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Teaching Wave Concepts Using Self-Made Wave Machine and Computer Simulator

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Abstract. This study aimed to investigate the effectiveness of utilizing a self-made wave machine and a computer simulator in teaching basic concepts of waves to Grade 7 students. Drawing on Schwab's Inquiry-based Learning Theory, the research explored how these hands-on and technology-based approaches impact student performance and interest in science education. The researcher used descriptive-correlational and comparative designs. A total of 109 students utilized the self-made wave machine, and 110 students used the computer simulator. These approaches were randomly assigned to the two groups of students. The findings revealed that the students' performances after using the self-made wave machine and computer simulator were both at the "outstanding" level. The data also indicated no significant difference in the students' performances after using the self-made wave machine and computer simulator. Furthermore, students' interest in using the self-made wave machine and computer simulator was generally "high." Lastly, no significant relationship was found between students' interest in activities using self-made wave machine and computer simulator and their performance. These findings suggest that hands-on and digital methods can effectively support science learning, providing educators with versatile tools to engage students. Incorporating self-made apparatus and simulators in science education may enhance student engagement and understanding without significantly altering performance outcomes.

Keywords: Computer simulator; Educational technology; Science education; Self-made wave machine; Wave phenomena.

1.0 Introduction

The COVID-19 pandemic has seriously disrupted education systems worldwide, making learning losses worse. This is especially true in science education, where students are already struggling with engagement and performance. Educational institutions and policymakers have noted a marked decline in student interest in science careers, an alarming trend given the critical role science education plays in economic and technological advancement (Toma & Greca, 2022). As countries strive to recover and rebuild, there is a pressing need to reinvigorate science education to nurture the next generation of scientists and innovators.

In the Philippines, educational challenges are especially severe. The country's learners consistently score below international averages in major assessments, such as the Programme for International Student Assessment (PISA) and the Trends in International Mathematics and Science Study (TIMSS). These assessments reveal significant gaps in scientific knowledge and skills among Filipino students, which, in turn, highlight systemic issues in the educational framework (Andy, 2022; Hadi & Novaliyosi, 2019). Contributing factors include inadequate educational resources, such as insufficient laboratory equipment, a lack of engaging instructional materials, and the need for improved teacher training (Soriano & Vargas, 2021; David et al., 2019). Addressing these deficiencies is essential for improving students' academic outcomes, fostering technological innovation, and preparing a skilled workforce to support the country's economic growth. Integrating interactive, hands-on materials and technology-based simulations into science education directly addresses these challenges, providing students with more engaging and effective learning experiences. As Pineda (2023) emphasizes, enhancing science education through improved curricula and teaching strategies can lead to better academic outcomes and greater employability in science-related fields. These advancements prepare students to contribute to the global knowledge economy and support the Philippines' long-term competitiveness.

While numerous studies have explored the use of localized apparatus and interactive simulators to enhance science learning, there remains a scarcity of research focused explicitly on innovative teaching aids for learning wave phenomena. Existing literature predominantly concentrates on other scientific concepts, such as electricity and motion, with less attention given to the pedagogical approaches in wave science (Duya, 2021; Dionson, 2021; Gainsan, 2021; Acabal, 2022). Thus, this study was pursued to fill this gap by developing and assessing the effectiveness of a self-made wave machine and a computer simulator. This dual approach aims to enhance the understanding of wave concepts, often abstract and challenging for learners, thereby addressing a critical need in science education.

This study sought to ignite learners' interest in science and encourage scientific careers by evaluating the effectiveness of a self-made wave machine and a computer simulator in teaching basic wave concepts. By combining hands-on learning with digital simulators, the research aims to enhance learners' understanding of wave phenomena and improve science education outcomes. Success could serve as a model for similar interventions, benefiting the Philippines and other regions facing similar challenges.

2.0 Methodology

2.1 Research Design

This study used descriptive-correlational and comparative designs. This inquiry is descriptive because it describes the students' performance after utilizing the localized apparatus and computer simulator. It also describes the students' interest in using the two methods of instruction. Furthermore, it is correlational because the students' interest in using the methods was correlated with their assessment results. Moreover, it is comparative since the students' performance utilizing the two methods was compared.

2.2 Research Locale

The study was conducted at Manjuyod National High School, located in Barangay Sundo-an, Manjuyod, Negros Oriental, where one of the researchers works as a science teacher. To minimize potential bias, the researcher adhered to established ethical guidelines, maintained neutrality in the study's procedures, and ensured that external experts objectively reviewed the results.

2.3 Research Participants

The study's respondents were the 219 Grade 7 students of Manjuyod National High School enrolled during the school year 2023-2024. They were divided into two groups based on their prior grades in science to ensure both groups had a similar level of knowledge. To validate that there were no significant differences in their prior grades, a t-test for independent samples was conducted. The results confirmed that the two groups did not differ significantly in their science knowledge.

2.4 Research Instrument

The study employed an activity guide designed by the researchers, which combined a self-made wave machine and computer simulator to help students grasp basic wave concepts. The self-made wave machine and the computer simulators were chosen based on insights from related studies and educational tools. The self-made wave machine, crafted using locally available materials, provided hands-on experience for students. At the same time, the interactive computer simulators, sourced from PhET Colorado, illustrated the behavior and properties of waves.

The researcher developed an assessment questionnaire to assess the students' understanding, which three General Science experts validated. Additionally, a questionnaire measuring students' interest in using both the wave machine and the computer simulator was adapted from Piñero et al. (2023). All questionnaires underwent content validation to ensure alignment with the study's objectives. A pilot test was conducted with a group of students not included in the final sample to evaluate the reliability of the items using Cronbach's alpha, yielding the following results: 0.701 for the computer simulator and 0.712 for the self-made wave machine, indicating that the items in evaluating students' interest were reliable.

2.5 Data Gathering Procedure

With the approval of the Dean of the Foundation University-Graduate School, the researcher submitted a formal request to the Schools Division Superintendent of Negros Oriental, along with a refined version of the questionnaire. Once the request was approved, a copy was sent to the principal of Manjuyod National High School to seek access to the subject teachers and class advisers. With all necessary permissions granted, the researcher briefed the students on the study's objectives and significance before proceeding with the activities and administering test questionnaires. The study was conducted over two days to teach basic wave concepts. On the first day, the researcher presented the fundamental concepts of waves to four different sections at various times.

The students were divided into two groups per section on the second day. The researcher then provided instructions on the procedures for using the localized wave machine and the computer wave simulator. Students followed the activity guide to manipulate the tools, perform the tasks, and answer the questions. The activity lasted one hour, after which the students were administered an assessment questionnaire. An additional questionnaire was distributed to measure the students' interest in the two approaches. Once all the questionnaires were completed, the researcher collected the results, which were tallied, analyzed, and interpreted for further evaluation.

2.6 Ethical Considerations

The study was conducted according to ethical standards. Ethical approval was obtained from the Foundation University Research Office's Ethical Committee. The application of the right to self-determination, secrecy, and anonymity and the study's advantages and disadvantages were closely scrutinized.

3.0 Results and Discussion

3.1 Difference in the Performance of the Students Using the Self-Made Wave Machine and Computer Simulator

Table 1 shows that both groups of students who utilized the self-made wave machine and computer simulator achieved an "outstanding" level of performance, with mean scores of 92.73% and 92.57%, respectively. These ratings are not significantly different ($p = 0.737 > \alpha = 0.05$) and suggest that students could grasp the concepts of waves effectively using the self-made wave machine and computer simulator. The students acquired the skills and knowledge and could utilize them in other performance tasks involving waves (DepEd Order No. 73, s. 2012). The standard deviations for both groups (3.58 and 3.90) indicate that the students' scores are slightly dispersed.

Table 1. Difference in the performance of the students using the self-made wave machine and computer simulator

Group	Performance	D	SD	t-value	p-value	Decision	Remark
Self-Made Wave Machine (n=109)	92.73 (Outstanding)	0.16	3.58	0.336	0.737	Accept H_{o1}	Not significant
Computer Simulator (n=110)	92.57 (Outstanding)		3.90				

The students' ratings further indicate that both instructional tools—the self-made wave machine and the computer simulator—are equally effective in promoting student achievement. The effectiveness of computer simulators and self-made apparatus in science education is well-documented, with research confirming their ability to enhance student understanding and engagement. Studies by Langbeheim and Levy (2019) reveal that simulators foster scientific inquiry, while Patron and Despojo (2020) highlight the benefits of self-made apparatus in addressing educational challenges and promoting active engagement, leading to improved student comprehension.

The lack of a significant difference in performance aligns with the findings of Benong et al. (2024) and Acabal et al. (2022), who reported no significant difference in the post-test performances of students who used localized apparatus and interactive computer simulators, such as PHET (Physics Education Technology). A study by

Langbeheim and Levy (2019) also demonstrates the effectiveness of both computer simulators and self-made apparatus in enhancing student understanding and engagement in science education. The above findings suggest that educators can choose either tool based on availability, cost, and classroom preferences without compromising the instructional quality.

3.2 Level of Interest of the Two Groups of Students in Activities Using the Self-Made Wave Machine and the Computer Simulator

Table 2 shows the level of interest among the two groups of students using the self-made wave machine and computer simulator. Generally, the results indicate that the group using the self-made wave machine has a composite mean of 4.05, while the computer simulator group has a composite mean of 3.93. These figures mean that both groups exhibit a "high" interest in learning about waves through these instructional tools. This finding highlights that the self-made wave machine and computer simulator are engaging tools that effectively capture students' attention. This is crucial for enhancing understanding and retention of scientific concepts.

Table 2. Level of interest of the two groups of students in activities using the self-made wave machine and the computer simulator

Indicators		Self-Made Wave Machine (n=109)			Computer Simulator (n=110)		
		w$\bar{x}$	**VD**	**EoI**	**w$\bar{x}$**	**VD**	**EoI**
1	The activities led me to the realization that learning science concepts goes beyond memorization of formulas.	4.22	SA	VH	4.27	SA	VH
2	The self-made wave machine/computer simulator helped me grasp the basic wave concepts effectively.	4.21	SA	VH	4.01	A	H
3	The use of a self-made wave machine/ computer simulator in the discussion of concepts of wave is interesting.	4.19	A	H	4.04	A	H
4	Using a self-made wave machine/ computer simulator makes me visualize basic concepts of abstract wave.	4.05	A	H	3.89	A	H
5	The use of the self-made wave machine/ computer simulator is what I want to learn other concepts in science.	4.05	A	H	3.81	A	H
6	The basic concepts of waves are very fascinating to me because of the use of a self-made wave machine/computer simulator.	4.01	A	H	3.97	A	H
7	The use of a self-made wave machine/ computer simulator makes me excited about the discoveries I am about to make, especially in the lesson on the fundamentals of waves.	4.01	A	H	3.82	A	H
8	Utilizing a self-made wave machine/ computer simulator sparks my interest in the fundamentals of science.	3.91	A	H	3.87	A	H
9	Interacting with the self-made wave machine/ computer simulator captured my focus, leading me to pay attention to the teacher.	3.91	A	H	3.80	A	H
10	The activity motivated me to utilize my object – manipulation skills.	3.91	A	H	3.83	A	H
Composite		**4.05**	**A**	**H**	**3.93**	**A**	**H**

Specifically, the data indicate that both groups claimed that the activities led them to realize that learning Science concepts goes beyond memorizing formulas (w$\bar{x}$ of 4.22 and 4.27). Additionally, the data show that both groups demonstrate a "high" level of interest because the activities allowed students to visualize abstract wave concepts, grasp other scientific principles, and maintain focus while using the self-made wave machine and computer simulator (w$\bar{x}$ ranges from 3.41 to 4.20). This display of student enthusiasm suggests that students are generally engaged and motivated when using these tools, which can positively influence their learning outcomes.

These results align with the studies by Acabal et al. (2022), Benong et al. (2024), and Piñero et al. (2023), which also found that students exhibit a "high" or "very high" level of interest when using localized apparatus and interactive simulators for learning science and mathematics concepts. Students reported that they found both instructional tools engaging and enjoyable and that these tools significantly improved their skills and conceptual understanding.

3.3 Relationship Between the Level of Students' Interest in Activities Using Self-Made Wave Machines and their Performance

Table 3 presents the relationship between students' interest in activities using the self-made wave machine and their performance. The Spearman Rank Order Correlation analysis shows a p-value of 0.826, indicating that there is no significant relationship between the level of students' interest in using the self-made wave machine and their performance.

Table 3. Relationship between the level of students' interest in activities using self-made wave machines and their performance

Variables	r_s	p-value	Decision	Remark
Level of Interest in Activities Using Self-Made Wave Machines and Their Performance	0.021	0.826	Accept H_{o2}	Not significant

The results suggest that variations in students' interests are not associated with changes in their performance. This lack of correlation may be due to students' relatively uniform levels of interest. The raw data shows that student's responses to the indicators are closely aligned, with nearly all reporting a high-interest level. Additionally, the findings suggest that cognitive ability and prior knowledge may play a more significant role in understanding wave concepts than interest alone. Students with a stronger foundation in physics likely face fewer barriers when engaging with the wave machine, leading to relatively uniform performance outcomes. The current findings are consistent with previous studies, such as those by Piñero et al. (2023) and Acabal et al. (2022), which found no significant relationship between students' interest and performance. These results connote that other factors may contribute to students' performance beyond their level of interest.

3.4 Relationship Between Students' Interest in Activities Using Computer Simulator and Their Performance

Table 4 shows that there is no significant relationship between students' interest in activities using the computer simulator and their performance ($p = 0.675 > \alpha = 0.05$).

Table 4. Relationship between the level of students' interest in activities using computer simulator and their performance

Variables	r_s	p-value	Decision	Remark
Level of Interest in Activities Using Simulator and Their Performance	0.041	0.675	Fail to reject H_o	Not significant

This result indicates that changes in interest do not directly influence performance, suggesting that interest alone is insufficient for mastering concepts. Other variables, such as prior knowledge, cognitive skills, motivation, and external support, may play a more significant role in learning. These findings highlight that interest is only one component of the learning process. While the computer simulator can generate engagement, it must be paired with effective teaching strategies and a supportive learning environment to enhance outcomes. This conclusion aligns with Langbeheim and Levy (2019), who suggest that developing interest in technology-based tools does not necessarily lead to improved performance.

4.0 Conclusions

Wave concepts are often abstract and can be challenging for students to grasp through traditional lecture methods alone. However, educational tools such as wave machines and simulators provide a more tangible approach. By allowing students to see and manipulate wave properties dynamically, these tools offer interactive and visual experiences that make abstract concepts more concrete and understandable. The hands-on engagement with wave properties, including amplitude, frequency, and wavelength, not only aids in visualization but also deepens comprehension. Furthermore, this interactive learning typically results in higher engagement levels, linked to improved learning outcomes and a deeper understanding of the material. By making science more accessible and enjoyable, these tools improve immediate learning outcomes and inspire sustained interest and confidence in pursuing further studies and careers in scientific fields. This positive impact can contribute to the development of future scientists and innovators equipped to address complex problems.

5.0 Contributions of Authors

The authors confirm their equal contribution to all aspects of this research. Mrs. Kleizi and Mr. Piñero conceptualized the research problem, while Dr. Futalan carried out the necessary protocols for conducting the study and handled the statistical analysis. All authors collaborated in discussing the findings, and they reviewed and approved the final version of this paper.

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7.0 Conflict of Interests

All authors declared that they have no conflicts of interest as far as this study is concerned.

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