaching approach can encourage students to learn one of them by using learning media. One of the learning media is student worksheet. Trianto [12] stated that a student worksheet is a student guide used to conduct the investigation or problem-solving activities. It also guides students in developing their cognitive aspect through exercises and guides the development of all aspects of learning. Based on the results of observations and interviews conducted by researchers on high school teachers in Banda Aceh, as preliminary data, it was found that science laboratories are not working properly, physics teachers do the teaching and learning process using conventional approaches whereas physics material requires the use of learning media.

The researcher wanted to do a study with ISLE-based STEM approach and selected harmonic motion in a simple pendulum as the topic because the students are only taught the concept without any practicum. Furthermore, most students are not confident and skilled enough in determining the parameters of the quantities in simple harmonic motion. In traditional simple pendulum experiments in high school, students only use a stopwatch to determine the time of a number of swing periods and then calculate the average period, assuming that each period requires the same amount of time. As a result, students get bored and saturated [3].

It is different when ISLE-based STEM approach is used. Teachers collaborate ISLE learning with the factual concept that students encountered. This method of learning focuses on the student's activeness, emphasizes on performance assessment and team cooperation. STEM is integrated with a smartphone, computer/laptop sensor accelerometer and tracker application. The combination of ISLE and STEM is expected to be an educational approach which can increase students' quality. Students will be very excited to see the result of the experiment which can be gained easily [5].

The purpose of this study is to find out (1) Validity of student worksheets (2) Students' response to worksheets, (3) and learning outcomes of the grade 10 students of high school in Banda Aceh by using worksheets ISLE Based STEM for simple pendulum topics.

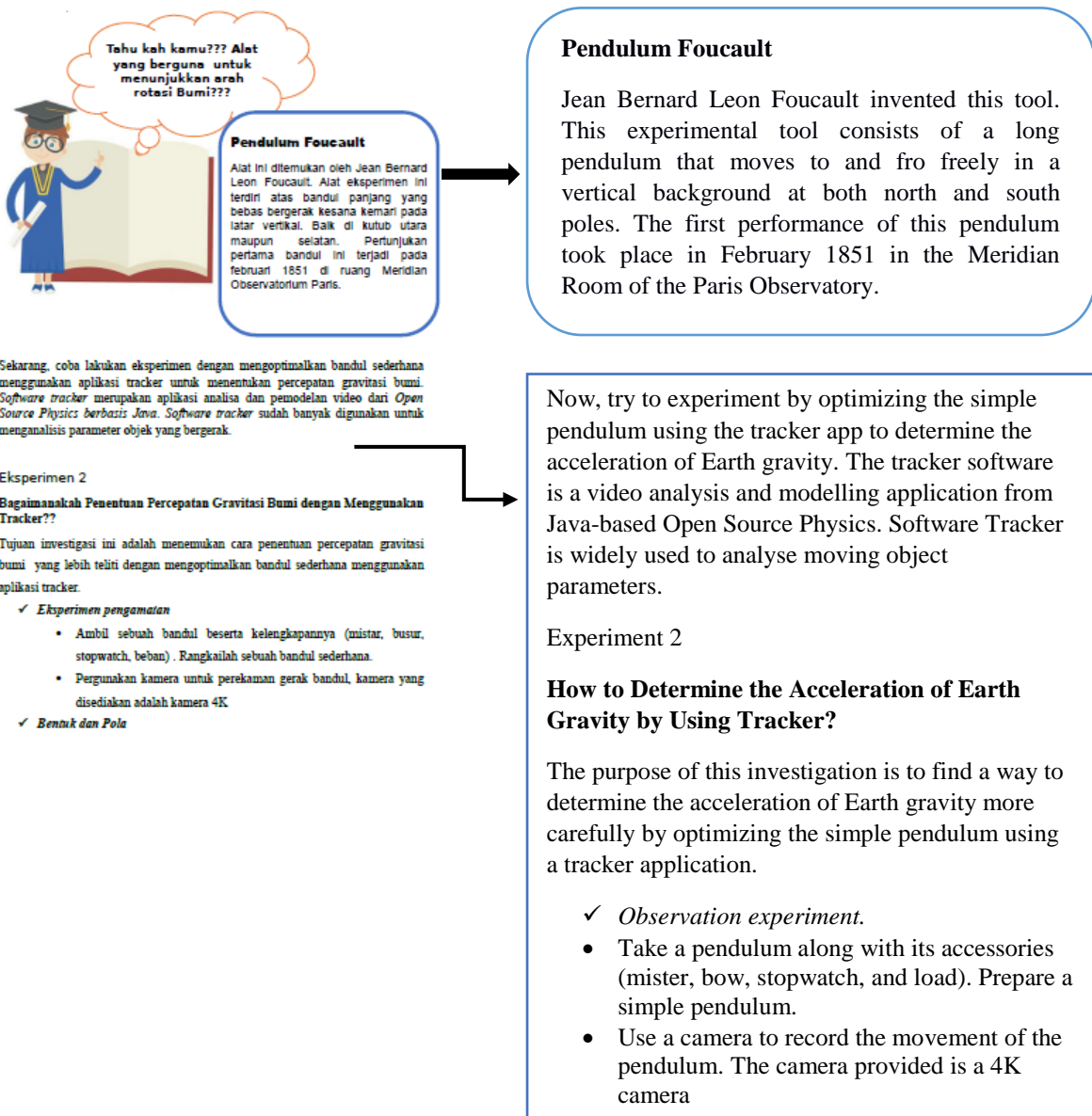
## 2. Method

This research was implemented in grade 10 of 4 senior high schools in the city of Banda Aceh; SMAN 1 Banda Aceh, SMAN 3 Banda Aceh, SMAN 11 Banda Aceh and SMA Lab School. It involved the total of 101 sample students who were selected by *purposive random sampling* technique; that is

determining the samples with certain considerations [8]. The schools were selected for the research because (1) they are among favourite schools in Banda Aceh, (2) they have adequate infrastructure (3) unimplemented learning concepts (4) they had granted the permission to conduct the research. As a Research and Development, this research aimed at developing accountable educational products. Product development in this research used ADDIE (*Analysis-Design-Develop-Implement-Evaluate*) models [2].

The data used in this research was quantitative data which were converted into qualitative data through data analysis. The acquired quantitative data consisted of (1) data validation of ISLE-based STEM student worksheet developed based on suggestion, comment and feedback from validators and physics teachers, (2) students' responses (3) data of students' learning outcomes by using ISLE-based STEM worksheets on simple pendulum topics. Stages of this research were:

- **Analysis**  
Stage analysis is a process of defining what students are learning, i.e. doing *the needs assessment* (needs) and perform analysis tasks (*tasks analyze*) consists of an analysis of the characteristics of students, material analysis, and analysis of the curriculum.
- **Design**  
Activities undertaken at this stage is designing worksheets ISLE Based STEM. This study focuses only on a) preparation of the learning device plan, b) selection of worksheets format, and learning outcomes test. This initial design is based on the results of needs analysis, curriculum analysis, and material analysis.
- **Development**  
At this stage, worksheets that have been designed will be developed through expert validation and product revision I. The activities are undertaken at this stage are as follows:
  - Expert validation, This stage aims to determine one aspect of product development quality, the aspect of the validity. This is done by testing the validity of product design by experts and subject of physics subject, as well as getting suggestion and criticism from validator to developed product.
  - Product revision stage I, The validation data obtained is then analyzed and revised. The first stage of product revision is development based on expert validation.  
The validation results revealed that the previously invalidated worksheets were not interesting and did not use 4K camera technology, while the already validated and revised worksheets were better and feasible to use because there was an illustration of the story about the development of pendulum. At the next stage, the worksheets were then tested for students to see their responses to the development of worksheets.  
The following (Figure 1) is the revised worksheets section after validation.



**Tahu kah kamu??? Alat yang berguna untuk menunjukkan arah rotasi Bumi???**

**Pendulum Foucault**

Alat ini ditemukan oleh Jean Bernard Leon Foucault. Alat eksperimen ini terdiri atas bandul panjang yang bebas bergerak kesana kemari pada latar vertikal. Baik di kutub utara maupun selatan. Pertunjukan pertama bandul ini terjadi pada Februari 1851 di ruang Meridian Observatorium Paris.

Sekarang, coba lakukan eksperimen dengan mengoptimalkan bandul sederhana menggunakan aplikasi tracker untuk menentukan percepatan gravitasi bumi. *Software tracker* merupakan aplikasi analisa dan pemodelan video dari *Open Source Physics berbasis Java*. *Software tracker* sudah banyak digunakan untuk menganalisis parameter objek yang bergerak.

**Eksperimen 2**  
**Bagaimanakah Penentuan Percepatan Gravitasi Bumi dengan Menggunakan Tracker??**

Tujuan investigasi ini adalah menemukan cara penentuan percepatan gravitasi bumi yang lebih teliti dengan mengoptimalkan bandul sederhana menggunakan aplikasi tracker.

- ✓ *Eksperimen pengamatan*
  - Ambil sebuah bandul beserta kelengkapannya (mistar, busur, stopwatch, beban). Rangkailah sebuah bandul sederhana.
  - Penggunaan kamera untuk perekaman gerak bandul, kamera yang disediakan adalah kamera 4K.
- ✓ *Bentuk dan Pola*

**Pendulum Foucault**

Jean Bernard Leon Foucault invented this tool. This experimental tool consists of a long pendulum that moves to and fro freely in a vertical background at both north and south poles. The first performance of this pendulum took place in February 1851 in the Meridian Room of the Paris Observatory.

Now, try to experiment by optimizing the simple pendulum using the tracker app to determine the acceleration of Earth gravity. The tracker software is a video analysis and modelling application from Java-based Open Source Physics. Software Tracker is widely used to analyse moving object parameters.

**Experiment 2**  
**How to Determine the Acceleration of Earth Gravity by Using Tracker?**

The purpose of this investigation is to find a way to determine the acceleration of Earth gravity more carefully by optimizing the simple pendulum using a tracker application.

- ✓ *Observation experiment.*
  - Take a pendulum along with its accessories (mister, bow, stopwatch, and load). Prepare a simple pendulum.
  - Use a camera to record the movement of the pendulum. The camera provided is a 4K camera

**Figure 1.** Worksheet after validation and revision.

- **Implementation**  
At this stage, the revised worksheets were then put on trial. Worksheet trial was conducted on the students of SMAN 1, SMAN 3, SMAN 11 Banda Aceh, and SMA Laboratory Unsyiah.
- **Evaluation**  
The evaluation stage included worksheet revisions by experts and physics teachers. Physics expert reviewed the data and physics subject matter were analysed by considering the experts' recommendations for revision before stage II started to obtain applicable worksheets.

The instrument used for validity analysis is the validation sheet filled by a validator. Qualitative data of a learning product was obtained through the analysis validation sheets for media experts and content expert. The assessment criteria of the validation sheet for content expert consisted of (1) content, (2) presentation and (3) language, while the media experts' validation sheet included such

formatting aspects as (1) clear numbering system, (2) appropriate layout arrangement, (3) readable font size, (4) clear instruction manual, (5) interesting cover design, (6) appropriate animation size, picture, shape and the writing in each page, (7) appropriate color in the media in each page, (8) animation and illustration quality, (9) practical learning media, and (10) manageable learning media. Data validation results by media experts and material experts were tabulated in tabular form, and then the average score from all validators was calculated. Then the average total score was converted into qualitative data based on conversion guidelines in the following table 1:

**Table 1.** Conversion score average guidelines.

Score Interval	Criteria
$\bar{x} > M_i + 1,8 S_{bi}$	very good
$M_i + 0,6 S_{bi} < \bar{x} \leq M_i + 1,8 S_{bi}$	good
$M_i - 0,6 S_{bi} < \bar{x} \leq M_i + 0,6 S_{bi}$	enough
$M_i - 1,8 S_{bi} < \bar{x} \leq M_i - 0,6 S_{bi}$	less
$\bar{x} \leq M_i - 1,8 S_{bi}$	very less

Explanation:

$M_i$  = ideal average = (ideal maximum score + ideal minimum score)

$S_{bi}$  = standard deviation = (ideal maximum score - ideal minimum score)

The ideal maximum and minimum scores are 5 and 1 respectively. The classification ratings obtained guidance learning device is shown in the following table:

**Table 2.** Guidelines for classification of learning tool assessment.

Score interval	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

Data on students' responses to learning with ISLE-based STEM learning media were analyzed descriptively in percentage. Data on the learning outcomes were analyzed descriptively using the terms of mastery of learning outcomes. Completeness of learning outcomes according to the Department of Education and Culture [15] is achieved if 85% of students achieve a defined score of 75.

Furthermore, the classical completeness is calculated based on the percentage formula, then the percentage of completeness is converted into qualitative data with scoring interval criteria. If the completeness is "very good" if it is  $> 80$ ; mastery is "good" if it is  $\leq 80$  or  $> 70$ , mastery is "enough" if it is  $\leq 70$  or  $> 60$ , the completeness is "inadequate" if it is  $\leq 60$  or  $> 50$  and mastery is "very poor" if it is  $\leq 50$ .

### 3. Result and discussion

#### 3.1. Results of needs analysis

The development of worksheets was started by the researchers through an observation. This observation began with observing the learning activities conducted in early October 2017 as well as interviewing teachers and students on learning issues they faced before performing needs analysis afterward. This early observation was conducted by the researchers themselves at SMAN 1 Banda

Aceh, SMAN 3 Banda Aceh, and SMAN 11 Banda Aceh. From the analysis stage, the following results were obtained:

- Constraints faced by both the teachers and the students, among others, are inadequate laboratory facilities and unavailable laboratory facilities for learning physics materials. Also, teachers rarely use self-designed worksheets for a specific purpose; as a result, students consider physics a difficult and unenjoyable subject.
- Based on the journals on social media, research has been conducted in Indonesia and especially in Aceh on the development of worksheets, but not using the ISLE-based STEM approach.

### 3.2. Expert validation result on the student worksheet

The information obtained was then used to design learning media in the form of worksheets (Draft 1) and instruments for feasibility assessment that were prepared at the design stage. Student worksheets that had been prepared at the design stage were consulted with the supervisor. From the consultation, some suggestions for improvements were obtained. The revised worksheets were then validated by the validators to evaluate their quality. The learning product validation was conducted by 4 validators, consisting of 2 expert lecturers, 1 teacher from SMAN 1 Banda Aceh, and 1 teacher from SMAN 3 Banda Aceh.

The purpose of this validation is to obtain input, evaluate the prepared learning products, to determine the validity of the contents and the constructs from the perspectives of physicists and educational practitioners, as well as to determine the feasibility of the learning media.

The results of the validation are tabulated as follows: The result of worksheet validation analysis showed that the worksheet material validity value of 3.91 was within valid criteria, and worksheet validation by media experts reached the value of 3.83, which is within valid criteria. This means that the worksheets are applicable in the learning process. The next stage was that the worksheets were tested on students to see their responses.

### 3.3. Students' response

The percentage of students' response to learning reached 85%. Based on the Likert scale with 5 criteria of responses (*strongly agree*, *agree*, *neutral*, *disagree*, and *strongly disagree*), this figure showed positive students response to learning using the developed learning media. This means that the learning media could be employed well [14].

### 3.4 Student learning outcomes

The test of this learning result consisted of five open-ended questions. The test results obtained by the students were briefly presented in the following table:

**Table 3.** Test of Learning Results.

Description	Test of Learning Outcomes (%)				Average Percentage
	SMAN 1	SMAN 3	SMAN 11	SMAN Lab School	
Completed	85 %	90%	82%	86 %	86 %
Unfinished	15%	10%	18%	14 %	14 %

Table 3 shows the data on the test of students learning outcomes after learning. 86% of students completed the test thoroughly based on the established thoroughness requirements. Thus, the results indicated that students had achieved learning mastery; and therefore the ISLE-based STEM worksheets developed were already good.

Based on the results above, it can be concluded that worksheets which were revised through ISLE-based STEM was applicable and was valid according to the experts and practitioners, so they could

already be used in the second stage of evaluation. It can be said that using ISLE-based STEM worksheets, the material on Simple Pendulum can be used to deliver appropriate and creative learning process. According to the theory put forward by Bruner in Tung [16], a learning process will run well and creatively if a teacher gives the students opportunities to discover their own rules through concepts, theories, definitions, etc. ISLE-based STEM worksheets help students discover and learn physics about the simple pendulum. In addition to the valid use by students, ISLE-based STEM worksheets also guide the development of students' ideas through (1) observing phenomena and finding patterns, (2) developing explanations for patterns, (3) using this explanation to make predictions about experimental test results, (4) deciding whether the test results are consistent with the prediction, and (5) revising the explanation if necessary. This encourages students to learn in fun and effective ways since the worksheets enable students to construct their own knowledge of a simple pendulum. This is in line with Bruner's opinion in Suyono and Hariyanto [13] that teachers should guide their students so that they can build their own knowledge base rather than being taught through rote memorization.

Based on the results of field trials conducted by physics teachers in grade X SMAN 1 Banda Aceh, SMAN 3 Banda Aceh, SMAN 11 Banda Aceh and SMA Lab School Banda Aceh, teachers and students could use ISLE-based STEM worksheets well, as shown by 85% positive responses on average from students. This indicates that worksheets helped and facilitated students in understanding the material. Therefore, it can be said that the worksheets have functioned in accordance with the worksheets used in learning [1], 1) as a teaching material that can minimize the role of teachers and enable students, 2) as a teaching material that makes it easier for students to understand materials provided, and 3) as a teaching material that helps the implementation of learning in students.

ISLE-based STEM worksheets gave a big influence on students' learning outcomes. The test results were indicating that as many as 86% of 101 students were able to comprehend thoroughly simple pendulum material available in the worksheets. This is in line with the explanation put forward by Trianto [14], that worksheets contain a set of fundamental activities that must be performed by the students to maximize their understanding to develop basic capabilities in accordance with indicators of the achievement of learning outcomes that must be pursued.

#### 4. Conclusion

Based on the results of this study, it is concluded that the ISLE-based STEM worksheets developed in this study can be used as one of the instruments of learning in learning physics. Based on its implementation, the use of ISLE-based STEM worksheets can also improve students learning outcomes. The assessment of students' skills after implementing the approach in the classroom indicates positive and promising results.

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