Light Emitting Diode (LED) as an essential prop component for STEM education in the 21st century: A focus for secondary school level

Irwandi, R Oktavia, Rajibussalim, A Halim, Melvina
Syiah Kuala University, Jl. Teuku Nyak Arief Darussalam, Banda Aceh 23111, Indonesia
E-mail: irwandi@unsyiah.ac.id

Abstract. Indonesian secondary science curriculum is often late to keep up with the rapid development of technology. For instance, the widely-used LED (Light Emitting Diode) technology is not familiar as props in secondary science instructions in Indonesia. This study aims to: (1) provide professional development for teachers in developing experiments using LEDs for learning physics concepts, and (2) increase teachers’ beliefs on their knowledge on using LEDs for physics experiments. The professional development only used a single group pre- and post-test research design in the form of a two-day workshop attended by 20 science teachers from secondary level schools in the city of Banda Aceh. The workshop used Investigative Science Learning Environment (ISLE)-STEM approach, an inquiry-based physics learning that incorporate STEM education approach in active learning and collaboration. The workshop used LEDs as experimental props. From the qualitative analysis of the pre- and post-questionnaires’ responses, we found that there are positive improvements on participants’ understanding of ISLE-based STEM approach and of the use of LEDs as props. From the questionnaire administered after the workshop, we found that most of the teachers were excited about the training using LED as props and 89.4% of them feel that their knowledge increased.

1. Introduction
Since its first participation on Programme for International Student Assessment (PISA), Indonesia consistently performed poorly in STEM subjects. In 2015, Indonesia ranked at the 63rd for Mathematics and at the 62nd for Science from 70 countries participated in the assessment. This result shows that the abilities of Indonesian students to apply and reason in Science and Mathematics are below average. One reason could be that common teaching practices in Indonesia rarely promote critical thinking skills [1]. Therefore, revision and improving curriculum to increase skills in STEM education are essential for teachers in Indonesia. However, the revision of the secondary school curriculum is often late to be conducted, and most of the time the curriculum was not able to follow the rapid development of technology. Meanwhile one of the educational goals of the 21st century is equipping students with problem-solving skills of today's world challenges. For example, in Indonesia, the use of LED technology (Light Emitting Diode) as components for toys and high-precision instruments were extensive, but the use of the technology as props is infrequent. In National Curriculum 2013 revised in 2016, the discussion of LEDs is only a part of discussions about Light Wave [1].
The lack of the use of LEDs as props in school physics experiments instigate the following questions. The first question is “Given different examples of ISLE-based STEM experiments using LEDs, how will teachers develop their understanding of ISLE-based STEM approach and the use of LEDs as props for physics?”, and the second question is “How does the professional development increase teachers’ beliefs on their knowledge?” These questions directed this study to aim for the following goals: (1) to provide professional development for teachers in developing ISLE-Based STEM experiments using LEDs for learning physics concepts, such as conductivity, electrical currents, and resistances, light wavelength, etc.; and (2) to increase teachers’ confidence in using LEDs for physics experiments.

1.1. ISLE-based STEM

STEM stands for Science, Technology, Engineering, and Mathematics. There are several definitions of STEM, and the most precise definition is "STEM education is an interdisciplinary approach to learning that removes traditional barriers separating the four disciplines of science, technology, engineering, and mathematics (and) integrates them into a real-world, rigorous, and relevant learning experience for students" [9]. A STEM is an approach that involves the application of skills and knowledge to solve problems or tasks and use engineering design processes to create products and solutions. Based on the sequence in the abbreviation we can say that STEM learning is learning Science by utilizing Technology in Engineering process as well as involving Mathematics calculation. The STEM approach is an approach that combines knowledge and skill in solving problems with various models including inquiry-based learning (IBL), discovery-based learning (DBL), and project-based learning (PBL). One of the models used in this study is the Investigative Science Learning Environment (ISLE). Prof. Eugenia Etkina from Rutgers University of New Jersey, USA developed ISLE models for learning physics. ISLE is a model that helps students mimic the way physicists create knowledge [3]. We have modified a simplified ISLE model [4] as shown in Figure 1.

![Figure 1. The simplified version of the ISLE model](http://www.islephysics.net/isle.php)

The ISLE learning cycle in Figure 1 showed that to figure out the physics concepts underlying a real-life phenomenon, we start by observing the phenomenon under different conditions (observation experiments) until we find patterns that will lead to the development of a relation, explanation, model, or hypothesis. Assumed that the hypothesis is correct, then we predict what would happen if we conduct testing experiments. If our prediction is accurate then, we convince that the hypothesis is correct; otherwise, we need to revise it or do some more observation experiments and continue the process until we get the proved hypothesis. Then we apply the proved hypothesis to solve real-life problems or to explain related phenomena.

One of the advantages of ISLE is that it is creating an environment favorable to the 21st-century skills such as critical thinking, problem-solving, communication, and collaboration. One of the authors’ experience was attending Workshop of PHYSWARE 2015: Preparing 21st Century Physics
Teacher. Trieste, Italy January 25-30, 2015 that intensively created collaboration atmosphere as shown in Figure 2 and communication atmosphere as shown in Figure 3. In Figure 2, the author’s group did an experiment that shows human bodies are conductors as well as media for currents to flow. In Figure 3 the author with his group discuss the patterns that they saw on observational experiments using LEDs to develop hypotheses. In Figure 3, we can see that the use of LEDs as props in experiments could lead to meaningful learning. Why do LEDs become essential for physics experiments? The facts that (1) LED (Light Emitting Diode) technology is widely used in our daily life in this digital era, (2) their cost is inexpensive, and (3) their effectiveness is extensive to explain physics concepts, are some of the reasons why students need to be familiar with this technology.

![Figure 2](image2.png)

**Figure 2.** Team collaboration to conduct investigations that the human body can act as a current conductor and a current flow between each other.

![Figure 3](image3.png)

**Figure 3.** The team is communicating with each other to discuss the relationship between voltage and current that flows in the LED.

### 1.2 The 21st century skills and challenges

Why do we need to use STEM approach such as ISLE in learning STEM? The answer is because the approach will help students to develop skills, abilities, and learning dispositions. These skills are those that are required for success in the 21st-century society and workplaces. These skills are not the same as skills traditionally prepared in schools, which are primarily content-knowledge-based skills. There are similar concerns on changing the focus of educations in many countries around the world. The education system should shift its focus to prepare students to master analytic reasoning, complex problem solving, and teamwork that lead to deeper learning, the skills needed to be successful in our current dynamic digital society [7].

In addition to the skills mentioned above, another important skill that could be considered as the ultimate skill needed to face the rapid changes in society and to overcome the challenges that an individual face now or lie ahead is the ability to "learn how to learn." The four pillars of learning: learning to know, learning to do, learning to live together, and learning to be the fundamental principles of the 21st century’s education. While mastering content-knowledge-based skills, students must also develop mastery of the essential skills such as critical thinking, problem-solving, communication, and collaboration, to be successful in this new era. A study suggested that skills like traditional reading, writing, and arithmetic are no longer the top skills demanded by U.S. Fortune 500 companies by the year of 2000 which preferred teamwork, problem-solving, and interpersonal skills [8,9].
1.3 LED technology and educational props

Russian inventor Oleg Losev invented light-emitting diode in 1927. His invention was distributed in Soviet, German and British scientific journals, but no practical use was made of the discovery for several decades [10]. Nick Holonyak at General Electric developed the first practical visible-spectrum (red) LED in 1962. Soon after that, LEDs became available as electronic components, and thus they gained the attention of the physics teaching community. The first paper on LEDs in The Physics Teacher appeared in 1974. Awareness that LEDs can be used in teaching several introductory physics topics emerged as early as in by Jewett 1991[11]. He described some activities with LEDs in the areas of electricity, optics, and modern physics. Since the LED technology developed and produce brighter, efficient, wide range of wavelengths of LED, they found many applications in the 21st century live. Etkina, E. and Planinši, G., publish four articles series about LED during 2014-2015 related the various application LED publish in The Physics Teacher [12,13,14,15].

In making the props, we always consider the ease of obtaining the materials, the assembly, and the cost. Based on the experience from the ISLE workshop [5], we have implemented the LED components to create customized props with available materials in Banda Aceh. This LED components had been used for workshop and training activities that we held in Banda Aceh [5]. Figure 4 shows a collection of props that utilizing LEDs technology. At the bottom, there are six types of LEDs with various spectra of infrared, red, yellow, green, blue, and violet. LED spectrum can be used to study the energy band gap, and if it is related to the wavelength, radiated Plank constant can be determined. Especially for infrared LED lights, red and yellow mounting on the 3V power source, they must use a resistor, and we make a resistor ladder (Figure 4a above) that can be used for various purposes. Connection terminal used for brass nails that will simplify the process of soldering. By adding a single transistor, LED lights (Figure 4b) can be used as a tool to check the conductivity, such as experiments conducted in figure 2. When using two transistors, the LEDs will result in a higher sensitivity so that it can be used to detect the presence of electrostatic charge.

![Figure 4. LEDs as physics learning props.](image-url)

2. Method

The professional development conducted in this study only used a single group pre- and post-test research design. Twenty secondary school science teachers in the city of Banda Aceh participated in a two-day workshop held in Syiah Kuala University, in Banda Aceh, Indonesia. The workshop used ISLE-based STEM approach, an ISLE learning that incorporates STEM education approach in active learning and collaboration. The workshop used LEDs as experimental props. To measure the effectiveness of the workshop in developing teachers’ understanding of ISLE-Based STEM approach and the use of LEDs in physics experiments, we administered a pre- and post- questionnaires consisting of nine items. At the end of the workshop, we also administered a questionnaire on participants’ beliefs on the benefits of the workshop to their knowledge.

3. Results and discussion

According to the results on the pre- and post-tests, the teachers showed an increase in their enthusiasm in participating in this workshop since they had learned and mastering new skills and knowledge. Figure 5 shows the participants conducting experiments and then presented the results (Figure 6).
The results of the qualitative analysis on the pre- and post-questionnaires’ responses, we found that there are positive improvements on participants’ understanding of ISLE-based STEM approach and of the use of LEDs as props. For example, one participant answered in the pre-test that hypothesis is the temporary answer from research findings, estimating, and observations, and did not answer what prediction is. This participant answered on the post-test that hypothesis is a temporary answer developed after observations, meanwhile, the prediction is the temporary guessing on what will happen on the testing experiment, a correct interpretation of the two important terms in ISLE. Another example of the improved understanding of a participant is evident when one participant who cannot answer in pre-test about where in the curriculum we can use LEDs as props, answered on the post-test that we could use LEDs on electronics lesson by changing the light bulbs that were usually used with LEDs. From the questionnaire on the participants' satisfaction with the workshop, we found that 89.4% of teachers experience that their knowledge is increasing and around 10.6% of the teachers acknowledge that their knowledge increased significantly. Also, 84.2% of teachers mentioned that the ISLE was easy to understand, in comparison to 15.7% of teachers who thought that ISLE was hard to understand. No teacher has an extreme opinion that ISLE is either very easy or very hard to understand.

4. Conclusions
Utilizing LEDs as props for physics lessons helped teachers realizing many objects in our everyday life are easy to find, inexpensive, and can be assembled without hassle to teach essential concepts in physics. The skills that the teachers gain from ISLE-based STEM approach is that they could apply this method, especially with LEDs in their classroom especially in creating an environment to build students' critical thinking, problem-solving, communication, and collaboration when the learning is fun for them. Most of the teachers participated in this study agreed that ISLE is a teaching approach that is easy to be understood. Most of them also agreed that the workshop had increased their knowledge and skills. Many more such professional developments will enhance science teachers' knowledge and skills in understanding concepts in physics and help students to understand the concepts.

Acknowledgments
Authors wishing to acknowledge ICTP (International Center for Theoretical Physics) and Director of Workshop Prof. Eugenia Etkina for opportunity attending Workshop Physware 2015 Preparing 21st Century Physics Teacher. This study is initially funded by LPPM Unsyiah (IbM) Award Number No. 1711/UN11/SP/PNBP/2016 support for public service activity, entitle Training of Inquiry-Based Learning (IBL) Method Through Investigating Utilization of LED (Light Emitting Diode) To Improve Teachers’ Abilities in Designing Scientific Based Experiment. This study is funded partially by the NAS and USAID under the USAID Prime Award Number AID-OAA-A-11-00012, and that any
opinions, findings, conclusion, or recommendations stated in the article are from the author only, and
do not always reflect the view of USAID or NAS.

References

[1] Ilyas H P 2016 Infusing critical thinking into English course books Journal of ELT Research 1 113
[2] Kemendikbud 2016 *Silabus Mata Pelajaran Fisika Sekolah Menengah Atas/Madrasah Aliyah (SMA/MA) Kurikulum 2013 Revisi 2016* (Jakarta: Kementerian Pendidikan dan Kebudayaan)
[3] Vasquez J A 2013 *STEM lesson essentials, grades 3-8: Integrating science, technology, engineering, and mathematics* (Great Britain: Heinemann)
[4] Etkina E and Heuvelen A V 2001 *Investigative Science Learning Environment: Using the processes of science and cognitive strategies to learn physics*
[5] Irwandi, Melvina, Syurki U 2017 *Training of Inquiry Based Learning (IBL) method through investigating utilization of LED (Light Emitting Diode) to improve teachers’ abilities in designing scientific based experiment* (Report of Public Services: unpublished)
[6] Etkina, Eugenia, Gorazd P, Irena D and Leos D 2015 *ICTP Workshop Physware 2015, Preparing 21st Century Physics Teacher* (Italy: Trieste)
[7] Dede C 2010 Comparing frameworks for 21st century skills 21st century skills: Rethinking how students learn 20 51
[8] Cassel R N and Kolstad R 1998 The critical job-skills requirements for the 21st century: Living and working with people Journal of Instructional Psychology 25 176
[9] P21 (Partnership for 21st Century Skills) 2011 *Framework for 21st Century Learning*
[10] Zheludev N 2007 The life and times of the LED—a 100-year history Nature Photonics 1 189
[11] Jewett J W 1991 Get the LED out The Physics Teacher 29 530
[12] Planinšič G and Etkina E 2014 Light-emitting diodes: A hidden treasure The Physics Teacher 52 94
[13] Etkina E and Planinšič G 2014 Light-emitting diodes: Exploration of underlying physics The Physics Teacher 52 212
[14] Planinšič G and Etkina E 2015 Light-emitting diodes: Learning new physics The Physics Teacher 53 210
[15] Planinšič G and Etkina E 2015 Light-emitting diodes: Solving complex problems The Physics Teacher 53 291