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Development of Sound Wave Resonance Props for Understanding the Phenomenon of Stationary Waves Using an ISLE-Based STEM Approach Model in Supporting Transformation Education

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Abstract: This study aims to develop ISLE-based STEM learning media and utilize standing wave resonance tube teaching aids to study the phenomenon of stationary (standing) waves. The method used is research and development (R&D) with the ADDIE development model (Analysis, Design, Develop, Implement, and Evaluate). The results obtained from this study are learning media in the form of Practical Teaching Aids (APP), wave simulation programs and student worksheets for traveling wave and stationary wave experiments. The two learning media have gone through the validation process of material experts and media experts and have been declared suitable for use/implementation by students. The developed APP makes it easy for students to visualize stationary waves in a tube. Student worksheets which is prepared using the ISLE-based STEM model approach, is used as a guide in achieving learning objectives by building students' thinking concepts about stationary wave material through resonance tube experiments. The use of APP provides a visualization display of experimental results so that it helps students understand the concept behind physics processes that are invisible like standing waves.

Keywords: APP; Student worksheets; ISLE-based STEM; Stationary wave

Introduction

The use of media in the learning process is one of the efforts to increase learning motivation which in turn can improve the quality of student learning outcomes. The reasons related to the benefits of teaching media in the learning process of students include (Rahmayani et al., 2018): (1) Teaching will attract more students' attention so that it can foster learning motivation, (2) Teaching materials will have a clearer meaning so that they will be better understood by students. students and enable students to achieve better teaching goals, (3) teaching methods will be more varied, (4) students do more learning activities, because not only listen to teacher descriptions but also other activities.

Technological developments are very rapidly influential in the world of education. The development of this technology results in the development of science that has both positive and negative impacts. The existence of this technological development makes the government need to increase development in the field of education in terms of quality and quantity (Mulyani et al., 2018; Ngafifi, 2014; Kristiyono, 2015).

Education is an effective means of supporting the development and improvement of human resources in a more positive direction. The progress of a nation depends on quality human resources, where it is largely determined by the existence of education (Kristiyono, 2015).

STEM (Science, Technology, Engineering and mathematics) education is designed to be directly

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applied in real-world learning activities, namely to solve problems in everyday life through a learning process like that used by scientists (Zubaidah, 2019). STEM, which is an acronym for Science, Technology, Engineering, and Mathematics, was first launched by the United States National Science Foundation in the 1990s as the theme of the educational reform movement in the four disciplines mentioned above to foster STEM literacy, and increase the United States' global competitiveness. (US) in science and technology innovation (Hanover, 2011; Oktavia et al., 2018).

So far, physics learning in high school is more often carried out in the classroom using lecture methods and visual videos (Abidin et al., 2021). Physics learning more often uses teacher centered learning, students only listen to explanations from the teacher (Gunawan et al., 2017). This is what causes students to be passive and less able to interact with one another. Students are also less able to interact directly with the surrounding environment. In fact, learning physics is closely related to nature and its phenomena so that it will be more effective if students interact directly with nature in learning physics so that the benefits of learning physics in everyday life can be directly felt by students (Andriani et al., 2020).

One instructional approach that can direct students to be able to make conceptual changes in physics is the ISLE approach developed by Etkina et al. (2016), Etkina (2015), Etkina et al. (2019), and Etkina et al. (2015). ISLE can help students learn physics by engaging in processes that reflect the activities of physicists as they construct and apply knowledge. This process involves observing, finding patterns, building and testing pattern plans, and using multiple representations to test about physical phenomena (Rahmayani et al., 2018).

From the various problems described above, there is a need for media to overcome learning that is less innovative and does not keep up with the times, and does not attract students' interest in learning, one of which is the creation of ISLE-based STEM learning media. Thus, considering the importance of the concept of oscillations in everyday life, it is necessary to understand the concept by minimizing these difficulties through the use of today's technology such as Arduino, the selection of wave material on closed end tubes for making learning media becomes increasingly urgent with consideration of the results of the research described above. which encourages researchers to produce an interesting and fun learning media for students and is expected to help students understand the oscillation concept through the ISLE-based STEM model approach.

Method

This study uses research and development (R&D) methods. There are three steps of R&D proposed by Sukmadinata, namely: 1) preliminary study, 2) conducting product development, 3) testing or validating the product. In this study, the product to be developed is in the form of ISLE-Based STEM learning media to help students understand the material for sound waves, especially the phenomenon of standing waves (stationary). There are two products to be produced, namely; (1) sound wave experiment props. (2) student worksheet designed by adding ISLE-Based STEM pedagogic elements. The research and development model chosen is ADDIE (Analysis-Design-Develop-Implement-Evaluate) (Dick et al., 2005).

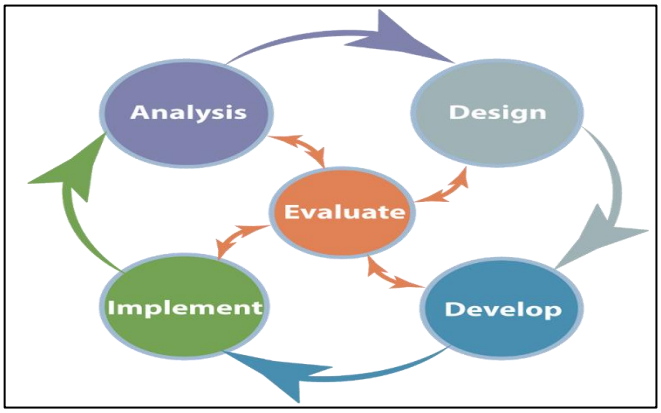

Figure 1. ADDIE development model

The feasibility level of the developed learning media is assessed based on validation by material experts, media experts, validation by field teachers and trial use by students. ADDIE development model (analysis, design, development, implementation, evaluation). This study involved two groups. The first is the experimental group, which is the group that is treated using the ADDIE method. The second group is the control group, which is a group that uses conventional methods.

Table 1. Calculation of learning outcomes for two classes (Sugiyono, 2013)

Group	Pretest	Treatment	Posst test
E	O_1	X_1	O_2
K	O_1	X_1	O_2

Explanation :
E : Experiment Group
K : Control Group
O_1 : Pre-Test Experiment Class
O_1 : Pre-Test Control Class
X_1 : Get Treatment (ISLE learning model)

X_2 : Not Receiving Treatment (lecture method)
O_2 : Experimental Group Post-Test
O_2 : Posttest Control Group

The location of the research was carried out at MAN 4 Tungkob, with product implementation carried out in class XI A and B. The determination of the sample was taken based on a purposive random sampling technique. Data collection techniques using several techniques, namely: 1) literature study, 2) questionnaire techniques, 3) product trials. Data analysis in this study were: 1) tool analysis, 2) expert validation analysis, 3) reliability test, 4) analysis of student assessment and learning implementation.

Result and Discussion

Analysis
Analysis of the 2013 Curriculum based on 21st Century Learning

The 2013 curriculum applies a scientific (scientific) approach to authentic learning and assessment that uses the principle of assessment as part of learning. The scientific approach to learning is strengthened by applying discovery/inquiry learning models (Susilawati et al., 2022), problem-based learning (Doyan et al., 2021) and project-based learning (Zulirfan et al., 2022).

Therefore, the authors also helped design worksheets using the STEM (Science, Technology, Engineering, and Mathematics) approach and the ISLE (Investigative Science Learning Environment) model. The development of ISLE-based STEM learning media aims to hone and test students' abilities in managing (acquiring) the knowledge gained in teaching and learning activities as well as providing full opportunities for students to make observations, find patterns/patterns in the form of general solutions that can be reused or repeated -rework to solve common problems. Students are also able to make relationships, interpret (explanation), make models, make hypotheses, make predictions and design writing to test hypotheses.

Analysis of Physics Learning in schools

After conducting interviews with the physics subject teacher at MAN 4 Tungkob Aceh Besar about the learning conditions of physics that have been taught so far in schools, it can be concluded that the learning that takes place is in accordance with K13 and the material being taught so far has been carried out through practicum and demonstration methods.

Therefore, the authors also helped design worksheets using the STEM (Science, Technology, Engineering, and Mathematics) approach and the ISLE (Investigative Science Learning Environment) model. The development of ISLE-based STEM learning media aims to hone and test students' abilities in managing (acquiring) the knowledge gained in teaching and learning activities as well as providing full opportunities for students to make observations, find patterns/patterns in the form of general solutions that can be reused or repeated -rework to solve common problems. Students are also able to make relationships, interpret (explanation), make models, make hypotheses, make predictions and design writing to test hypotheses.

Design
Learning Device Design

At this stage the design is carried out, namely the design of learning tools in the form of student worksheets and Teacher Guides and also development, namely: 1) practical teaching aids (APP), in this study using hardware and software as follows.

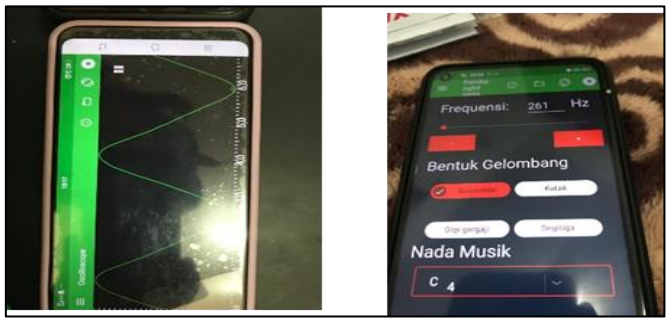

Figure 2. Physic toolbox application

Figure 3. Wave Simulation Program

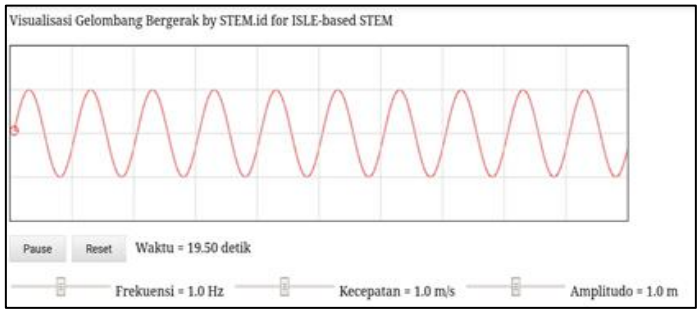

Figure 4. Wave simulation program

Physic toolbox is a software that is very useful for STEM Education, academia and industry, this application uses sensor input devices to collect, record and export data in csv (comma separated value) format. This application can be obtained from various smartphone app markets.

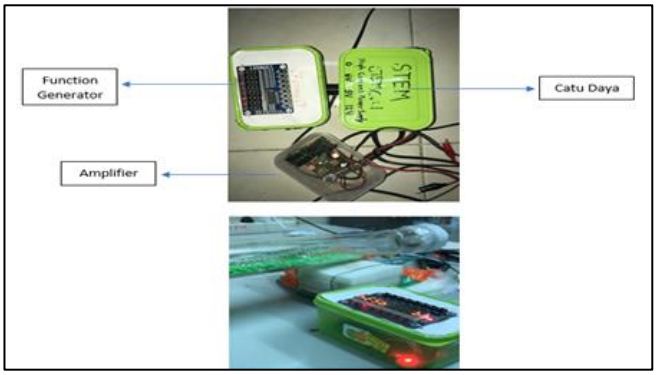

Figure 5. Standing wave resonance tube experiment

Visualization of Measurement Results

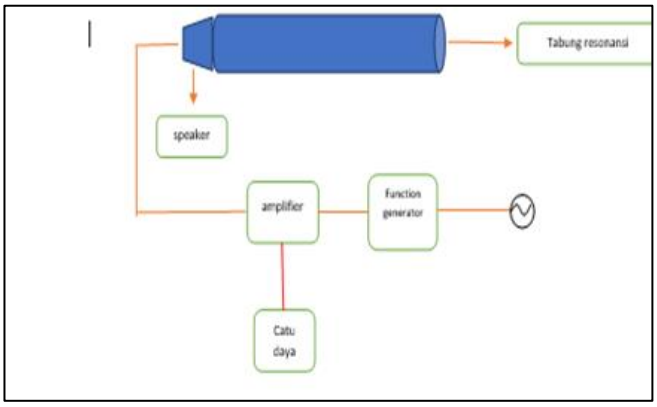

Figure 6. Stages of developing resonance tube props

Utilization of Simulation Programs

In addition to the experiments above, testing the relationship between frequency and wavelength can also be carried out by simulating waves through the moving wave simulation program by STEM.id for ISLE-based STEM software. The trick is to open the program.

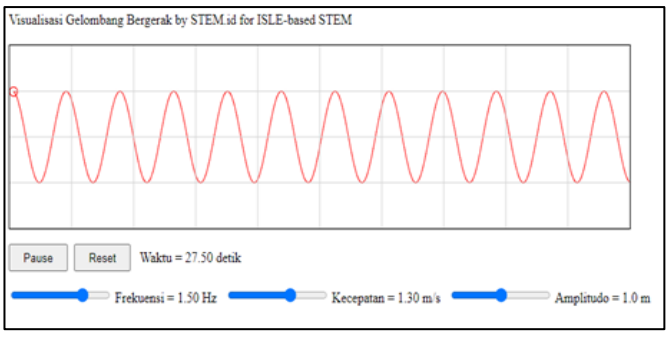

Figure 7. Walking wave simulation program

Measurement of Data Results from Software

Knowing : f = 1.50 Hz
v = 1.30 m/s
Asked : λ ?

$$\lambda = \frac{v}{f}$$
$$= \frac{1.30\ m/s}{1.50\ Hz}$$
$$= 0.86\ \text{m}$$

The results of these calculations show that the moving wave visualization software program calculates the measurement results properly and can be used for traveling wave experiments.

ISLE-Based STEM Student Worksheets
ISLE-Based STEM-based Student Worksheets development

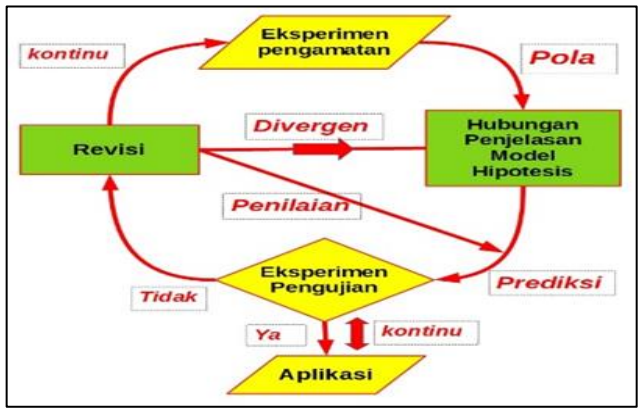

Figure 8. ISLE-based STEM development model

The development of ISLE-based STEM learning media begins with compiling a framework of thought which the author then develops into 3 parts, namely; Student Guide/ Student Worksheets, Teacher Guide and Technology Guide.

Student Worksheets Guide

Student Guide/ student worksheets: development of all aspects of learning (cognitive, affective and psychomotor) in the form of an experimental guide. In addition, student worksheets aims to train students in finding and developing skills (Hasni, 2020). This guide is designed differently from what has been used so far, which is generally procedural into investigation. The student guide is made as simple as possible with the aim of providing opportunities for students to explore independently with a team. Through this student worksheets, students are also encouraged to build character and think more critically.

Teacher's Guide

The teacher's guide is a teacher reference/guideline that is used during teaching and learning activities using ISLE-based STEM learning

media. This guide contains the stages of experimental activities using the ISLE cycle in more detail than the student guide. It is intended that teachers can guide students if students experience problems in completing the ISLE stage during the experiment.

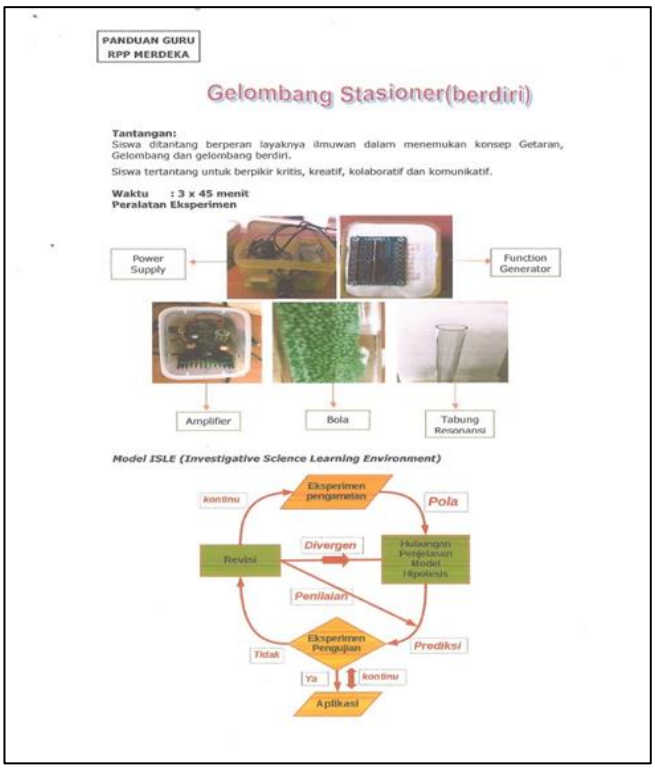

Figure 9. Teacher's guide

Technology Guide

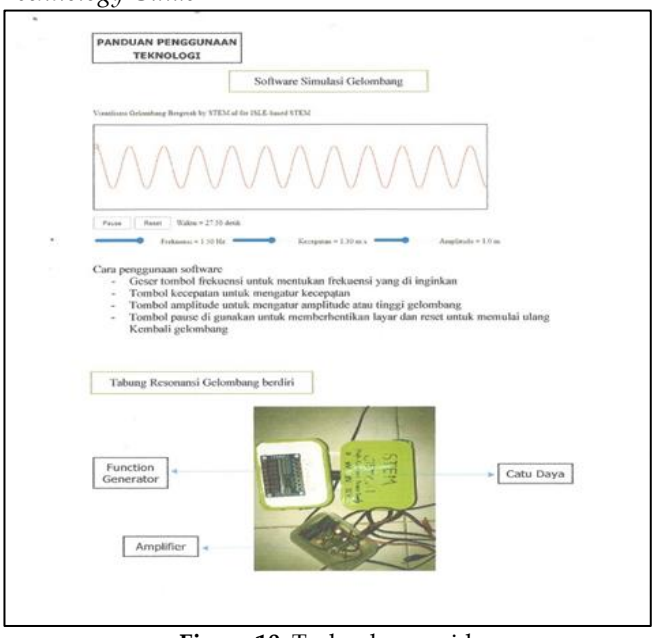

Figure 10. Technology guide

When conducting experiments, students will use several physics measuring tools, create graphs, and so on, so it is necessary to make a separate sheet containing a brief guide to the operation of the technology. STEM-based learning requires students not only to know technology, but also to be able to use it in explaining scientific phenomena in fact in the form of measurement data.

Development

Media Expert Validation Analysis Results for APP

The validation of the tool was assessed by one expert who was a Physical Lecturer in Mathematics and Natural Sciences at Unsyiah.

Table 2. Data validation results by media experts for APP

Rated aspect	Score Percentage(%)	Score Percentage(%)
Tool resistance	3.66	73.2
Tool accuracy	3.25	6510
Tool efficiency	3.33	66.6
Aesthetics	4.00	80.0
Security	4.00	80.0
Kid's box	4.50	90.0
Amount	22.74	458.8
Average	3.79	76.4
Category		Very good

Based on the assessment by media experts for APP, the percentage value for the aspect of tool durability is 73.2%, tool accuracy is 65%, tool efficiency is 66.6%, aesthetics is 80%, security is 80%, ease of storage/kit box is 90%. The average percentage for all aspects assessed is 76.4%. Because the indicator value obtained is above the minimum class interval of 75%, the model developed is in the very good category. and declared eligible for use in learning activities.

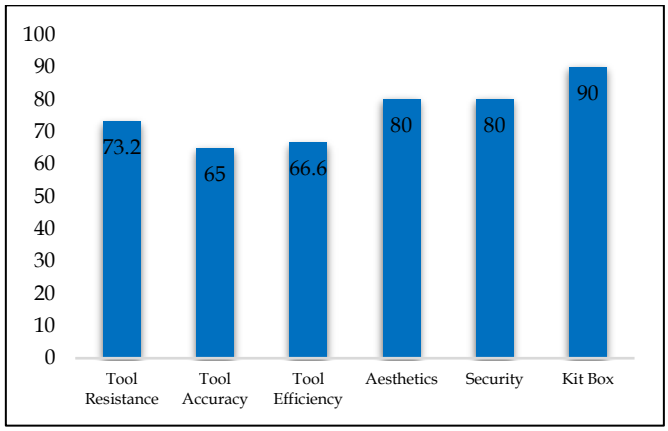

Figure 11. The results of the media expert validation for APP are presented in the diagram

Data from ISLE-based STEM Student Worksheets Media Expert Validation Results

Table 3. Results of Validation of Media Experts for Making Student Worksheets

Rated aspect	Score Percentage(%)	Score Percentage(%)
Tool resistance	4.0	73.2
Tool accuracy	3.6	72.0
Tool efficiency	4.0	80.0
Amount	11.6	11.6232
Average	3.8	77.3
Category		Very good

Based on table 3, the data analysis of student worksheets validation results by media experts shows a very good category in every aspect of the assessment with an average value of 3.8 from a maximum scale of 5 for all aspects of the assessment. Based on the assessment by media experts for student worksheets, the percentage value of all aspects assessed is 77.3%. The percentage results obtained are then converted into a qualitative scale based on the categories that can be seen in table 3.5. Because the indicator value obtained is above the minimum class interval of 75%, which is 77.3%, the student worksheets developed is in the very good category and is declared feasible to be used in learning activities. Media expert validation results for student worksheets are presented in Figure 12.

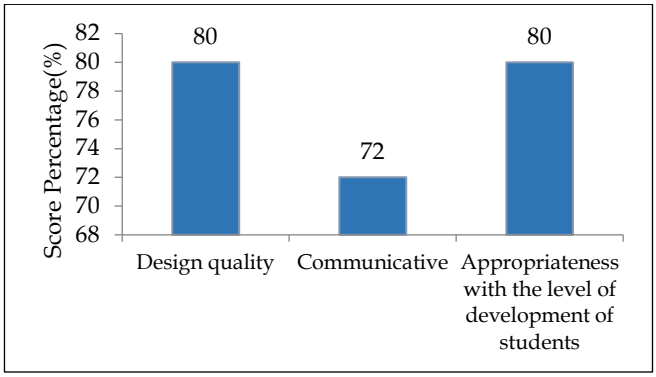

Figure 12. Assessment of ISLE-Based STEM student worksheets by Media Experts

Material Expert Validation Results Data

Assessment by material experts for student worksheets obtained a percentage score for all aspects of 83.13%. Because the indicator value obtained is above the minimum class interval of 75%, the student worksheets developed is in the very good category and is declared feasible to be used with slight revisions before being implemented in learning activities.

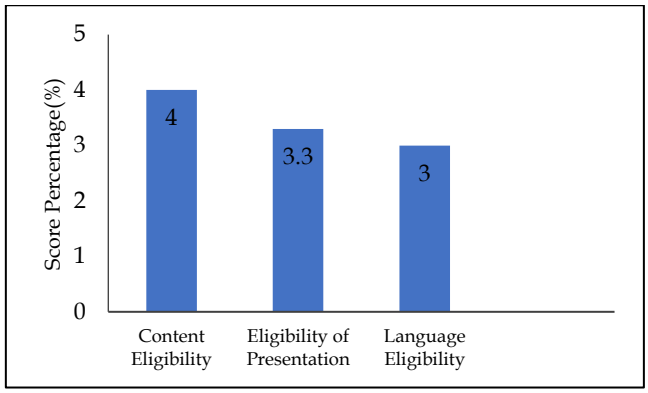

Figure 13. Assessment of ISLE-based STEM student worksheets by material experts

Data on Results of Assessment by Study Field Teachers

The assessment was carried out for two media namely Practicum Teaching Aids (APP) and Student Worksheets. In general, the assessment given by the teacher is in a very good category with an average score obtained of 4.31 on a maximum scale of 5. The percentage value is calculated using equation 4.1 and based on the assessment by the teacher, the percentage score for all aspects of APP and student worksheets is 79.08. % entered into the very good category, and declared feasible to be used in learning activities.

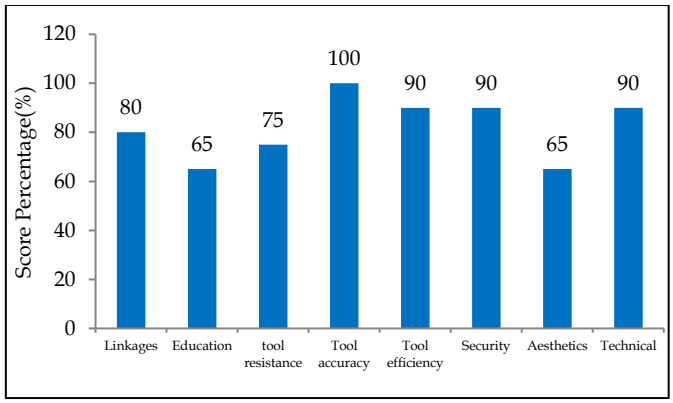

Figure 14. APP assessment by subject teachers

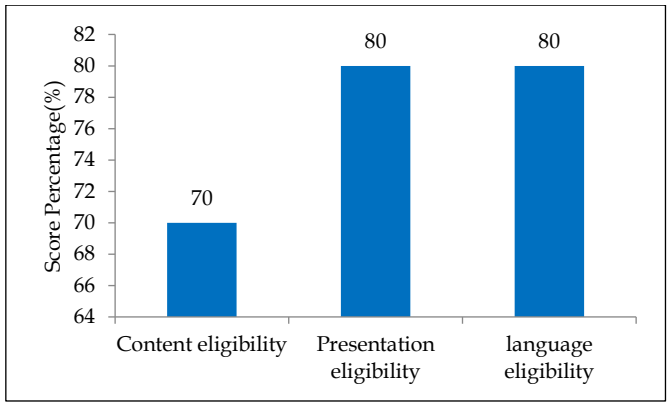

Figure 15. Student worksheets assessment by subject teachers

Student Observation Data

Based on the results of observations made it appears that the atmosphere of learning physics is still based on material from the teacher, the methods are still conventional, and students tend to be passive.

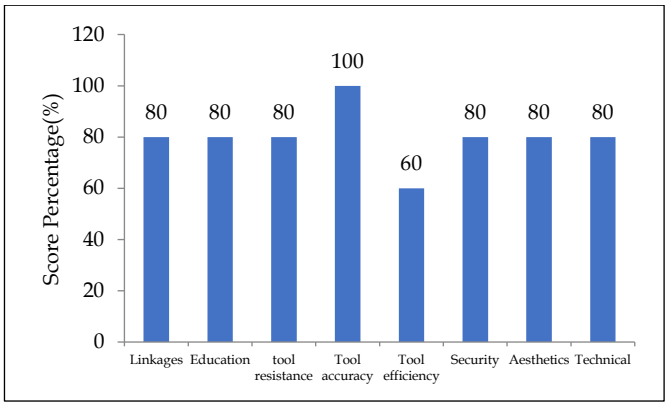

Figure 16. The results of the student observer validation of the teaching aids

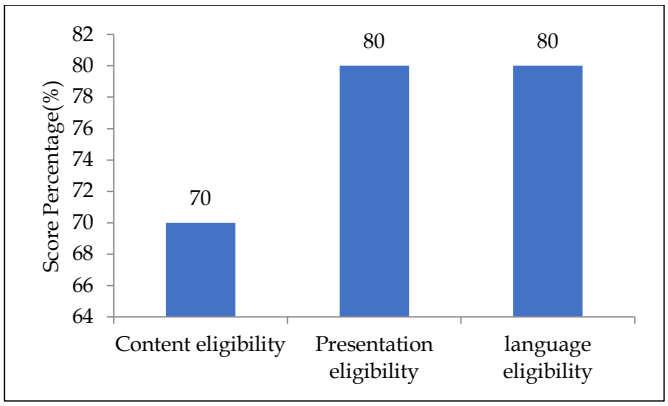

Figure 17. Student observer validation results on student worksheets

Learning activities begin with giving facts and concepts through the lecture method, giving examples of questions and giving homework. The learning model that is carried out does not match the characteristics of physics itself, does not involve students in learning to implement science process skills. Facts based on observations show that it is necessary to make improvements to physics learning with learning models that can improve students' thinking skills, one of which is the ISLE learning model (Investigative Science Learning Environment).

It can be concluded that this learning media challenges students to act like a scientist in formulating physics concepts. In addition, students are challenged to think critically, creatively, collaboratively and communicatively. Some of the advantages of developing ISLE-based STEM learning media, such as the innovation in the form of technology-based APP development that can inspire teachers to also be able to develop tools that are easily found in online stores at relatively affordable prices. As it is known that many physics APPs are produced by factories with high selling prices and not all schools are able to procure these practicum tools, another alternative is to design and develop APP that can be used by students to conduct small-scale experiments. In this research, we program a traveling wave simulation and a resonant tube for visualization of standing waves.

Based on the results of the limited test on ISLE-based STEM media to 10 students of class XI MAN 4 Tungkob, based on the value of student responses to the use of ISLE-based STEM learning media, it was in the very good category with an APP percentage of 80% and student worksheets of 89%.

Conclusion

The standing wave resonance tube Practice Trainer (APP) has been successfully developed for standing wave experiments. The developed APP makes it easy for students to understand the concept and visualize standing waves. The student worksheet based on constructivism has been successfully compiled. Student worksheets which is prepared with the ISLE-based STEM model approach is used as a guide in achieving learning objectives by building students' thinking concepts on standing wave material through closed resonance tube experiments. The transformation of education today is closely related to the transformation between pedagogical content and technology. In this transformation, the active role of students/students is also needed. There will be more and more digital activities in the virtual world, including in the realm of education. For this reason, higher education institutions or schools can hold multidisciplinary and blended-learning activities, utilizing IoT, based on this, ISLE-based STEM learning is in line with the educational transformation that is being developed now, where in ISLE-based STEM students are required to play an active role and utilize more IoT, and based on experimental results, it was found that ISLE-based STEM learning was able to improve student learning outcomes, in other words, ISLE-based STEM learning was able to support the current educational transformation.

Acknowledgements

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