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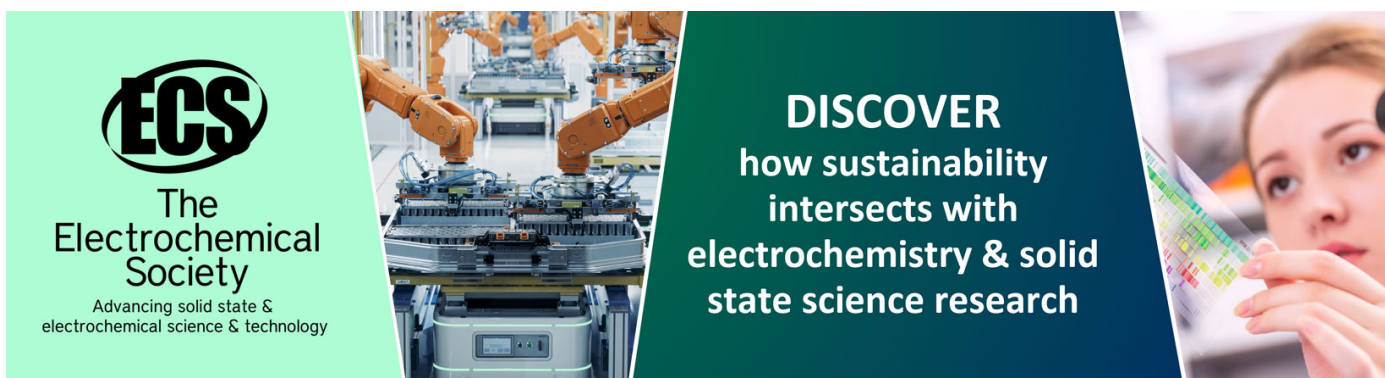
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Development of a do-it-yourself physics apparatus for STEM learning: standing wave generator

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Abstract. This study aimed to develop and investigate the efficiency of the DIY Standing Wave apparatus for STEM demonstration and laboratory in Grade 7 for the topic transverse waves under the K-12 curriculum. The efficiency of the apparatus was determined through successive experiments and the percentage error was compared to the Mechanical Wave Vibrator of the College of Science and Mathematics, MSU-IIT. The assessment on the DIY Standing Wave apparatus manual was the basis for the modification of the DIY Standing Wave apparatus and revision of the manual. Results revealed that there was no significant difference in the percentage error between the DIY Standing Wave apparatus and Mechanical Wave Vibrator. The DIY Standing Wave apparatus and the Mechanical Wave Vibrator had an average percentage error of less than ten percent, so the DIY Standing Wave apparatus was also efficient. The manual for the DIY Standing Wave Apparatus can guide teachers on what materials are needed and how to fabricate the apparatus. The manual was appropriate for the DIY Standing Wave apparatus and was intended for the in-service Physics teachers. The apparatus can be a tool for an effective STEM learning.

1. The Problem and Its Scope

1.1. Introduction

It is said that learning is much relevant when students got engaged on some concrete objects that could bring abstract ideas to life especially in indulging in the field of science. The very challenge in teaching complex science especially Physics is imparting information and ideas to the students effectively. Physics has always been regarded by students as the hardest subject to comprehend in class discussion. This is because it demands a higher level of imagination, thinking and analyzing skills. Thus, teachers should find the possible means and ways to make Physics enjoyable, pertinent and significant to students.

In the nineties, science educators believed that laboratory is an essential means of activity in science instruction, becoming a maxim for every science educators and teachers. The use of laboratory is an educational method that provides permanent knowledge, encouraging mental activities and allowing students to develop learning by doing skills. It was suggested that the laboratory activity was designed to help students to gain better idea of the nature of science and scientific investigation by emphasizing the discovery approach. Today, the laboratory method means a procedure dealing with first hand experiences regarding materials or facts often derived from investigation or experimentation [1]. It also serves as a source of interaction for the students; interaction between instructor and students, with the subject material itself, or with their prior knowledge and ideas about a topic. Laboratories allow students to become active learners [2].



However, in the education setting of the Philippines, chalk-and-board has been the routine in teaching Physics due to the lack of science equipment to carry out laboratory activity, particularly in rural areas and some in urban areas. There might be equipment present but its number cannot cater the students in a class. For some reasons, each equipment cost a lot of money and often schools do not have enough to spend for it. On the other hand, only few science teachers have the adequate knowledge on operating science equipment.

In order to alleviate this problem, the researchers desired to develop a Do-It-Yourself Standing Wave apparatus for the demonstration and/or laboratory in Grade 7 under the K-12 curriculum. This DIY apparatus includes readily available and affordable materials to make it accessible for the teachers.

1.2. Objective of the Study

This study aimed to develop and investigate the efficiency of the DIY Standing Wave apparatus which can be a tool for an effective STEM learning.

1.3. Scope and Limitation of the Study

This study was limited to developing a Do-It-Yourself Standing Wave apparatus for Physics topic in Grade 7 on Mechanical Waves specifically on transverse wave under the K-12 curriculum and was intended for the in-service teachers teaching Physics. The fabrication was done by the researchers for reason that there is a lack of instrument in the DepEd especially in the rural areas. This instrument could demonstrate concepts on waves that were intended for classroom instruction in Grade 7. It was evaluated by the fourth year and third year BSEd-Physics students of Mindanao State University – Iligan Institute of Technology.

1.4. Statement of the Problem

The following questions are the bases of this study:

1. How is the Do-It-Yourself Standing Wave apparatus developed?
2. What is the efficiency of the DIY Standing Wave apparatus?
3. What is the assessment of the DIY Standing Wave apparatus manual?
4. What is the level of readability of the DIY Standing Wave apparatus manual?

1.5. Null Hypothesis

The following null hypothesis was tested at 0.05 level of significance.

H_0 : There is no significant difference between the percentage error of the Do-It-Yourself Standing Wave Apparatus and Mechanical Wave Vibrator.

2. Related Literature and Studies

A periodic wave repeats the same pattern over and over, each repeating section transporting the energy that was used to generate it. A periodic water wave can be produced by steadily dropping a series of pebbles into the water; periodic wave on a cord can be produced by taking one end of the cord and moving it up and down, over and over, in a repeating pattern. As the wave propagates along the cord, every point on the cord oscillates with the same up and down pattern, though with a time delay that depends on the wave speed [3].

The standard “real world” analogy for standing waves involves guitar or violin strings. The unique feature of these particular strings is their clamped immobile ends, which imposes a set of boundary conditions on those waves. As a result, standing waves have discrete wavelengths (λ), which are dependent on the string length (L) here n may be any integer and refers to number of half-wavelengths that will fit on string with length L . These occur at specific points along the length of the string and at the clamped ends. Since the length of the string on a guitar is constant, an increasing number of nodes in a standing wave correspond to a smaller wavelength. Since wavelength and frequency are inversely proportional, more nodes yield a higher frequency wave, that is, one with a higher pitch [4].

A study was conducted on the “Development of a Do-It-Yourself (DIY) Science Equipment in Electromagnetism: Brushless Generator” showed that the developed DIY Physics equipment was workable. The illustrative paper of the DIY Physics equipment can guide the teacher on what to do in the fabrication of the equipment. Moreover, the DIY illustrative paper was appropriate for the equipment [5].

Another study was conducted about the development and validation of a Laboratory Activity using Heat Conductivity showed that after being subjected to the developed laboratory activity, the respondents were able to understand the topic on Heat Conductivity. Most of the performance level of the respondents got satisfactory performances. The respondents had positive attitudes towards the laboratory activity and the DIY apparatus [6].

3. Methodology

3.1. Subjects of the Study

The respondents of this study were the third year and fourth year BSE Physics students of MSU-IIT. There were fifty respondents that had already taken the subjects Physics 12 (Introductory Physics II) and Physics 12.1 (Introductory Physics II laboratory) specifically the transverse wave topic and EdSc 137 (Science Instrumentation Workshop). These respondents were deemed to have adequate understanding and competencies on the topic Transverse Wave. For this reason, they were asked to evaluate the manual of the Do-It-Yourself Standing Wave apparatus.

3.2. Research Design

This study utilized a quantitative approach in examining the gathered data. Quantitative method was involved in this study especially in determining the significant difference in the percentage error between the DIY Standing Wave apparatus and Mechanical Wave Vibrator. The modification of the DIY Standing Wave apparatus was based on the comments and suggestions of the respondents, adviser, and panel members. The revision of the manual for the DIY Standing Wave apparatus was based on the comments and suggestions of the respondents through the rating sheet.

3.3. Instruments Used

1. Do-It-Yourself Standing Wave Apparatus Manual Rating Sheet

The manual was assessed through different criteria in terms of title, introduction, concept, materials/tools, procedure, layout, spelling and grammar, and references.

2. Flesch-Kincaid test

This was intended for the in-service teachers' readability. This was designed to indicate how easy a text to read using Flesch-Kincaid Reading Ease and to indicate the grade level the test can be appropriate.

3.4. Data Gathering Procedure

The first part deals with the fabrication of the standing wave apparatus followed by the testing of the apparatus. At the same time, the manual was also made and underwent readability test and assessment. The findings became the bases of the modification of the apparatus and revision of the manual.

3.5. Statistical Analysis

This study employed descriptive and inferential statistics in analyzing the data. The mean was used to determine the rating of the DIY Standing Wave apparatus manual. The t-test was used to determine the significant difference between the percentage error of the DIY Standing Wave apparatus and the Mechanical Wave Vibrator.

The interpretation on the ratings was based on the following scale: 1.00-1.74 (Poor); 1.75-2.49 (Fair); 2.50-3.24 (Good); 3.25-4.00 (Very Good).

4. Results and Discussions

4.1. Efficiency of the DIY Standing Wave Apparatus

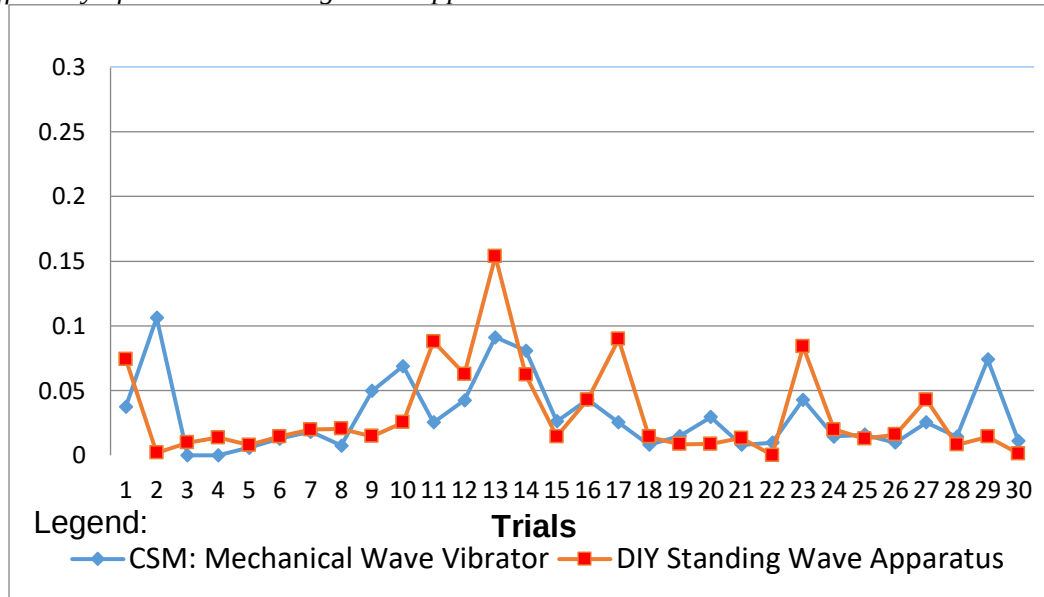


Figure 1. Line graph comparison of the efficiency between the mechanical wave vibrator and the standing wave apparatus.

The line graph shows the comparison of the percentage error between the Mechanical Wave Vibrator and the DIY Standing Wave Apparatus in thirty (30) trials displayed horizontally and a percentage error displayed vertically. The blue line represents the data for Mechanical Wave Vibrator the while the red line represents the data for the DIY Standing Wave apparatus. Calculations were done by the researchers and found out that the efficiency of the DIY Standing Wave apparatus was close to the efficiency of the Mechanical Wave Vibrator.

Table 1. Difference between the percentage error of the DIY standing wave apparatus and mechanical wave vibrator.

Apparatus	Mean Percentage Error	t-value	p-value	Remark
DIY standing wave apparatus	0.032035	0.162	0.872	Not significant
Mechanical wave vibrator	0.030689			

H₀: There is no significant difference between the percentage error of the do-it-yourself standing wave apparatus and mechanical wave vibrator.

Table 1 shows the difference between the percentage error of the DIY Standing Wave apparatus and Mechanical Wave Vibrator. Based on the experiment and comparison done by the researchers on the developed DIY Standing Wave apparatus and Mechanical Wave Vibrator of CSM, both apparatuses got almost the same result in terms of the percentage error. This means that both apparatuses had nearly the same efficiency. The t-value shows that the mean percentage error of the DIY Standing Wave apparatus is greater than that of the Mechanical Wave Vibrator, which means that the Mechanical Wave Vibrator is more efficient than the DIY Standing Wave apparatus. However, there is no significant difference in the percentage error between the two apparatuses since the p-value of 0.872 is greater than of 0.05 level of significance. The DIY Standing Wave apparatus and the Mechanical Wave Vibrator have an average percentage error of less than ten percent, so the DIY Standing Wave apparatus is also efficient to use.

4.2. Assessment of the DIY Standing Wave Apparatus Manual

Table 2. Assessment of the DIY standing wave apparatus manual by the third year and fourth year BSE physics students.

Criteria	Mean Rating	Interpretation
Title	3.64	Very Good
Introduction	3.52	Very Good
Concepts	3.48	Very Good
Materials/Tools	3.80	Very Good
Procedure	3.80	Very Good
Layout	3.74	Very Good
Spelling and Grammar	3.69	Very Good
References	3.72	Very Good
Total	3.67	Very Good

Legend: 3.25-4.00 (Very Good); 2.50-3.24 (Good);

1.75-2.49 (Fair); 1.00-1.74 (Poor)

Based on the assessment done by the third year and fourth year BSE Physics students on the manual, the manual had the highest mean rating in terms of materials and procedure because the materials that were used were readily available and accessible in stores and in homes. Also, the procedure was rated as very good which means that it is very organized and easily understandable. However, the manual had the lowest mean rating in terms of its concepts because it does not completely provide detailed explanation of the concepts but it is brief and concise, no misconceptions, and gives general overview.

Based on the assessment done by the third year and fourth year BSE Physics students on the DIY Standing Wave apparatus manual, it revealed that the manual had an overall mean rating of “Very Good”. This implies that the DIY Standing Wave apparatus manual was appropriate in the gathering of materials and fabrication of the DIY Standing Wave apparatus.

The result is in accordance to the study of Belnas (2016) on “DIY Science Equipment in Electromagnetism Brushless Generator”, where the illustrative paper and the DIY Physics equipment were rated as “very good” by the pre-service third year and fourth year BSE Physics students. Moreover, the DIY illustrative paper was appropriate for the equipment.

4.3. Modification of the DIY Standing Wave Apparatus

One of the comments gathered by the researchers was to “improve or beautify the apparatus” referring to the wooden case of the apparatus in order to have a presentable picture of the DIY Standing Wave apparatus on its fabrication manual. The fabricated DIY Standing Wave apparatus was still made of readily available and accessible materials like transparent plastic cup, vibrating rod made out of syringe, hook screw as fix string retainer, recycled extension cord, marine plywood, step up and step down transformer, and sixty hertz plastic type speaker. However, the apparatus seemed not to be so presentable enough to catch the students’ attention.

In this case, the wooden case was coated with red varnish. In terms of the dimension, the set-up, the internal feature, and the efficiency of the modified DIY Standing Wave apparatus had no modifications. Below are the illustrations of the fabricated and the modified DIY Standing Wave apparatus.



Figure 2. Fabricated DIY standing wave apparatus.

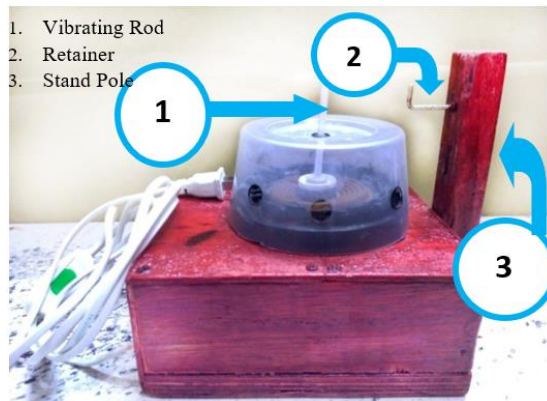


Figure 3. Modified DIY standing wave apparatus.

4.4 Revision of the DIY Standing Wave Apparatus Manual

The overall assessment of the DIY Standing Wave apparatus manual by the third year and fourth year BSE Physics students is “very good”. The researchers looked into the consideration the comments and suggestions of the respondents in improving the quality of the manual of the DIY Standing Wave apparatus. Below are the revised parts of the manual.

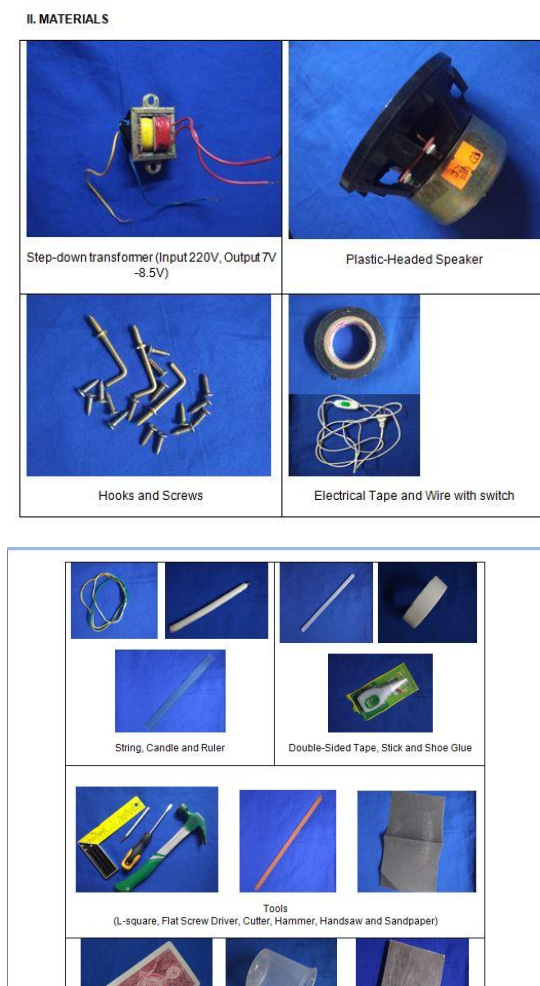


Figure 4. Materials before the revision.



Figure 5. Materials after the revision.

The figures show the materials before and after the revision. The tools and materials were resized, rearranged, and categorized according to their use. Bright colors were used for the background of the pictures of the materials, as suggested by the respondents, in order to see the materials clearly.

Table 3. Descriptions in the procedure.

Before revision	After revision
2. Separate the magnet from the plastic case of the speaker. (Caution: Ask adult for assistance)	2. Separate the magnet from the plastic case of the speaker. (Caution: Ask expert for assistance)
3. Remove the paper covered on the upper part of the speaker. Furnish the remaining cover paper. (Caution: Ask adult for assistance)	3. a) Remove the paper covered on the upper part of the speaker. b) Furnish the remaining cover paper. (Caution: Ask expert for assistance)
4. Cut the plastic case into half using hacksaw. Using shoe glue, stick the deck-playing card to the hole in the center of the plastic being cut. (Caution: Ask adult for assistance.)	4. a) Cut the plastic case into half using hacksaw. b) Using shoe glue, stick the deck-playing card to the hole in the center of the plastic being cut. (Caution: Ask expert for assistance.)
5. In making the case box-type, use hacksaw in cutting two “2 by 6 inches”, two “2 by 4 inches” and two “6 by 5 inches.” Use hammer and 1 inch nails to assemble the box-type case. Make measurement of the circle for the speaker (Caution: ask adults for help)	5. In making the case box-type, use hacksaw in cutting the marine plywood in to two “2 by 6 inches”, two “2 by 4 inches” and two “6 by 5 inches.” Use hammer and 1 inch nails to assemble the box-type case. Make measurement of the circle for the speaker (Caution: Ask expert for assistance)
6. Connect the step-down transformer and speaker. After connecting the two, connect the wire of used electric fan to the input of the step down transformer then test the device if it works properly. (Caution: ask adults/electricians for help)	6. a) Connect the step-down transformer and speaker. b) After connecting the two, connect the wire of used electric fan to the input of the step down transformer then test the device if it works properly. (Caution: Ask expert/electricians for assistance)
7. Place the connected transformer & wire to the box-type case and lock the plywood on the upper part of the case. Assemble the cut plastic-case in the procedure #2 to the upper part of the speaker then polish the excess (e.g. card, plastic). (Caution: ask adult for help)	7. a) Place the connected transformer & wire to the rectangular wooden box. b) Screw the plywood on the upper part of the case. c) Assemble the cut plastic-case in the procedure #2 to the upper part of the speaker. d) Glue the syringe e) Then polish the excess (e.g. card, plastic). (Caution: Ask expert for assistance)

Table 3 shows the descriptions in the procedure in fabricating the DIY Standing Wave Apparatus Manual. The researchers took account the comments of the respondents, the panel members and the adviser. The “Caution: Ask for adults” was changed to “Caution: Ask expert for assistance” to indicate and assure that a specific person has the right knowledge in executing the state step on the procedure to avoid injuries. Its bold colored text was changed from bold black text to red bold text to indicate that it is a warning and must be done cautiously. Description with two or more steps was given assigned letters to indicate that two or more figures of corresponding execution are shown. The figure below shows the additional procedure.

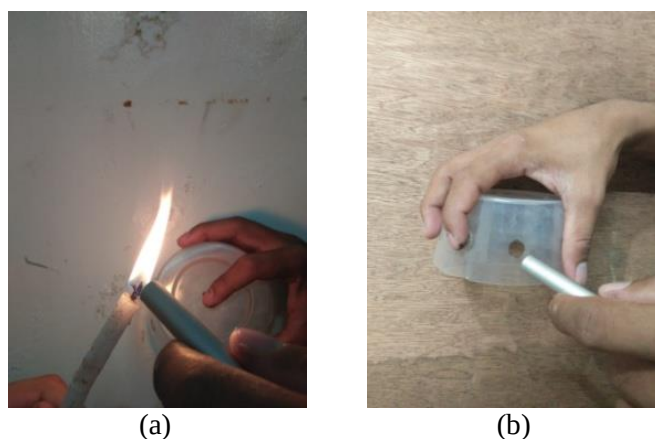


Figure 6. Additional procedure: a) Heat the aluminum rod with a candle; b) Pinch 8 holes on the side of the transparent plastic cup and 1 hole at the center of the surface.

4.5. Readability of the DIY Standing Wave Apparatus Manual

Table 4. Readability of the manual using Flesch-Kincaid test.

Parts of the Manual	Score	Grade Level	Interpretation
Introduction	74.8	7 th Grade	Fairly easy to read
Procedure	68.4	8 th and 9 th grade	Plain English, easily understood by 13-15 years old

The introduction of the manual gained a score of 74.8, which had an equivalent level of a 7th grader, with an interpretation of “fairly easy to read”. For the procedure, it gained a score of 68.4, which had an equivalent level of an 8th to 9th grader, with an interpretation of “Plain English which means it can be easily understood by 13 to 15 year old student”. The words were clear and less complex. The sentence was simple, which means that there were no dangling words present and was easy to comprehend. Results revealed that the manual was really intended for the in-service Physics teachers.

5. Conclusion

The developed DIY Standing Wave apparatus can be a tool for effective STEM learning. The manual for the DIY Standing Wave Apparatus can guide teachers on what materials are needed and how to fabricate the apparatus. The manual is appropriate for the DIY standing wave apparatus and is intended for the in-service Physics teachers.

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