Improving ISLE-based STEM learning outcomes for building the 21st century skills and characters through a lesson study: A case study on Torque and Moment of Inertia

Z Ulfa1,2, I Irwandi1,2,*, M Syukri1,4, Al Munawir1 and A Halim1,4

1 STEM Research Center (STEM.id), Universitas Syiah Kuala, Indonesia
2 Physics Department, Universitas Syiah Kuala, Indonesia
3 SMA Lab School, Universitas Syiah Kuala, Indonesia
4 Educational Physics Department, Universitas Syiah Kuala, Indonesia
5 Mechanical Engineering Department, Universitas Teuku Umar, Indonesia

*E-mail: irwandi@unsyiah.ac.id

Abstract The objectives of this study are as follows: (1) Developing ISLE-based STEM learning media, (2) Building 21st-century skills and character, (3) Analyzing the improvement of learning outcomes through lesson study. This research is a descriptive quantitative study developed at the STEM UNSYIAH Research Center and carried out at Unsyiah Laboratory High School. The instruments used in this study are validation rubric for media and material experts and Teacher Observation sheets and monitoring sheets for the increasing 21st-century character. Based on the data analysis: 1) Validation of the Moment of Inertia props from 2 media experts obtained an average percentage value of 86.4% with an excellent category. 2) Validation of Student Worksheet by two validators expert in material teaching obtained an average percentage value of 84.77% with an excellent category. 3) The teaching and learning results using teaching aids and LKPD through a Lesson Study conducted by the observer obtained a percentage with an average of 83.5% excellent category. 4) There is an increase in 21st-century character in students by 77% with an excellent category. ISLE-based STEM Learning Media is very suitable for improving 21st-century skills.

Key Word: ISLE Based STEM Teaching Media, 21st century skills, Lesson Study.

1. Introduction
The OECD announced the PISA results for Indonesia in 2018. PISA measurement aims to evaluate the education system by measuring student performance in secondary education. Indonesia's reading ability is at a score of 371 from the highest score of 555 achieved by China and mathematics and science scores, namely 379 and 396 with comparable scores obtained by other countries of 591 and 569. This shows that students' learning abilities have not met the educational standards of century 21, which are oriented towards 4C (Critical thinking, Creativity, Collaboration, and communication) [1].

Based on the background above, it can be analyzed that one of the causes why students did not understand a learning concept is the use of inappropriate learning methods and media. Learning media development is more directed towards science, technology, and developing process engineering and can be interpreted using mathematics. In a multidisciplinary approach, such as a combination of
science, technology, engineering, and mathematics (STEM) by raising environmental problems, it is appropriate to make an investigative approach [2].

Investigation in science learning has been applied and developed by Etkina with the Investigative Science Learning Environment (ISLE) model. ISLE has been successfully taught in various countries with different student populations; this is not just a curriculum but how to think about physics and science in general [3,4,5]. The integration of ISLE in STEM makes it possible to actualize environmental literacy and creativity [6].

Therefore, the development of appropriate models and approaches in implementing the teaching and learning process can also increase students' understanding of the studied topics. One of the most suitable models and strategies to be applied in physics lessons, especially in the case of inertia, is ISLE Based STEM. The ISLE model can develop students' thinking and knowledge dimensions, while the STEM approach can integrate science, technology, engineering, and mathematics. In this case, the development of the ISLE-based STEM model and approach is very appropriate because it follows the demands of the 2013 curriculum, which emphasizes 21st-century learning, 4C, and Higher Order Thinking Skill (HOTS) learning [7,8].

To record teaching and learning activities that have increased, one way is by conducting class-level studies (Lesson Study). The lesson study process is divided into three stages, namely: 1. Plan (plan), 2. Do (Implement), 3. See (Reflect / Evaluate) this series of activities will then be referred to as cycle 1. In the lesson study, there will be 2 or 3 cycles that are carried out to record an increase in student understanding. Hence, the combination of media development, approaches and models, and conducting studies at the class level is a whole part of being able to increase student understanding. Based on the above background, this research is significant to carry out.

2. Methodology
This research is a descriptive study with a quantitative approach by observing the character building of the 21st century students and observing the ISLE Based STEM learning media using an assessment instrument by expert validators. In making props (mechanics), it begins with designing the tool's shape and size, which is used as a reference for making tools[7]. In making tools using necessary materials from stencil and iron, this material's choice is because stencil and iron have heat resistance, relatively high mechanical stress compared to wood or plastic types so that the tools made can last a long time. To design this learning tool, the researcher first conducts an experimental design by determining what physical variables are measured to provide the appropriate equipment in developing the prototype/learning tool. The following is the design of the moment of Inertia props.

![Figure 1. Props Mechanic Design](image)

To design a learning tool, the researcher first conducts an experimental design by determining what physical variables are measured to provide the appropriate equipment in designing props/props for spring vibration experiments. In this study, the variable radius (r) and mass (m) can be measured using a digital meter and scale. In contrast, the physical variable angular acceleration (α) can be measured using the Gyroscope Sensor GY-521 Module, a core module of the GY-521 Gyroscope six-axis Motion Processing Unit. The GY-521 sensor contains an integrated MEMS Accelerometer and a
MEMS Gyroscope. This sensor is very accurate with internal hardware facilities 16 bit ADC for each channel and will capture the channel values of the X, Y, Z, and α axes simultaneously at one time.

Figure 2. Hardware Design

The measurements using these sensors are read by a microcontroller based on IoT (Internet of Thing) and transferred to the desktop via wifi (wireless) for visualization and analysis. This study using the ESP-12F MCU node.

Figure 3. Software Design

Validation sheet design is used to obtain learning device assessment data by the validator with a value range of 1-5 and to get suggestions for improving the learning tools that have been developed. The Validation Sheet used in this study includes the LKPD validation sheet, the Teacher Guide validation sheet, the pretest and posttest validation sheets, and the tool validation sheets. Expert validators and practitioner validators validate this sheet. An observation sheet is a measuring tool for assessing the achievement of the learning steps observed through lesson study. This observation sheet is filled out by four observers[9].

3. Result and discussion

Figures 4 and 5 below were the equipment that was designed using ISLE based STEM approach.
The Moment of Inertia Teaching Tool's Mechanics consists of a rotating iron rod and a spring as a torsional moment. Students will obtain the necessary data on student worksheets by following the ISLE cycle. Whereas in Figure 5 below shows the results of the GY-521 Gyroscope series connected to the NodeMCU ESP-12F.

Teaching aids and student worksheets that have been developed through the ISLE Based STEM are applied to class XI students of the Laboratory High School of Unsyiah. Based on the data obtained by analysts: 1) Validation of the Moment of Inertia props from 2 media experts obtained an average percentage value of 86.4% with an excellent category. 2) Validation of Student Worksheet by two validators expert in material teaching obtained an average percentage value of 84.77% with an excellent category. 3) The results of the assessment of the implementation of learning using teaching aids and LKPD through Lesson Study conducted by the observer obtained a percentage with an average of 83.5% excellent category. 4) There is an increase in 21st-century character in students by 77% with an excellent category.

4. Conclusion
By improving ISLE-based STEM Learning Media, students can understand the moment of inertia concept, collaboration, critically and creatively, and communicate well the learning outcomes. So ISLE-based STEM Learning is very suitable for improving 21st-century skills-based on lesson study.

References
[1] www.kemdikbud.go.id
[2] Vasquez J A 2013 STEM lesson essentials, grades 3-8: Integrating science, technology, engineering, and mathematics (Heinemann)
[3] Etkina E, Van Hauvelen A 2001 Investigative Science Learning Environment: Using the Processes of Science and Cognitive Strategies to Learn Physics Proceedings of the Physics Education Research Conference 17-21 Rochester, New York

[4] Etkina E, Planinsic G and Van Heuvelen A 2019 College physics: explore and apply (Pearson: CERN Didactic Library)

[5] Etkina E and Planinišić G 2015 Defining and developing “critical thinking” through devising and testing multiple explanations of the same phenomenon The Physics Teacher 53 432-437

[6] Irwandi I, Oktavia R, Rajibussalim, Halim A and Melvina 2018 Light Emitting Diode (LED) as an essential prop component for STEM education in the 21st century: A focus for secondary school level J. Phys. Conf. Ser. 1088 012060

[7] Rahmayani E, Irwandi I and Rajibussalim R 2018 Developing worksheets through ISLE-based STEM approach and implementing them on senior high school students J. Phys. Conf. Ser. 1088 012091

[8] Irwandi I, Sari I M, Oktavia R and Syukri M 2020 MEMS and IoT Applications in ISLE-based STEM Physics Learning Media for Mechanics Topics with LabVIEW Integration J. Phys. Conf. Ser. 1462 012066

[9] Oktavia R, Irwandi I, Rajibussalim R, Mentari M and Sari I M 2018 Assessing the validity and reliability of questionnaires on the implementation of Indonesia Curriculum K-13 in STEM Education J. Phys. Conf. Ser. 1088 012014

Acknowledgments
The authors would like to acknowledge the undergraduate and master students focusing on Physics Teaching in Universitas Syiah Kuala who participated in this study. This research was supported financially by the research project Implementation Assignment Category A STEM Research Center Number 291/UN11/SPK/PNBP/2020. The LabVIEW software we used in the study came from NAS and USAID support under USAID Prime Award Number AID-OAA-A-11-00012.