Utilising Investigative Science Learning Environment (ISLE) based STEM module for enhancing students’ understanding of Physics concepts

R Rajibussalim 1,2, E Rahmayani 1 and I Irwandi 1,2

1 Physics Department, Syiah Kuala University, Darussalam-Banda Aceh, Indonesia
2 STEM Research Centre, Syiah Kuala University, Darussalam Banda Aceh, Indonesia

E-mail: rajibussalim@unsyiah.ac.id

Abstract. The Investigative Science Learning Environment (ISLE) is an approach that encourages students to be active, creative and innovative in learning Science including Physics. The ISLE based STEM method helps students in solving real-life problems and involving collaborative group activities. Many students assume that learning Physics is difficult but with the ISLE-based STEM approach, the students will learn Physics theories and concepts with ease and fun. This is in line with the Indonesian government program to enhance the students’ literacy and capacity in Science, Technology, Engineering, and Mathematics (STEM) among high schools and undergraduate students in Indonesia. This study has utilised the ISLE based STEM module and approach for teaching Physics concepts to the high school students at four selected senior high schools in Banda Aceh, the capital city of Aceh province, Indonesia. The results of the study were encouraging and it would leverage and enrich the current state of knowledge related to the learning Physics and Science concepts.

1. Introduction

Many students believe that learning Physics is difficult and not interesting. There is a widespread concern around the world that the students’ interest in learning Physics has been declined significantly due to this negative perception {Whitelegg, 1999 #783}. The difficulties may come from abundant representation such as formulas, calculations, graphs, conceptual explanations, and experiments at the same time {Ornek, 2008 #804}. In Indonesian, a similar problem is faced by educational institutions, especially in higher education (HE) level. The students’ interest in STEM (Science, Technology, Engineering, and Mathematics) field and in particular Physics continue to decline during the past decade. As a result, the availability of skilled STEM graduates that can fulfill the high standard of industries in Indonesia is limited {Tong, 2013 #388}.

The government along with university and educational practitioners and expert need to find a solution to this imminent problem. The negative image that learning Physics is difficult need to be eradicated. The Physics contents and the way it delivers need to be reformed thus the Physics as one of the important fields in science is no longer avoided by the majority of high school students. The Physics as knowledge need to be delivered in a way that not deters students but challenges them {Whitelegg, 1999 #783} thus they will be motivated to learn more Physics. The researcher has proved that Physics can be used to help students develop their scientific habits by training them “thinking like a physicist” {Etkina, 2017 #794}. This scientific habit is one of important skills need to be possessed.
by students in order to succeed in the 21st-century workplace. The habits may include students reflect to what they have learned (reflective learning) {Rajibussalim, 2010 #286} and developing the concept of critical thinking in which students thinking critically by asking questions, developing models, planning, analyzing and interpreting the data {Etkina, 2015 #792}. One approach that can facilitate the development of this scientific habits is ISLE (Investigative Science Learning Environment) that was first developed by Professor Eugenia Etkina of Rutger University New Jersey {Etkina, 2007 #805} (a more detailed discussion on ISLE framework is presented in the next section). Using the ISLE-based STEM approach, the students were trained to think like physicists when they learn a new Physics concept. Unlike the traditional process of learning in which the process of learning is a teacher-centered, the ISLE-based learning approach is a student-centered where student actively engaged in experimental-based activities. The ISLE-based STEM approach combined the Physics concepts with experimental activities performed in the group. The group activities are conducted systematically following the ISLE cycles explained in the next section. Since the ISLE based learning connects Physics concepts with the implementation of the concepts in real life, experimental based learning will be enjoyable. The students feel motivated since the experiment is easy to do and they may have seen them in real life. The STEM integration in ISLE based learning approach in the experiments is by integrating the technology for data acquisition such as slow-motion cameras, smartphones, laptops, and digital stopwatches.

The concept of harmonic motion using pendulum has been chosen for the ISLE-based STEM module because of the following two reasons: (1) based on the school observation that the learning of this concept at school has not been accompanied by experimental activities. (2) the harmonic motion concept is considered a difficult Physics topic by some students with the traditional learning approach.

2. Curriculum 2013 and ISLE-based STEM approach

The curriculum serves as a blueprint for educational institutions to guide them in the process of studying and learning. The curriculum has been designed with a special purpose that certain educational mission and vision can be achieved. The 2013 curriculum (K-13) was introduced to increase the level of competency of Indonesian students in three dominant aspects: attitude, knowledge (cognitive), and skills. There the K-13 contents emphasis the implementation of these three learning aspects in their process of learning at schools. However, during its implementation, there were a lot of problems in the field to fully embrace the three dominant learning aspects proposed in K-13. For example, the last aspect is to enhance the skills and proficiency of students was hardly achieved. One indication that the process of teaching and learning at Indonesian schools rarely teaches and promote the scientific habit of critical thinking during the learning process {Rajibussalim, 2016 #374;Tong, 2013 #388}.

In order to minimize this problem and provide an enhanced approach to increase good scientific habits among Indonesian students, a more practical based learning that can promote critical thinking of Indonesian students was proposed. This approach is called Investigative Science Learning Environment (ISLE). To date, the ISLE has been improved and implemented at a number of universities across the U.S. and Europe. “The ISLE is an educational framework that can guide the design of instruction and student learning. ISLE engages students in the processes that mirror scientific practice to help them learn physics” {Planinšič, 2015 #796@212}. The ISLE-based STEM approach can encourage students to be creative, active, and innovative in learning with experiments. The detailed process of an ISLE based learning cycles (ISLE cycles) is illustrated in Figure 1.
In ISLE based approach, students beginning to learn a new concept by observing a few simple experiments (observational experiments) to identify patterns. Then, they develop ranges of explanations for those patterns and test them. In the process of testing the explanation, they design and develop new experiments called testing experiments to prove or disprove pre-made prediction of the outcomes. After the completion of the testing experiments and comparing the predictions to the outcomes, they take a conclusion judgment to the explanation they developed {Planinšič, 2015 #796}. The testing of proposed explanations using deductive reasoning is one of the most important features of ISLE approach. This approach also represents the most common reasoning in Science, especially in experimental Physics {Planinšič, 2015 #796}. In this paper, we would utilize the ISLE cycles as a framework for students to learn the Physics concept related to harmonic motion using a simple pendulum.

3. Methodology

3.1. Module Development Procedures
This research applied the Analysis-Design-Develop-Implementation-Evaluation (ADDIE) model as depicted in Figure 2. The 1st phase is to do an initial analysis of both high school students and materials needed in the research. This includes the needs assessment and students’ character and material analysis of the current K-13 curriculum on the topic of harmonic motion of the simple pendulum. The 2nd phase is to follow-up the analysis stage by designing the modules on a simple pendulum topic. In designing the module, there are several aspects has to be considered including the format, language, and the expected outcomes. During the 3rd (development) phase, the module was submitted to the experts (university teaching staff) and educators (Physics teachers) to validate the contents and format of the module. The feedback of the validators was taken into consideration by revising the module based on the validator comments. After validation, the module was ready to be implemented at four selected senior high schools (4th phase), namely SMAN 1, SMAN 3, SMAN 11, and SMA Laboratory school. All four selected schools are based in Banda Aceh, the capital city of Aceh province. These schools were selected based on the following criteria: easy to get access, among the favorite schools in Banda Aceh, and have adequate infrastructures such as science laboratory and library. The final phase was an evaluation of the outcomes after the implementation at the selected schools. During the evaluation process, the data were analyzed by means of the quantitative and qualitative method.
3.2. Module Implementation at schools

One of the most important stages in this research project is the implementation of the module at schools. This is because the design and creation of the module have to be in-line with the school timetable. Therefore, the coordination and communication with the Physics school teacher at each school are very crucial. Since the module was on the topic of a simple pendulum, the school timetable at each school for this topic is at the same week during the semester, thus the implementation of the module at school has to follow that the tight schedule in that week. The first module implementation was at SMAN 1 Banda Aceh as this school was the first to respond to the request for data collection with the ISLE-based STEM module implementation. The next module implementation were at SMAN 3, SMAN 11 and SMA Lab School in Banda Aceh as depicted in Figure 3. During the stage of module implementation at schools, the teachers were asked to evaluate the modules and by means of multiple instruments namely questionnaires, observation sheets, post-test, and direct observation of students’ attitude during the module implementation.

3.3. Participants and assessment criteria

This research employed a purposive random sampling technique was deployed to select the students’ participants. As a result, 101 samples or participants were selected among the four schools involved in the research. For the purpose of the assessments, five open-ended question was formulated and students were asked to complete the questions. The completeness is calculated based on the percentage formula, then the percentages of completeness are converted into qualitative representation such as very good, good, or inadequate criteria. If the completeness > 80, it is classified as “very good” if it ≤ 80 or > 70, it is classified as “good” if it ≤ 70 or > 60, it is classified as “enough” if it ≤ 60 or > 50, it is classified as “inadequate” and if it ≤ 50, it is classified as ‘very poor’.

Figure 2. The ADDIE methodology was used to develop the learning media (module)
Figure 3. The modules implementation and evaluation at four selected schools in the city of Banda Aceh

4. Results and discussion

4.1. Validation of the module

Before the ISLE-based STEM module could be implemented at the school, the module has to be validated by four validators consist of educational experts and practitioners such as university teaching staff and school Physics teachers. The validators would assess the module against validation criteria formulated on a validation sheet (instrument). The validation criteria were categorized into two main aspects: content and media experts. The content expert included content, presentation, and language. While media expert consisted of mostly formatting aspect namely numbering system, clear instruction, font and animation size, and color. The results of validation from four validators were tabulated as depicted in Figure 4 with the average validation score was 3.85. This score was within the valid value of the validation criteria which means that the module was useful in the process of learning Physics concepts.

Figure 4. Results of Validation shows that the four validators gave a good mark for the module
4.2. Learning outcomes
The implementation of the module of harmonic motion at four Senior High Schools in Banda Aceh shows encouraging results as shown in Figure 5. Among the four schools, on the average, the students were able to complete above 86% of the task given. The highest completion rate was achieved by students at SMAN 3 (90%) and the lowest was at SMAN 11 Banda Aceh (82%). According to the Indonesian Department of Education and Culture, the completion of learning outcomes is achieved if more than or equal 85% of students reached the score of 75 {Trianto, 2010 #806}. Therefore, the level of completeness indicated that the ISLE-based STEM module had achieved its purpose to enhance the students’ understanding of the Physics concept, in particular, the concept related to the harmonic motion.

![The Completion Rate for Students' Test Results with ISLE-based STEM Module](image)

**Figure 5.** Students' learning outcomes with ISLE-based STEM modules showed high percentages of completion rate.

4.3. Students’ engagement
The students’ engagement in a learning process is very important {van Uden, 2014 #809; Shernoff, 2014 #808; Pekrun, 2012 #807}. One approach to increase the students’ engagement in learning is by using digital technology for delivering the contents and engage with the learner {Henrie, 2015 #812}. However, the use of digital technologies nowadays not only for delivering the contents but also as a mean to collect the data of an experiment or research. In our case, smartphones, slow-motion cameras, and laptops were used by students for collecting and analyzing the data. Researchers observed that utilizing the current digital technologies would also increase the students’ participation and engagements in the learning activities as pictured in Figure 6 and Figure 7.
5. Conclusion and future work

The ISLE-based STEM module that has been designed and then implemented at four senior high schools in Banda Aceh has achieved its purpose. Based on the data collected and field observation by researcher and local Physics teachers, the module is achieved the high standard of a learning media set by the Department of Culture and Education of Indonesia. The ISLE-based STEM module is a student-centered approach that encourages students to be active, creative and innovative in learning Physics concepts of harmonic motion in the simple pendulum. It offers an alternative to the traditional learning approach that is teacher-centered. The implementation at four senior high schools has proved that the ISLE-based STEM approach with the simple pendulum module is able to create positive scientific habits and attitude toward learning Physics and learning Science in general. As a future work, the ISLE-based STEM learning approach with module could be extended to include more Physics or/and Science concepts in the near future.

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