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Examining the effect of LENS exploration and navigation stations on students' gain score in bio-inspired optics

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ABSTRACT

The study examines the impact of lens exploration and navigation stations (LENS) activity on students' academic performance in bio-inspired optics, focusing on the gain score, to provide empirical evidence on its effectiveness in fostering deeper comprehension and engagement. The design of the study is quantitative research and uses a pretest-posttest control group in a quasi-experimental approach. The design makes it possible to compare the LENS activity's efficacy with the traditional method of teaching by comparing the students' pre- and post-test scores. The researcher chooses one class comprising 56 students from academic track, science, technology, engineering, and mathematics (STEM) strand where random assignment was used to determine the treatment group and control group (N=28). The study utilizes dependent sample comparing pretest and posttest scores, and independent sample comparing posttest mean scores between experimental and control groups. The study found that there is a significant difference in post-test scores between the experimental group using LENS activity and the control group using traditional teaching methods. The study indicates that LENS activity significantly increased students' academic performance in understanding bio-inspired optics, demonstrating its effectiveness in enhancing learning outcomes and deeper understanding of the subject. This highlights the importance of activity-based learning (ABL) in enhancing learning outcomes.

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1. INTRODUCTION

In today's 21st century system of education, traditional teaching methods have still been considered appropriate as they have always been the backbone of education for shaping learners. However, as we stride into the 21st century, new ways of teaching are needed to develop better teaching and learning processes [1]. Education is now more than just classroom learning; it involves students and educators experiencing content to ensure its effectiveness [2]. Over the years, there has been a notable shift in the traditional classroom model with regards to the modality of material delivery. Student-centered learning (SCL) is one of the most popular concepts in K-12 education today [3]. Teachers use various SCL practices to better prepare students for challenges after graduation. Teachers must adapt to the evolving needs of students and the classroom to keep subjects engaging. These methods foster curiosity, allowing learners to develop a passionate interest in subjects. Without constant observation, students are more likely to take initiative, delve deeper into topics, and participate actively in discussions [4]. SCL promotes independence, critical thinking, problem-solving, empowerment, and conversation. The activities focus on students which allows them to learn actively and it gives students more decision-making opportunities, leading to greater engagement in their education [5]. This allows the students to define, evaluate, and decide how to accomplish their own goals in learning.

Activity-based learning (ABL) as a SCL approach develops self-learning skill among the learners and allows a student to study according to his or her skill. With ABL, the teacher serves as a facilitator, supporting and guiding the students as they learn. It is the teacher's responsibility to use variety of techniques and strategies for instruction to stimulate interest in even the most challenging students [6]. Therefore, teachers are responsible for adapting pedagogical approaches to support effective learning. This requires significant effort in designing lessons and activities that support students' learning goals that would boost students' interest and encourage them to actively participate in meaningful learning.

These progresses in education call for efficient and new strategies in the transmission of knowledge so that student outcomes in different disciplines are improved. One of these methods is the proposed lens exploration and navigation stations (LENS) activity as an effective learning activity for introducing bio-inspired optics. LENS is a teacher made activity that will create learning structures to promote students' investigations, and problem-solving activities anchored on the concept of optics. This method emphasizes active engagement, allowing students to explore and manipulate lenses, through the entire process of acquiring knowledge. The use of active learning techniques has been widely supported in the past research and the previous studies have underscored the efficiency of such approaches for enhancing the students' comprehending and recalling of the entire scientific concepts [7]. LENS activity is made for the implementation of ABL for students with the reference to bio-inspired optics. It consists of several stations that help the students to use lenses, investigate their characteristics, and compare them with biological examples. This method fits into the constructivist learning theories that stress learning through doing or rather practical experience that is supposedly to enhance the understanding of knowledge construction [8].

The use of LENS in the classroom is meant to reduce the gap between theoretical knowledge and its application. In this context, LENS aims at increasing students' gain scores through the participation of students in activities that illustrate the use of the principles of optics. Prior studies have established that activities, which entail the use of hands-on learning, enhance gain score in contrast to conventional lecture method [9]. Additionally, bio-inspired optics is a converging discipline; there is a strong correlation between science, technology, engineering, and mathematics (STEM) education objectives and bio-inspired optics application which include problem solving, critical thinking, as well as collaboration skills. Bio-inspired optics is a good example of how biological concepts can be used in explaining the difficult truths of science. When students are required to study optical characteristics and create their model of it then they will be able to fully understand both biology and physics majoring in interdisciplinary learning and invention [10]. While educators are still in the process of trying to find ways to equip learners for the challenges of the new society, the application of new teaching enrichment activities, such as LENS, is becoming more and more crucial [11]. Therefore, this paper will analyze the effect of a teacher made activity entitled LENS on students' gain score in bio-inspired optics. The findings of this study should add significantly to the conversation on innovative methods in scientific education and offer insightful information about the possibilities of LENS as a teaching tool.

2. LITERATURE REVIEW

Education is a field that is always changing based on new pedagogical approaches and technological developments. Today, one technique that has been utilized by 21st century classrooms to respond to these changes is activity based learning [12]. The ABL approach emphasizes sensory-based, hands-on activities, allowing students to learn through experience and personal action. It helps students grasp and apply new concepts through tasks, scenarios, and interactive activities [13]–[15].

Philippines' physics education system is currently struggling with difficulties. Because it is such an abstract and complicated subject, students' interest in it is far lower than in other high school disciplines. One scenario that needs to be addressed by teachers is the performance of students in physics which is often due to traditional teaching methods and a lack of instructional resources to support understanding of physics concepts [16]. Based on the study [17], it is recommended that STEM curricula be revisited and re-engineered to be more relevant and responsive to the demands of the new industrial revolution and the society. It is also necessary to incorporate into the curriculum performance activities that are relevant, engaging and contextualized. This is a challenge for science teachers to create or innovate techniques to make teaching-learning engaging. Physics teachers need to develop strategies and interventions to improve their students' performance, as many studies show that using instructional materials can enhance learning effectiveness [18].

The LENS activity aims to enhance students' understanding of optical principles through practical learning. It gives students a chance to explore and manipulate with light using stations set up with various lenses and optical instruments. Working with physical models and simulations helps students better understand abstract concepts and improve their capacity to think. This hands-on approach helps them visualize and understand complex concepts more [19]. The key component of the learner-centered approach known as the ABL is actively involving students in the teaching process [20]. This method promotes student involvement and deepens their comprehension of the subject matter being taught [21]. ABL prioritizes engaging the learners in practical exercises, critical thinking and collaborative learning. Through active engagement in the variety of supervised activities provided by the teacher, students build their knowledge and comprehension through experimentation, expression, and investigation. ABL helps learners construct knowledge and understanding in a meaningful and enjoyable way [22]. This supports constructivist learning theories by placing a strong emphasis on inquiry, investigation, and active participation [23]. Therefore, ABL and constructivist theory are closely related because they both place a strong emphasis on the active role of the students in creating knowledge through their experience and social interaction [24].

This aligns with the features of the K to 12 curriculum by the Department of Education where the focus of the teaching-learning process is the student. Thus, the curriculum uses pedagogical approaches that are constructivist, inquiry-based, reflective, collaborative, differentiated, appropriate, relevant, and integrative as based on the DepEd Order No. 21 s.2019. In the Philippines, the use of ABL as teaching strategy is growing and shows its positive impacts. Students engage actively in the gathering, analyzing, and application of knowledge as well as their own active exploration of information [25]. Student participates both physically and mentally in the lesson when learning is centered on activities which means that they learn by doing. Acquiring information requires hands-on experience. Research has shown that individuals can learn and retain information for a longer duration of time when their senses are stimulated to a greater extent [26]. Therefore, these hands-on activities spark learners' interest and intelligence.

In science, learning becomes more engaging when there are real-life scenarios to engage with and natural phenomena are studied through experimentation and direct observation [27]. Therefore, ABL is a useful technique for helping students study science. Because of their real and authentic learning perspective, the approach fosters conceptual understanding and raises learners' motivating interest [28]. Studies shows that ABL in teaching earth science to grade 7 students found increased motivation, mastery of concepts, and a love for the subject. Student-driven activities take center stage instead of teacher-centered lectures [29]. By interacting more actively and practically with the topic, students learn by doing. Both teachers and students gain new skills and capacities because of learning by doing. This means that the more they practice, the more they love learning and growing [30]. This approach can present challenges for students when it comes to relating abstract concepts, such as bio-inspired optics, to practical applications. Without sufficient hands-on exposure and engaging educational opportunities, students may struggle to achieve a deeper understanding and remain actively involved in the learning process [31]. The lack of interactive and experiential learning experiences can limit their ability to connect conceptual knowledge to real-world contexts, ultimately hindering their overall comprehension and curiosity in the subject matter [32].

Therefore, this study fosters an environment where learners are actively engaged in investigating ideas in bio-inspired optics. This engagement is expected to lead to a clearer comprehension of the significance of optics in real-life situations and applications. By incorporating more interactive and hands-on learning opportunities, students can better grasp the principles of lenses and their practical uses, resulting in improved learning outcomes and a deeper understanding of the topic [33]. The approach used in the study aims to transform theoretical knowledge into tangible skills, enhancing both student involvement and educational success.

3. STATEMENT OF THE PROBLEM

This research aims to investigate the impact of LENS activities on students' academic performance and conceptual understanding in bio-inspired optics of the grade 12 STEM-1 students of Emiliano Tria Tirona Memorial National Integrated High School. By focusing on the gain score, which measures the improvement in students' knowledge before and after the instructional intervention, this research seeks to provide empirical evidence on the effectiveness of LENS in fostering deeper comprehension and engagement in the subject matter. The results of this investigation may provide valuable insight into the potential of LENS as a classroom instructional tool, ultimately contributing to the enhancement of students' learning in optics.

3.1. Research objectives

The goal of this study is to analyse the significant effect of a teacher made activity entitled LENS on gain score of the grade 12 STEM-1 students in bio-inspired optics. Specifically, it seeks answers to the following questions:

- What is the students' score in bio-inspired optics before and after the implementation of LENS within an ABL environment?
- How does the integration of LENS impact the gain scores of grade 12 STEM students in the context of bio-inspired optics?

– Is there a significant difference in the gain scores between grade 12 STEM students who receive traditional instruction versus those who experience LENS in bio-inspired optics?

3.2. Conceptual framework

The Figure 1 shows that there the two different groups involved in the study, the experimental group and the control group. A pre-test is given to both groups before LENS activity is utilized by the experimental group. The control group follows the traditional method in teaching while the experimental group utilizes the teacher made activity LENS. Both groups were then provided with a post-test after the conclusion of the intervention. The results collected during the pre-test and post-test were used to determine their gain score and were analyzed using independent sample t-test.

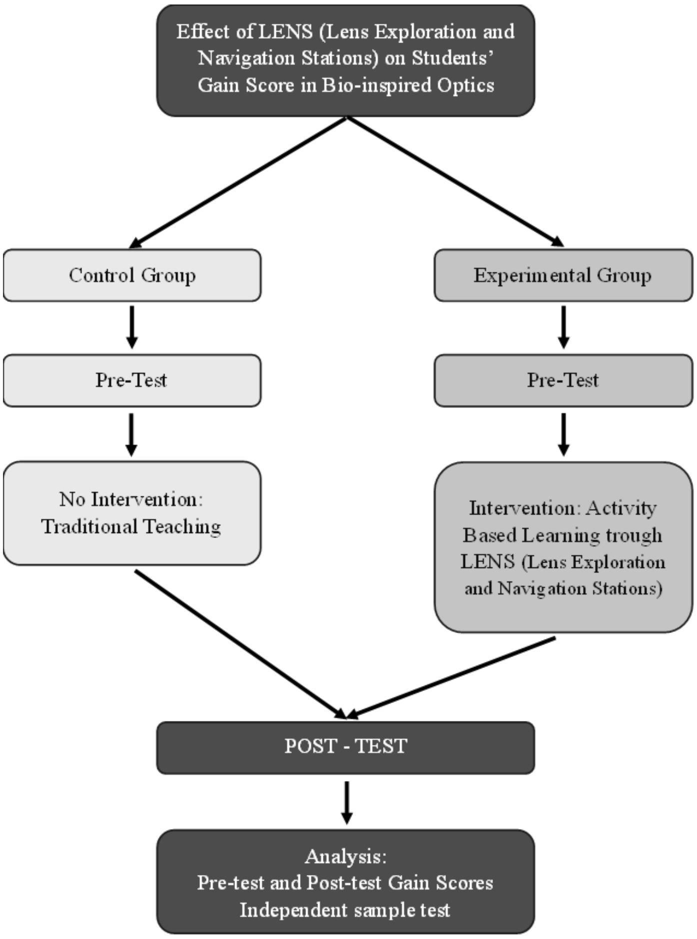

Figure 1. Analysis on the use of LENS in bio inspired optics

4. METHODOLOGY

The research design used in this study is quantitative research and uses a pretest-posttest control group structure in a quasi-experimental approach. This design enables a comparative analysis of the effectiveness of the LENS activity against traditional teaching methods by assessing students' pre- and post-test scores.

4.1. Research design

The study utilized an experimental design, specifically using a pretest and a posttest group design to compare the gain scores of students in both the control and experimental groups. While the control group did not receive any treatment, the experimental group engaged in the LENS activity, allowing the researcher to assess its effectiveness on their gain scores. In Table 1, A1 and B1 represent the pretests for the experimental and control groups, respectively, while A2 and B2 denote their posttests. The variable X indicates the treatment, which is the LENS activity used for teaching bio-inspired optics.

Table 1. Group pretest-posttest design

Experimental group	A1	X	A2
Control group	B1		B2

4.2. Sampling

Although the study is in quantitative research design, purposive sampling is the approach used in this study to choose participants. Purposive sampling, also known as judgmental, selective, or subjective sampling, is a broad category of non-probability sampling techniques that relies on the researcher's judgment in selecting the study units, usually with a relatively small sample size [34]. The researcher used purposive sampling in the study because LENS is an activity developed especially for STEM–general physics students. The study also used purposive sampling as the researcher chooses participants according to predetermined traits, which in this case is the student's homogeneity in terms of their academic performance. Class STEM 1 was selected as respondents of the study as the section is a homogenous group of students who have similar characteristics in terms of their academic performance. By using the purposive sampling method, it guaranteed that the sample was purposefully chosen to support the goals of the study, helps identify high-quality, unbiased samples, and enhances the credibility and reliability of results [35].

4.3. Participants

One class comprising 56 students (N=56) from academic track, science, technology, engineering and mathematics strand was chosen to be the participants of the study. STEM 1 was chosen as the study's respondent group because it consists of homogeneous students with similar academic performance. This enhances the internal validity, ensuring that any observed changes in results are attributable to the intervention applied to the other group. The study makes use of control groups to compare against the experimental groups, helping to isolate the effect of the independent variable. The researcher also used random assignment to identify one group as the treatment group (N=28) and another group as the control group (N=28). Randomly assigning the participants to different groups also ensures that confounding variables are equally distributed across all groups.

4.4. Instruments

The instruments used in this study includes the researcher made pre-test and post-test and an activity worksheet entitled LENS. Both the pre- and post-test multiple choice questions given to the students and the LENS worksheet have been validated by an expert which is a science/division learning resources evaluator. The evaluation sheet used in the teacher made materials were the standard evaluation rating sheet for print resources of the department of education which is used to evaluates the quality and suitability of learning materials for public schools, ensuring they are free from errors [36]. The evaluation sheet covers content, format, presentation, and technical quality, focusing on accuracy, relevance, organization, presentation, and organization, as well as the physical aspects like paper quality and printing quality of the resources. After evaluation and revisions, the LENS worksheet, the pre-test, and the post-test are deemed appropriate for use in this study.

4.5. Data analysis

The data collected in the study was based on the students' scores on the multiple-choice questionnaires from the pre- and post- test prepared by the researcher. To determine whether the means of the experimental and control groups differ significantly from one another, independent sample test was used by the researcher. The researcher also utilized the study by Lantajo and Tipolo [37] in order to convert the raw scores into achievement scores. It was also based on Department of Education Memorandum No. 160, s. 2012.

The experimental and control groups' scores were assessed both before and after the intervention using the mean percentage score (MPS). The study utilized T-test to determine if there was a significant difference between the mean scores of the two groups before and after the intervention. The same statistical tool with a dependent sample was also used by the researcher to analyze if there was a significant difference in the performance of each group during the pretest and posttest. Conversely, an independent samples t-test was conducted to assess whether there is a significant difference in the posttest mean scores between the experimental and control groups.

4.6. Ethical issues

The study was coordinated and approved by the subject group head of science before its implementation. All participants of the study received information through an informed consent form about the study's goals and objectives. The students agreed to the processing and analysis of the data collected during the study. No personal data on its respondents was also collected during the study as it focuses only on the gain scores of each student on the pre-test and post-test result.

4.7. Research limitations

The study's generalizability of the results may be limited because it was carried out in a particular classroom setting. A more thorough understanding of the effects LENS activity used in teaching bio-inspired optics could be obtained by conducting in different educational settings and student populations. This can be related to another limitation of the paper which was the restricted diversity of its participants. To ensure wider representation and the relevance of the findings, the study would benefit from a more diverse participant pool. Having students from different backgrounds may highlight possible differences in learning results and levels of achievement in using LENS.

5. RESULTS

After the pre-test and post-test were given to determine the effectivity of LENS activity, the data obtained was then calculated and analyzed. Table 2 below presents the scores of students in both the experimental and control groups. Based on the descriptive equivalent of their pretest and posttest, both groups fall within the average range during the pre-test. However, in the posttest, both teams' MPS increased but the experimental group performed better than the control group.

Table 3 also shows that the experimental and control groups have pretest MPS of 42.14 and 42.86 respectively, which are both interpreted as average based on Table 2. Prior to the experimental group using the LENS, the pretest MPS for both groups showed little to no difference in the students' scores. This implies that at the beginning of the study, both groups' knowledge of bio-inspired optics was comparable. The validity of the study is thus strengthened by the balanced performance of the student-respondents at the beginning of the study.

Table 2. Mastery/achievement level

Descriptive equivalent	MPS (%)
Mastered	96–100
Closely approaching mastery	86–95
Moving towards mastery	66–85
Average	35–65
Low mastery	15–34
Very low	5–14
Absolutely no mastery	0–4

Table 3. MPS of the pretest-posttest of both the experimental and control group

Group	Pre-test (MPS)	Descriptive equivalent	Post-test (MPS)	Descriptive equivalent
Experimental	42.14	Average	61.25	Average
Control	42.86	Average	48.39	Average

During the posttest, the MPS of the experimental group was 61.25, and the control group was 48.39. The result indicates that each group performed better during the post-test. Although the MPS of the experimental group was higher than the control group, the two groups' performance in the post test is still both interpreted as average. However, since both groups' scores are still considered average, it might be beneficial to explore additional or alternative methods to further boost student performance. Table 4 indicates that, at the 0.05 level of significance, there was a significant increase in the pretest and posttest mean scores for the experimental group (p-value=0.000). In contrast, the control group, which employed traditional teaching methods, had a p-value of 0.084, indicating no significant difference in the students' pretest and posttest scores within the control group.

The result of the study indicates that the performance of the experimental group improved significantly after the implementation of the LENS activity. Therefore, the use of the teacher made activity, provided the students with the better understanding of the concepts in bio-inspired optics. This also indicates that ABL improves student understanding and learning.

Table 4. Mean score of the experimental and control group in the pretest and posttest

Group	Pre-test Mean	Post-test SD	p-value Mean	Significance SD	Group	Pre-test
Experimental	8.43	2.38	12.25	2.46	0.000	Highly significant
Control	8.57	2.17	9.68	2.52	0.084	No significance

Significant at α=0.05

Table 5 presents the comparison of the mean gain scores between the pretest and posttest for both groups. The mean gain scores of the two groups were compared to determine which strategy in learning was more effective in the understanding of bio-inspired optics. Table 4 shows that the mean gain score in the experimental group that uses LENS activity is 3.82 with a standard deviation of 2.82, while the mean gain score at the control group which is under traditional method of teaching is 1.1 with a standard deviation of 2.47. The calculated p-value for the mean gain score between the two groups is 0.0003 at the 0.05 level of significance. Therefore, the computed p-value suggests a highly significant difference in the posttest scores between the experimental and control groups.

Table 5. Mean gain score of experimental and control group

Group	Mean gain	SD	p-value
Experimental	3.82	2.82	0.0003
Control	1.1	2.47	

Significant at α=0.05

6. DISCUSSION

The study found that the LENS activity significantly enhanced students' understanding and achievement in bio-inspired optics. In contrast, the control group showed little improvement with traditional teaching methods, while the experimental group's post-test scores rose significantly due to the activity-based approach. Overall, the results indicate that LENS is an effective tool for improving academic performance in bio-inspired optics concepts. Similar to the study [38], it concluded that students who received instruction using ABL techniques demonstrated a greater interest in Physics, which helped them in achieving better academic performance compared to their counterparts who received teaching through traditional method. Research indicates the use of hands-on approach enhances the learner's interest in instructional materials both inside and outside the classroom by searching for appropriate instructional materials to meet their learning need [39]. Through the use of LENS activity, students were able to investigate by his own and gave an ideal learning environment, they were actively interacting with different learning objects in order to help them build mental models that also enable "higher-order" performance, such as applied problem solving and the transfer of knowledge and skills [40].

The study [41] also emphasized the importance of hands-on instruments in physics lessons. Teacher respondents agreed on the necessity of such tools for effective teaching, with one participant noting the difficulty of conveying concepts without experiments and hands-on activities. This aligns with the study's' findings that ABL, such as the LENS activities, provides a better understanding of bio-inspired optics. This shows that LENS is a useful teaching resource that may be included in science classes to improve student learning.

The LENS activity serves as an example of how ABL involves students in a hands-on exploration of topics linked to lenses and their practical applications. This practical method promotes a deeper grasp of bio-inspired optics while also helping to better comprehend the fundamentals of lenses. According to the findings, integrating these exploratory activities into science classes might boost students' learning outcomes and help them understand complicated scientific ideas on a deeper level. This emphasizes the importance of innovative teaching strategies that promote active learning and student engagement in science education [42]. ABL ensures that learners are actively engaged in investigating ideas in bio-inspired optics and that students had a better grasp of the principles of lenses and their practical uses, resulting in improved learning outcomes and deeper understanding of the subject [43].

7. CONCLUSION

The research demonstrates that the LENS activity greatly raises students' test scores, proving how successful it is as an instructional material. The LENS activity improves the gain scores of the learners and promotes a deeper comprehension of the subject matter by actively involving students in the exploration of concepts in bio-inspired optics and helps them gain a better understanding of lenses and their practical applications. The study then shows how beneficial ABL is for teaching science. The results demonstrate that interactive, practical learning opportunities, like the LENS activity, can significantly raise students' comprehension and learning outcomes. This also emphasizes how introducing innovative approaches to instruction that encourage inquiry and active interaction can improve students' comprehension of difficult scientific ideas. The study adds to the increasing amount of evidence that supports the use of experiential learning techniques, and activity-based teaching in the classroom.

The LENS activity has shown a positive impact on students' understanding of bio-inspired optics. Future research may examine the effectivity of the LENS activity in a larger group of students or diverse student populations to determine its broad applicability and effectiveness. Other research may explore the integration of advanced technologies, such as virtual reality (VR) and augmented reality (AR), into the LENS activity that will improve student comprehension of difficult ideas and create an engaging learning environment. By addressing these areas, future research can further validate and expand upon the findings of this study, contributing to the development of more effective and engaging science education practices.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

INFORMED CONSENT

Informed consent was obtained from all individuals who participated in this study, ensuring their voluntary participation and understanding of the research objectives, procedures, and potential risks involved.

ETHICAL APPROVAL

The research involving human participants complied with all relevant national regulations and institutional policies in accordance with the tenets of the Helsinki Declaration. The study was reviewed and approved by the subject group head and the school principal of Emilianno Tria Tirona Memorial National Integrated High School.

DATA AVAILABILITY

The data that support the findings of this study are available on request from the corresponding author, [RJLM]. The data, which contain information that could compromise the privacy of research participants, are not publicly available due to certain restrictions.

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