Development of a do-it-yourself physics equipment in electromagnetism: brushless generator

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Abstract. The main objective of this study was to develop a DIY Physics equipment, brushless generator, to be used in demonstrating the concepts of electromagnetism. This study employed quantitative and qualitative methods in analyzing and interpreting data. The equipment and its illustrative paper were designed by the researchers. Rating sheets were used to assess the workability of the equipment and illustrative paper. Enhancements were made by the researchers to improve the workability of the equipment as well as the illustrative paper. The pre-service and in-service Physics teachers assessed the DIY Physics equipment as workable. The illustrative paper was appropriate to the in-service Physics teachers and DIY Physics equipment.

1. The Problem and Its Scope

1.1. Introduction
Physics educators believed that science equipment is an important means of demonstration in science instruction. Teachers appreciate the use of laboratory equipment and usually complain of lack of materials and equipment to perform hands-on practice. In fact, many schools in the Philippines especially in the rural areas, science teaching has always been just a board-and-chalk routine due to lack of science equipment. This has been the cause of concern to educators, considering the understanding of the concepts in science.

A study emphasized that laboratory can be a source of interaction for the students; interaction between instructor and students, with the subject material itself, or with the prior knowledge and ideas about a topic. Laboratories allow students to become active learners especially when they are given opportunities to manipulate science equipment [1].

1.2. Objective of the Study
The main objective of this study was to develop and investigate the workability of the Do-It-Yourself (DIY) Physics equipment, a brushless generator, with the use of electromagnets and permanent magnets, as a tool in demonstrating the concepts of electricity and magnetism.

1.3. Scope and Limitation of the Study
The study focused on the development of a Physics equipment which was the brushless generator that was intended for Grade 9 and 10 learners. Enhancement of the equipment was done to produce an improvised equipment that can demonstrate the concepts of electricity and magnetism. The enhancement was based on the findings of the assessment made by the pre-service Physics teachers and in-service Physics teachers on the workability of the equipment and readability of the illustrative paper.
1.4. Statement of the Problem
This study was conducted to answer the following questions:
1. How is the DIY Physics equipment developed?
2. What is the assessment of the illustrative by the
   a. Pre-service Physics teachers?
   b. In-service Physics teachers?
3. What is the readability of the illustrative paper?
4. What is the assessment of the DIY Physics equipment by the
   a. Pre-service Physics teachers?
   b. In-service Physics teachers?
5. What enhancement can be done to improve the workability of DIY Physics equipment by the
   a. Pre-service Physics teachers?
   b. In-service Physics teachers?

2. Related Literature and Studies
A study was conducted which emphasized that the idea of discoveries does not stop on the discovery itself, but in telling the world about such discoveries. It is the duty of the teachers to let the students understand its concept through teaching. Teaching the concepts of Physics is hard to accomplish by just using a traditional lecture method. It is part of the teacher to transform the teaching environment in such way that the students will be motivated to learn by using any alternative methods that will suit to the learning content. It was found out that the performance of the students improved. Thus, the developed activity was of great help to the learners and teachers [2].

Another study was conducted to modify the DIY differential radioscope apparatus in such way that it could be utilized as a tool for teaching radiant energy regardless of whether condition. Based on the result of his study, the apparatus has improved and met the aim of its modification. Thus a development of a laboratory activity was recommended for the implementation of the apparatus and to orient teachers on its utilization [3].

A researcher developed and evaluated a laboratory apparatus that will help teach several topics in magnetism like Faraday’s Law, Lenz’s Law, Electromagnetic induction, and Motors by using improvised laboratory device. The study revealed that the improvised apparatus was very acceptable in terms of (a) constructional appearance and economy; (b) convenience and scientific rigor and (c) performance output. The reflections and insights of the students considered that they have no choice but to do the activity, yet they found themselves enjoying the activity and seeing its value in real-life situations [4].

In a study entitled “Improvized Apparatus Based on Faraday’s Law of Electromagnetic Induction for Practical Work Activity”, the researcher designed and constructed an improvised apparatus made from low cost and locally available materials. She concluded that the fabricated improvised apparatus has been shown to be very significant in demonstrating Faraday’s Law of Electromagnetic Induction in secondary physics instruction [5].

3. Methodology

3.1. Subjects of the Study
The participants of this study were the BSEd Physics students of the College of Education, MSU-IIT, the thesis adviser and the panel members, Physics teachers in MSU-IIT who were considered as experts, and the Physics teachers from public and private high schools in Baroy, Lanao del Norte.

3.2. Research Design
This study employed a quantitative method because it used a mathematically based method in analyzing numerical data gathered from the thorough assessment on the workability of the DIY Physics equipment and laboratory activity kit. Also, it employed qualitative method because the researcher sought to
conduct an in-depth analysis of the data by deciphering the context of the results or findings of assessment, collecting detailed views of the participants, and using inductive reasoning in interpreting the process, as well as the outcomes.

3.3. Instruments Used
This study made use of the following instruments:

1. Workability of DIY Physics Equipment Rating Sheet. This was used to assess the developed DIY Physics equipment in terms of its physical feature, ease of manipulation, efficiency, safety, and appropriateness.
2. Illustrative Paper Rating Sheet. This was used to assess the illustrative paper in terms of title, introduction, concepts, materials and tools, procedure, layout, spelling and grammar, and references.

3.4. Data Gathering Procedure
3.4.1. Phase 1
Stage 1: Fabrication of Brushless Generator
Designed by the researchers, the brushless generator was chosen to demonstrate the concepts of electromagnetism. The equipment was appropriate to the key stage standards of the K-12 curriculum.

Stage 2: Composition of the Illustrative Paper
After the fabrication of the device, composition of the illustrative paper followed. The illustrative paper illustrated the procedure in manipulating the device.

3.4.2. Phase 2
Stage 1: Assessment of the Illustrative Paper
Assessment of the illustrative paper in terms of its readability was needed to make sure that the illustrative paper was effective.

Stage 2: Assessment of the Workability of the DIY Equipment
The DIY equipment was presented to the participants and was assessed with the use of a rating sheet. The feedbacks were gathered for the enhancement of the equipment.

Stage 3: Readability of the Illustrative Paper
Assessment of the readability of the illustrative paper was needed to make sure that the illustrative paper is effective. The illustrative paper was assessed with the use of the Flesch-Kincaid test.

3.4.3. Phase 3
Suggestions and recommendations from the in-service teachers of public and private high schools were utilized by the researchers to manufacture an enhanced DIY equipment.

3.5. Statistical Analysis
The mean was used to determine the average rating of the participants in assessing the workability of the DIY equipment. To interpret the students’ level of satisfaction, the following descriptions were used: 1.00-1.74 (Poor); 1.75-2.49 (Fair); 2.50-3.24 (Good); and 3.25-4.00 (Very Good).
4. Results and Discussions

4.1. Fabrication of the DIY Physics Equipment

Figure 1 shows the flow of the fabrication of the DIY physics equipment, gathering of materials, construction of stator and rotor, and testing of the device. The DIY Physics equipment was developed by the researcher in terms of physical feature, ease of manipulation, efficiency, accuracy, safety and appropriateness to test the equipment’s workability. The development of the DIY Physics equipment was based on these concerns: versatility of the equipment in terms of concept and its appropriateness to the key standards of enhanced K–12 basic education curriculum in Grade 9 and 10. The figure below shows the designed DIY Physics equipment.

Figure 2. Designed DIY physics equipment.

4.2. Composition of the Illustrative Paper
The illustrative paper was composed by the researchers guided by the different criteria in terms of title, introduction, concepts, materials/tools, procedure, layout, spelling and grammar, and references. The illustrative paper was composed to show the best illustration in the gathering of materials, fabrication of the DIY Physics equipment, manipulation, testing and costing of the device.
4.3. Assessment of the Illustrative Paper

Table 1. Assessment of the illustrative paper by pre-service and in-service physics teachers.

| Criteria       | Pre-Service Physics Teachers | In-Service Physics Teachers | Overall          |
|----------------|-----------------------------|----------------------------|------------------|
|                | Mean Rating | Interpretation | Mean Rating | Interpretation | Mean Rating | Interpretation |
| Title          | 3.73        | Very Good      | 3.33        | Very Good      | 3.53        | Very Good      |
| Introduction   | 3.61        | Very Good      | 3.29        | Very Good      | 3.45        | Very Good      |
| Concepts       | 3.63        | Very Good      | 3.33        | Very Good      | 3.48        | Very Good      |
| Materials/Tools| 3.66        | Very Good      | 3.43        | Very Good      | 3.55        | Very Good      |
| Procedure      | 3.56        | Very Good      | 3.37        | Very Good      | 3.47        | Very Good      |
| Layout         | 3.80        | Very Good      | 3.61        | Very Good      | 3.71        | Very Good      |
| Spelling/Grammar| 3.73      | Very Good      | 3.42        | Very Good      | 3.58        | Very Good      |
| References     | 3.83        | Very Good      | 3.33        | Very Good      | 3.58        | Very Good      |

Legend: 1.00-1.74 (Poor); 1.75-2.49 (Fair); 2.50-3.24 (Good); 3.25-4.00 (Very Good)

Based on the assessment done by the pre-service and in-service Physics teachers on the illustrative paper, the paper had the highest mean rating in terms of layout because the title and subheadings were given emphasis, it had readable texts, and the design was consistent. The paper had the lowest mean rating in terms of its introduction because it did not provide relevant and clear concepts. It was brief and concise, with no misconceptions, and gave general overview.

Based on the assessment done by the pre-service and in-service Physics teachers on the illustrative paper, the overall assessment revealed that the illustrative paper had a mean rating of “Very Good”. Among the seven (7) criteria, the illustrative paper had the highest overall mean rating in terms of its layout so the paper had best quality of illustrating the fabrication of the DIY Physics equipment. This implies that the illustrative paper was appropriate in the gathering of materials, fabrication, testing, and manipulation of the DIY Physics equipment.

4.4. Assessment on the Workability of the DIY Physics Equipment

Table 2. Assessment on the workability of the DIY physics equipment by the pre-service physics teachers.

| Criteria          | Pre-Service Physics Teachers | Mean Rating | Interpretation |
|-------------------|-----------------------------|-------------|----------------|
| Physical Feature  | 3.46                        | Very Good   |
| Ease of Manipulation| 3.49                    | Very Good   |
| Efficiency        | 3.86                        | Very Good   |
| Safety            | 3.65                        | Very Good   |
| Appropriateness   | 3.90                        | Very Good   |

Legend: 1.00-1.74 (Poor); 1.75-2.49 (Fair); 2.50-3.24 (Good); 3.25-4.00 (Very Good)

Based on the assessment done by the pre-service Physics teachers on the developed DIY Physics equipment, the equipment had the highest mean rating in terms of appropriateness because the equipment was appropriate for the age, year level, and maturity of students. It was also appropriate for learning Physics concepts. The equipment had the lowest mean rating in terms of its physical feature because it needed improvement on its design according to the evaluations, it was not properly built, not highly innovative, but was made from accessible and affordable materials. The device needed improvement on the following: placement of the LED is not permanent, stability of the vertical stand, enough grip of the rotor, wavering of the chopping board, and portability of the equipment.
Based on the assessment done by the in-service Physics teachers on the developed DIY Physics equipment, the equipment had the highest mean rating in terms of efficiency because the device was functional, provided opportunities for interactive student participation, and developed fundamental understanding of key physics concepts, principles, and theories or laws. The equipment had the lowest mean rating in terms of ease of manipulation because the participants found that there were construction errors. The equipment was not portable because of its size and weight, and was not easy to assemble because of its design.

### 4.6. Enhancement of the DIY Physics Equipment

The researchers gathered all the comments and suggestions of the pre-service and in-service Physics teachers during the pre-assessment and assessment of the DIY Physics equipment. The researchers thought of ways on how to minimize the errors on the construction of the DIY Physics equipment.

In terms of the equipment’s physical feature, the designed DIY Physics equipment was made from accessible and affordable materials like PVC pipes, permanent magnets, copper wire, and chopping board. However, the equipment was not highly innovative because it was not presentable enough to catch the student’s attention. The equipment was not well built because the Light Emitting Diode (LED) was not properly attached. It was also observed that the chopping board was sometimes misaligned because it was not so stable.

The enhanced DIY Physics equipment was still made from accessible and affordable materials like PVC pipes, permanent magnets, neodymium magnets, chopping board, copper wire, and grip tape. The enhanced DIY Physics equipment had the same parts with the designed equipment but the enhanced equipment was already well built because the LED was already attached properly. In the designed DIY equipment, the respondents found out that there were loose connections on the circuit. The researchers decided to put the LED on the circuit board to stabilize the circuit.
The respondents had difficulties in manipulating the device because the rotor required more friction to spin in the original DIY equipment. The researchers then decided to put a grip tape on the rotor handle in the enhanced DIY equipment. The purpose of the grip tape was to increase the friction on the rotor handle for easy manipulation.

The chopping board of the rotor was also enhanced to really prove the ease of manipulation of the enhanced DIY equipment. The designed DIY Physics equipment’s chopping board was just inserted on the rotor handle resulting magnets on the chopping board to get attracted to the iron cores of the stator and wavering during the spin. The chopping board was glued to the rotor handle in the enhanced DIY equipment to minimize wavering and prevent magnets and iron cores attraction.
One of the concerns was the weight of the equipment. The unnecessary parts of the base and rotor of the equipment were removed. The unnecessary parts were the extended PVC pipe and the additional stand on the base.

**Figure 9.** Designed DIY equipment with unnecessary parts.

**Figure 10.** Enhanced DIY equipment with unnecessary parts removed.

**Figure 11.** Designed DIY equipment with unnecessary parts.

**Figure 12.** Enhanced DIY equipment with unnecessary parts removed.

**Figure 13.** Designed DIY equipment.

**Figure 14.** Enhanced DIY equipment.
4.7. Enhancement of the Illustrative Paper
The researchers considered the criteria that were observed during the assessment of the illustrative paper. The overall assessment on the illustrative paper by the pre-service and in-service Physics teachers was “Very Good”. The researchers also made sure that the comments and suggestion of the respondents were given consideration in improving the quality of the illustrative paper. The major enhancement of the illustrative paper was on its procedure.

| Before                                                                 | After                                                                 |
|-----------------------------------------------------------------------|-----------------------------------------------------------------------|
| Remove 2.5-cm insulation at both ends of each of the bolt for connection of light emitting diode (LED). | Remove 2.5-cm insulation at both ends of each of the bolt for connection of light emitting diode (LED). |
| Caution: Be careful in using sharp materials. If possible, use sand paper. | Caution: Be careful in using sharp materials. If possible, use sand paper. |
| Cut an 18-cm diameter circle out of the chopping board using an electric powered saw. | Cut an 18-cm diameter circle out of the chopping board using an electric powered saw. |
| **Note**: Use 1-cm thick chopping board for easier attachment to the PVC shaft. | **Note**: Use 1-cm thick chopping board for easier attachment to the PVC shaft. |
| Drill a 2.5-cm diameter hole at the center of the circular board to fit the PVC coupler. | Drill a 2.5-cm diameter hole at the center of the circular board to fit the PVC coupler. |
| Caution: Ask for adults help in using the hand saw. | Caution: Ask for adults help in using the hand saw. |
| Drill a 2.5-cm diameter hole at the center of the circular board to fit the PVC coupler. | Drill a 2.5-cm diameter hole at the center of the circular board to fit the PVC coupler. |
| Caution: Ask for adults help in using the drilling machine. | Caution: Ask for adults help in using the drilling machine. |

5. Conclusion
The developed DIY Physics equipment was workable. The illustrative paper of the DIY Physics equipment was very good and can guide the teacher on what to do in the fabrication of the equipment. The illustrative paper was appropriate for the DIY Physics equipment.

6. References
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