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ORIGINAL ARTICLE

Investigating the Effects of Socioscientific Issues-based Learning Module in Enhancing Students' Physics Knowledge

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ABSTRACT

This study investigated the effect of using socioscientific issues (SSI)-based learning modules in enhancing physics knowledge. Three SSI-based learning modules were developed in this study and obtained a "Very Satisfactory" rating after the expert's evaluation, electromagnetic (EM) waves module (M = 3.82, standard deviation [SD] = 0.13), applications and uses of EM waves module (M = 3.81, SD = 0.08), and Images Formed in Plane and Spherical Mirrors module (M = 3.84, SD = 0.08). A mixed-methods approach using a purposive one-group pre-test–post-test design was used to investigate the use of SSI-based modules in class. Participants of this study were Grade 10 students in a public school in Manila City, Philippines, selected using purposive sampling, with corresponding parental consent. Quantitative data obtained from the 35-item researcher-made physics test were analyzed using a paired-sample t-test, and qualitative data were gathered from student interviews. After the use of SSI-based learning modules for 4 months, a significant change was revealed in students' physics knowledge as shown in the difference between the pre-test and post-test scores for Module 1 ($t(46) = 12.18$, $p < 0.05$), Module 2 ($t(46) = 15.08$, $p < 0.05$), and Module 3 ($t(46) = 24.27$, $p < 0.05$). The yielded effect sizes for this analysis were 0.67 for Module 1, 0.72 for Module 2, and 0.80 for Module 3, which indicates that there were medium effects on students' knowledge in Modules 1 and 2, whereas a large effect in Module 3. Results of this study showed that the implementation of SSI-based learning modules increases physics knowledge, which led students to explore the connection of the SSI to the presented physics topics. Future research may carry out the study on a larger scale with a control and experimental group.

KEY WORDS: Physics knowledge, socioscientific issues, SSI-based learning modules

INTRODUCTION

The demand for science and technology literacy is rooted in the idea that society requires many professionals who can participate in modern science and technology today (Genisa et al., 2020). As an action to support this fulfillment, promoting scientific literacy among students has become one of the fundamental aims of science education (Kruit and Bredeweg, 2020). The National Research Council defined scientific literacy as the "knowledge and understanding of scientific concepts and processes required for personal decision-making, participation in civic and cultural affairs, and economic productivity" (1996, p. 22). According to Roberts and Bybee (2014), scientific literacy has two visions: understanding ideas within a scientific context and understanding ideas in other contexts, such as real-life situations that are scientific but are influenced by social, political, and ethical issues. The development of scientific literacy is vital because it will prepare students to become informed citizens who can make judgments and decisions regarding the applications of scientific knowledge that may have social, environmental, and health impacts (Department of Education [DepEd], 2016).

In the Philippine context, one of the domains of science learning in curriculum design is understanding and applying scientific knowledge in the local and global setting. Success in this domain can be facilitated with various approaches. As such, in the Conceptual Framework of the Philippine K-12 Basic Education Curriculum, among the student-centered approaches that can be used to achieve the goals of science education is issue-based learning (DepEd, 2016). Students are always compelled by emerging issues, problems, and controversies in today's society, and educators need to be informed about them. Sadler et al. (2016) mentioned that one of the roles of teachers is to emphasize to students that it is essential for issues, problems, and controversies to be addressed using scientific ideas, concepts, theories, and data behind them. This leads students to open windows of opportunity to explore and understand the nature of the issues. It also enables them to plan their investigation, gather and interpret data, and be involved in higher-order practices about the societal issues being considered (Najmonnisa and Saad, 2017). In addition, Suryawati and Osman (2017) mentioned that students learn better when learning takes place in a context similar to the context in which it will be applied in the real world. This helps students fully understand and correlate science content and daily phenomena, and makes them see how the science–technology–society relationship goes in harmony in addressing prevailing societal issues.

Literature Review

Producing scientifically literate individuals has been one of the main goals of science education. In recent years, research studies have shown a new trend in science education by introducing research-based frameworks that encourage explicit teaching based on socioscientific issues (SSI) to promote scientific literacy (Genisa et al., 2020). SSI is an open-ended social problem with conceptual and procedural links to science (Sadler et al., 2016). It is related to science and technology in nowadays society, and it usually entails controversy due to the social, ethical, and environmental implications of some scientific and technological advances (Zeidler and Nichols, 2019). Given that SSI helps achieve this goal, many educators studied its characteristics, including selecting science topics that can be introduced as an SSI (Levinson, 2006). Chowdhury et al. (2020) enumerated valuable aspects of SSI: (1) It is an ill-structured and controversial problem that is relevant to students, (2) it requires students to be involved in a debate, dialog and evidence-based argumentation to make an informed decision, and (3) it has connections to science content and significantly affects society.

Presley et al. (2013) developed a framework based on nine studies from various environments that used SSI-based instruction. The framework comprises three core aspects: design elements, learner experiences, and teacher attributes, shaped by various contexts such as the classroom, school, community, and national policy. Design elements highlight using a compelling issue to build instructions and presenting the issue first. Learner experiences represent different learning opportunities that students should be engaged with and have access to in an SSI-based education. Finally, teacher attributes refer to the characteristics and practices teachers should hold to successfully support and facilitate SSI-based education implementation.

Physics knowledge has been regarded as content knowledge in an SSI-based education (Sadler et al., 2016). Content knowledge is related to understanding physics concepts and principles outlined in the physics curriculum, which is considered the main component for a basic understanding of an issue (Zeidler et al., 2019). Engaging in the physics content through its application to societal issues can help provide a valuable context for learning (Sadler et al., 2016). Positive outcomes on students' understanding of physics concepts relevant to the addressed issue have been reported (Sadler et al., 2016; Ture et al., 2020).

Salvato and Testa (2012) designed a 4-week laboratory-based intervention to improve students' capability to use physics content knowledge when discussing SSI. The topics used to create four SSI scenarios in the teaching context were energy transfers, conservation, modeling, and data quality. Pre- and post-semi-structured interviews were used to assess the effectiveness of the intervention implemented on 14–15-year-old secondary students. The analysis showed that after the intervention, students were able to meaningfully address the physics concepts to support their decisions about the proposed SSI in an informed way. It was also revealed that students' capability of discussing and deciding upon a given SSI, relying on content knowledge, might depend on what activities have been followed during the intervention. The study also supports SSI-based interventions in the physics school curriculum.

A study conducted by Sadler et al. (2016) demonstrated statistically significant gains on both proximal and distal content knowledge tests when taught using SSI. In this case, the SSI intervention focused on teaching energy resources using a nuclear power plant. Doing proximal and distal tests showed that the SSI-based instruction helped students learn the content for class assessments and more generalized assessments, such as state testing. Ture et al. (2020) investigated the effect of teaching Newton's Laws of Motion by embedding the SSI in 8th-grade students with the case-oriented station technique on their academic achievement as a manifestation of content knowledge. The control group was taught using the traditional lecture type, whereas the experimental group used the SSI case-oriented station technique. The SSI achievement test was used to measure the science achievement of 71 students in the 8th-grade. Using a mixed-method approach, results revealed that teaching the SSI with a case-oriented station technique positively affected the students' academic achievements. The interviews also showed that the students found learning SSI helpful, fun, and remarkable using the case-oriented station technique.

Several studies have also explored the effect of using SSI in teaching science in the Philippines. In a study by Gutierez (2015), she investigated the impact of using SSI on the decision-making skills of Grade 8 students using a quasi-experimental research design. One group was exposed to SSI-based teaching, whereas the other was exposed to traditional teaching. After comparing the scores obtained in the pre-test and post-test, the results showed a significant difference in the decision-making skills between the two groups. Talens (2016) conducted a study wherein 220 students enrolled in business courses in the Physical Science Department of De La Salle University-Lipa served as the respondents. An interview guide was developed to examine how effectively students engaged with socio-scientific issues (SSIs) in their Physical Science class, specifically on the topic of energy sources. Results of the study showed that through the teaching of SSI to understand sources of energy, the non-science major students were able to have an enhanced knowledge of the topic and answer questions based on laid evidence.

The literature review shows continuous efforts to improve the teaching–learning process toward producing scientifically literate students. However, there is a limited integration of SSI in the current Philippine physics curriculum, which tends to be more content-driven and focused on conceptual understanding rather than real-world applications. In addition, there is a lack of instructional materials that blend SSI with physics concepts, especially materials tailored to the Philippine setting. Most textbooks and teaching resources do not emphasize SSI-based learning or contextualized physics problems. These are the research gaps that the researchers want to address in this study. Developing a more flexible curriculum that incorporates SSI would make physics more relevant to students' daily lives and encourage interdisciplinary thinking. The development of new instructional materials, including textbooks, multimedia resources, and inquiry-based learning tools that incorporate local SSI, would greatly enhance SSI implementation in physics education in the Philippines.

Research Questions

The study aimed to design and develop SSI-based learning modules and investigate its effect on students' physics knowledge. This study aimed to guide the implementation of SSI-based teaching and learning in physics and envisioned contributing to SSI-based teaching and learning research. More specifically, this research aimed to answer the following questions:

1. What are the validators' evaluations on the developed SSI-based learning modules in terms of (a) content, (b) format, (c) presentation and organization, (d) readability, (e) accuracy and up-to-datedness of information, and (f) SSI?
2. How effective is the use of an SSI-based learning module in enhancing students' physics knowledge, as reflected in their pre-test and post-test scores and the interviews?
3. Is there a significant increase in students' physics knowledge before and after the implementation of the SSI-based learning modules in physics?

METHODOLOGY

Research Design

A mixed-methods approach using a purposive one-group pre-test–post-test design was used in this study. Quantitative data were gathered through the pre-test and post-test to describe the changes in students' physics knowledge, and student interviews in the form of a focused group discussion (FGD) were used as the qualitative data to further substantiate the results obtained from the quantitative data.

Research Locale and Participants

The study participants of this study were Grade 10 students in a public school in Manila City, Philippines, composed of 24 boys and 24 girls, which made up the 48 students in this class. The Grade 10 students were sectioned heterogeneously based on their Grade 9 academic performances. To ensure the collection of meaningful and relevant data, purposive sampling was employed to select participants for this study. Furthermore, the study was conducted from November 2023 to February 2024. Specifically, this study happened in the 3rd quarter, covering 50 regular days with 45 min sessions of synchronous every Thursday to Saturday and 45 min of asynchronous every Tuesday to Wednesday. Consent from students and parents was obtained in the conduct of this study.

Research Instruments

SSI-based learning modules evaluation tool for validators

To have a basis for determining the acceptability of the developed SSI-based learning modules, a criterion-based reference module evaluation tool from DepEd was adapted. It assessed the module for compliance with standards indicated in the criterion items under six factors: Content, format, presentation and organization, readability, accuracy, up-to-datedness of information, and SSI. Evaluators were requested to rate the module using a 4-point Likert scale: 1 = Not satisfactory, 2 = Poor, 3 = Satisfactory, 4 = Very satisfactory, representing the standards of the modules to each criterion item under the six factors. Based on the minimum number of criterion items under each factor, evaluators marked the appropriate column to indicate if the module compiled or not with the standards. Toward the end of the evaluation, the validators were requested to give their final recommendation. These recommendations were (1) minor revision which means that the material is found to be compliant with the minimum requirements in all six factors, (2) major revision which means that the material is non-compliant with the requirements in one or more factors and (3) for field validation which means that the material is found compliant to all factors with no corrections. A portion was provided where evaluators could give suggestions and comments to enhance the features of the modules.

Pre-test and post-test

This physics test was a researcher-made pre-test and post-test that consisted of 35 items, a multiple-choice type of test with four options. These were used to measure changes in students' learning in physics in terms of knowledge before and after being exposed to SSI-based instruction. Each item was scored one point for every correct answer, and all the items were independent of one another. For each module, there were separate pre-tests and post-tests developed.

Research Procedure

The main focus of this study is to investigate the effect of using an SSI-based learning module on students' Physics knowledge. In the conduct of this study, the following procedures were undertaken.

Phase 1: Development and validation of SSI-based learning modules in physics

In preparing the instructional design where the use of SSI will be used in the classrooms, three SSI-based learning modules were developed. This phase also involved analyzing the SSI-based instruction and mapping its construct with the current module features of DepEd, developing the instructional design of the module, and validating the module. This section provides a detailed discussion of the planning, developing, and validating phases employed in making the SSI-based learning module, as shown in Figure 1.

The planning phase involved examining and unpacking the most essential learning competencies (MELCs) prescribed by the DepEd for physics in 10th-grade Science. MELCs are a streamlined set of learning standards developed by the DepEd in the Philippines and were introduced primarily in response to the COVID-19 pandemic to ensure that learning could continue in a more focused and manageable way, especially through alternative delivery modes such as modular and online learning. The researcher also looked at the physics textbooks and related materials provided by the school in this phase. The SSIs for each module that would form the core of the learning experience for students were also identified in this phase. Moreover, measurable learning objectives related to the SSI, aligned with the DepEd's desired outcomes and standards, were identified. The MELCs in each topic and the chosen SSI for the three topics are shown in Table 1.

After determining the target learners, topics, and SSIs to be modularized, the researcher structured the modules. The developing phase involved designing the module and choosing the software/apps to be used. The template design for all the modules incorporated the learning theories and principles considered in this study. The information gathered in the planning phase was used to outline the structure and content of the learning module. This involved developing the instructional strategies, teaching methods, and assessment approaches, including the appropriate technology and resources required for the module. The sequence of activities, lessons, and interactions that students would be engaged with during the learning process was also identified in this phase.

Three SSI-based learning modules were developed in this study following the MELCs. The developed SSI-based learning modules follow this format: Instruction on how to use the module, parts of the module, expectations, pre-test, tune-up, generating ideas, restructuring of ideas, let's see more, share your thoughts, and post-test. In public schools, self-learning modules (SLMs) approved by DepEd have already been given to students. With this, the researchers wrapped around the SSI-based learning modules with the SLMs given to students

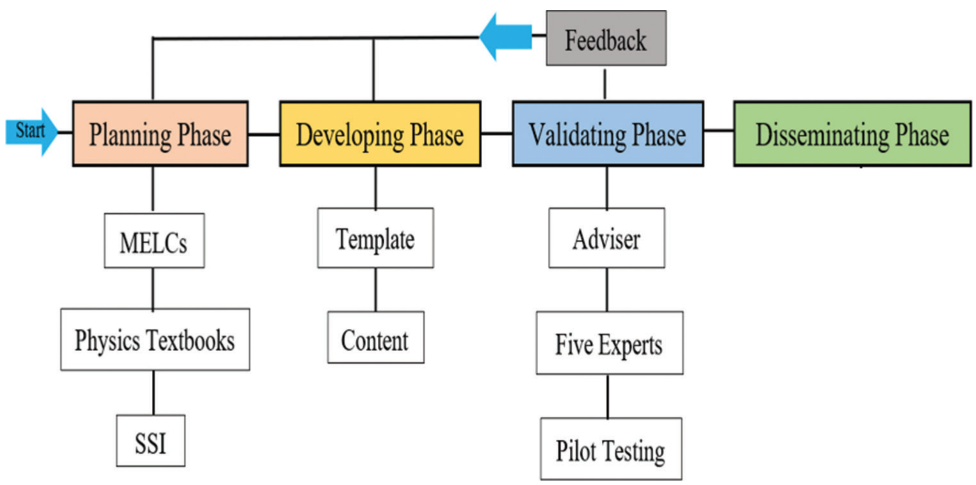

Figure 1: Framework for socioscientific issues-based learning module development

Table 1: Most essential learning competencies (MELCs)

Content Standards The learners demonstrate understanding of...	Most Essential Learning Competencies (MELCs)	SSI-based Learning Modules	
		Electromagnetic Waves	
The different regions of the electromagnetic spectrum	(a) Compare the relative wavelengths of different forms of electromagnetic waves (b) Cite examples of practical applications of the different regions of EM waves, such as the use of radio waves in telecommunications (c) Explain the effects of EM radiation on living things and the environment	Module 1: Electromagnetic waves Module 2: Applications and uses of electromagnetic waves	Do cell phones pose health hazards to humans? What is your take on balancing the potential benefits of cancer treatment using gamma rays and the risks and potential side effects associated with it?
		Images Formed in Plane and Spherical Mirrors	
The images formed by the different types of mirrors and lenses	(d) Predict the qualitative characteristics (orientation, type, and magnification) of images formed by plane and curved mirrors.	Module 3: Images formed in plane and spherical mirrors	Should bicycles be required to install side mirrors?

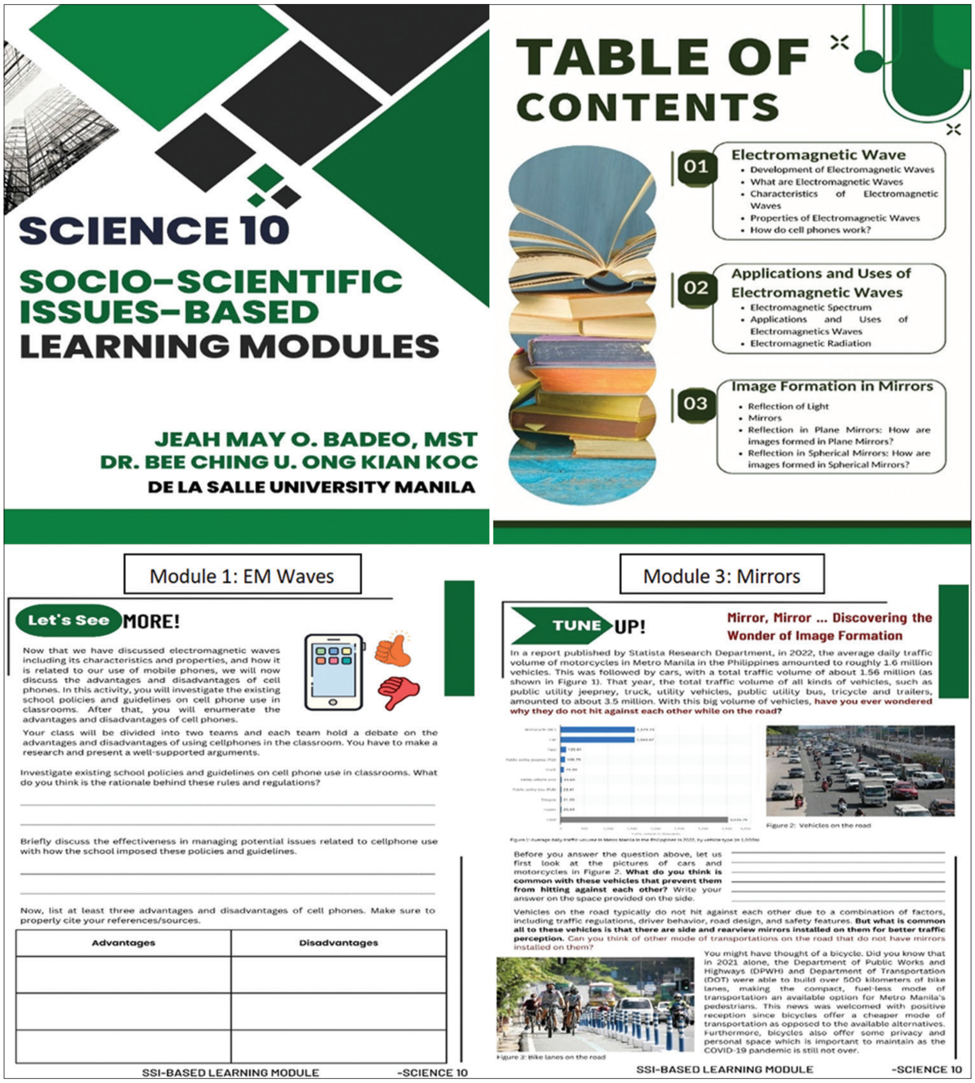

Figure 2: Cover page and table of contents of the socioscientific issues-based learning module

to minimize students' workload. Figure 2 shows sample parts of the developed modules.

For the validation phase, to gather evidence that would support the content, format, presentation, and organization, readability, accuracy, and up-to-datedness of information, and the SSI of the developed learning modules to its intended users, experts' judgments were sought by the researchers. The modules were submitted for validation by five identified experts. Revisions were made again following the recommendations of the recognized experts, and the modules were returned to them for final evaluation. Finally, pilot testing was conducted on a certain number of students after the module received an approved remark from the validators.

The developed SSI-based learning modules were sent for experts' review using a criterion-based reference module evaluation tool in a Google format adapted from DepEd. A letter of request enclosing the details about the modules and the guidelines on how to evaluate them was sent to the experts. Initially, they were requested to validate the modules by giving comments and suggestions on the overall appearance and content, as well as how the modules could be further improved. Revisions were made to the module to address the comments and suggestions made by the experts. After doing the revisions, the modules were sent back to the experts for final rating. The five invited experts were requested to make comments and suggestions on the modules before the modules were subjected to a rating. Experts' comments and suggestions were made purely online, and the researcher received complete expert feedback after 5 weeks. The researchers communicated with the experts via email whenever they needed to clarify a comment or suggestion made on the modules.

Experts from the field of physics and SSI were requested to validate the modules to ensure that the modules were designed with the overlapping theories of teaching and learning physics and SSI, and to ensure compliance with standards indicated in the criterion items of the above-mentioned six factors. Expert A is a national champion in DepEd's contextualization and localization module development contests and holds a doctorate degree in both Physics and Educational Management. The first expert evaluator has 15 years of experience in the field of physics teaching. Expert B, a Ph.D. candidate and a physics major, has been at the DepEd for 8 years and is currently the head of the science department in their region. Expert A and Expert B were the invited experts for the physics content of the module. Expert C, a Ph.D. candidate and a biology major, has been a high school teacher for 5 years in a public school in Cavite, Philippines. Her expertise includes SSI-based teaching and module development, with her master's thesis on SSI recognized as an Outstanding Thesis. Expert D holds a doctorate in physics and is an international expert who publishes studies about the effect of SSI in teaching science. Both Expert C and Expert D were the invited experts to evaluate the developed module, focusing on the appropriateness of the SSI discussion. Finally, the last expert evaluator is an international expert with 15 years of experience in teaching and a holder of a doctorate in physics. Expert E is the invited expert for both the physics and SSI content of the module.

Phase 2: Integration of SSI-based learning modules in classroom

Instructions designed based on the SSI-based learning modules were delivered through a hybrid mode. After securing the necessary permits from the division office of Manila and the public school where SSI-based learning modules would be implemented, and the Research Ethics clearance from DLSU-Manila, study participants were oriented and briefed regarding the instructions. To confirm students' agreement to participate in the study, they were instructed to affix their signatures to the informed consent form. This form included the research's purposes and duration, and confirmed their voluntary participation in this study.

The SSI-based learning modules were delivered to the students in the 1st week of implementation. In this material, students were guided on how to use the modules. Along with the overview and template of the SSI-based learning modules, the pre-tests were also given. After which, the students accessed Module 1, which was about Electromagnetic (EM) Waves. After 2 weeks, students submitted their modules and took the post-test. Module 2, about the Applications and Uses of EM Waves, and Module 3, about Images Formed in Plane and Spherical Mirrors, followed the same flow of instruction as Module 1. After the students finished Module 3, they took the post-tests.

In this study, the researcher conducted the lessons, facilitated discussions, and guided the students through the activities. The study implementation took from November 2023 to February 2024, participated by Grade 10 students in a public high school in the City of Manila. Classes with students were done in a hybrid mode. Classes were conducted online via Google Meet from Tuesday to Wednesday, and from Thursday to Saturday, classes were done face-to-face. Table 2 shows the proper implementation of the lessons conducted using the SSI-based learning modules.

In this phase, a purposive one-group pre-test–post-test approach was utilized to describe the changes in students' knowledge and attitude before and after being exposed to SSI-based learning modules. Students' changes in physics knowledge were measured by evaluating the learning gained from pre-test and post-test scores in the three developed modules. The pre-test and post-test scores per SSI-based learning module were the instruments used to measure changes in students' physics knowledge before and after the intervention. The pre-test was given to students before starting the module, whereas the post-test was given to students at the end of the module. The questions on these tests were adapted from DepEd, wherein the highest possible score for both the pre-test and post-test is 35.00 points.

Phase 3: Interview

An interview with random students in the form of a focused group discussion was also conducted to substantiate the quantitative data gathered. Through a developed interview protocol, students were asked about their experience during the administration of the comic-based learning module in their class.

Data Analysis

The instruments used in the study generated quantitative and qualitative data. These data were analyzed using various statistical tools, and the results were interpreted accordingly.

Table 2: Implementation procedure

Module	Activity	Topic
Preliminary	• Orientation about the study and introduction to SSI-based teaching and learning physics process • Disseminating and securing informed consent forms from the students and parental consent	
Module 1	• Students did the SSI-based learning module about EM waves • Pre-test • Activities (content of the module) • Culminating experience • Post-test	Electromagnetic waves
Module 2	• Students did the SSI-based learning module about the applications and uses of EM waves • Pre-test • Activities (Content of the module) • Culminating experience • Post-test	Applications and uses of EM waves
Module 3	• Students did the SSI-based learning module about the images formed in plane and spherical mirrors • Pre-test • Activities (content of the module) • Culminating experience • Post-test	Images formed in plane and spherical mirrors
End	• Students' FGD on their learning experience	

Collected quantitative data were analyzed first, whereas collected qualitative data were analyzed next to further substantiate the quantitative analysis results. The quantitative data were tallied using Microsoft Excel 2019 and were analyzed using the Statistical Package for the Social Sciences (SPSS) version 23. The qualitative data generated from the participants were analyzed using the thematic analysis protocol. The paired t-test was used to determine if there was a significant difference between Grade 10 students' Physics knowledge before and after the implementation of the SSI-based learning modules. Finally, Cohen's d was used to measure the effect size of the implementation of the modules, which was interpreted as 0.2 = Small effect, 0.5 = Moderate effect, and 0.8 = Large effect. Cohen's d is a statistical measure of effect size that quantifies the difference between two means in terms of standard deviation (SD) units. It provides insight into how much of an impact the use of SSI in science classrooms has, beyond just statistical significance. In this study, Cohen's d was used to assess the magnitude of the effect of the module implementation. According to conventional benchmarks, a value of 0.2 indicates a small effect, 0.5 a moderate effect, and 0.8 a large effect. This means that higher values of Cohen's d reflect a more substantial difference between the pre- and post-implementation outcomes, which suggests greater effectiveness of the modules used.

FINDINGS OF THE STUDY

Validation of SSI-based Learning Modules

In preparing the instructional design where the SSI-based instruction would be manifested in classrooms, SSI-based learning modules were developed. To gather evidence that would support the content, format, presentation, and organization, readability, accuracy, and up-to-datedness of information, and the SSI of the developed learning modules to its intended users, experts' validations were sought by the researchers. Experts' comments and suggestions were categorized according to the six factors considered in evaluating the modules. Table 3 shows the summary of comments and suggestions on the developed modules after the experts' review and the action taken by the researcher.

After addressing and incorporating the comments of the experts, they were requested to rate the modules considering how their comments and suggestions were addressed during the initial validation. Quantitative and qualitative data were collected from the SSI-based learning module evaluation tool. The experts' quantitative evaluations of the modules in terms of the six factors are presented in Table 4.

Table 4 shows that the mean rating in all six factors, as well as the overall mean rating, fall under the interval for "Very Satisfactory" based on the Likert scale questionnaire interpretation procedures of Lapada et al. (2020). It can be seen from the table that for Module 1, the accuracy and up-to-datedness of information received the highest mean rating (M = 4.00, SD = 0.00), interpreted as "Very Satisfactory," followed by the SSI (M = 3.85, SD = 0.11). Readability (M = 3.83, SD = 0.14), content (M = 3.78, SD = 0.15), and presentation and organization (M = 3.76, SD = 0.17) all received a "Very Satisfactory" rating from the five experts. Finally, the format (M = 3.69, SD = 0.20) of the learning Module 1 received the lowest mean rating but was still considered "Very Satisfactory." In general, the five experts gave a very satisfactory rating to all indicators in the evaluation; hence, Module 1 adheres to the experts' standards for having an overall mean of 3.82 and a SD of 0.13.

The mean rating in all six factors, as well as the overall mean rating, fall under the interval for "Very Satisfactory" for Module 2. It can be seen from the table that the accuracy and up-to-datedness of information received the highest mean rating (M = 4.00, SD = 0.00), interpreted as "Very Satisfactory," followed by the content criterion (M = 3.87, SD = 0.08). The SSI (M = 3.83, SD = 0.07), readability (M = 3.80, SD = 0.07), and presentation and organization (M = 3.72, SD = 0.10) all received a "Very Satisfactory" rating from the five experts. Finally, the format (M = 3.63, SD = 0.15) of the learning Module 2 received the lowest mean rating but was still considered "Very Satisfactory." As shown in Table 4, the overall evaluation of the experts is 3.81 with a SD of 0.08, which can be concluded that Module 2 adheres to the experts' standards.

Finally, the mean rating in all six factors, as well as the overall mean rating for module 3, fall under the interval for "Very Satisfactory." It can be seen from the table that the accuracy and up-to-datedness of information received the highest mean rating (M = 4.00, SD = 0.00), interpreted as "Very Satisfactory," followed by the modules' readability (M = 3.87, SD = 0.09). The SSI (M = 3.85, SD = 0.17), content (M = 3.82, SD = 0.08), and presentation and organization (M = 3.76, SD = 0.07) all received a "Very Satisfactory" rating from the five experts. Finally, the format (M = 3.71, SD = 0.12) of the learning Module 3 received the lowest mean rating but was still considered "Very Satisfactory." The overall mean from the experts' evaluation is 3.84, with a 0.08 SD. This result shows that Module 3 passed the experts' standards and can now be used by the target users.

Toward the end of the evaluation, experts were requested to give their final recommendation, whether or not the module is ready and suited for implementation. All five experts agreed that the three modules were ready for implementation and field validation, as their comments and suggestions had already been addressed. Experts mentioned that:

> *"I appreciate the integration of real-world socioscientific issues into the learning modules. It helps students understand the relevance of the content and its impact on society." – E1*
>
> *"The learning modules effectively engage students in critical thinking and decision-making processes. Moreover, the inclusion of group discussions, debates, and role plays promotes active learning and collaboration among students" – E2*

Table 3: Summary of comments and suggestions on the developed modules after Experts' review

Experts' suggestions	Action/s taken
Factor 1: Content	
• DepEd modules generally contain 35-40 pre-test and post-test items. You can also follow these so students can simulate with your modules, as with the DepEd modules. • Limit the number of questions in the pre-test and post-test to a maximum of 40. You can put other questions in the pre-test and post-test as short exercises after the discussion of each topic. • Add more narratives to expound on the "Tune-up" part of the module. For instance, in module 3, you can add the efforts made by DPWH and DOT to ensure the safety of bicycle riders. This will ensure that students have a foundation before diving into the complexities of the issue. • I noticed that you gave too much highlight on the application and uses of EM waves, and only a little discussion on the potential risks. Ensure balance in the discussion, as this will guide students when they make decisions in the latter part of the module. • Add more discussion on the principles of radiation protection in module 2. Elaborate how time, distance, and shielding radiation hazards.	• Limited pre-test and post-test questions on the module to 35 items. • Placed other pre-test and post-test questions as learning checks after the discussion of each topic on the module. • Added more narrative to expound on the "Tune-up" part of the developed modules. • Added more discussion about the potential risks and principles of radiation protection.
Factor 2: Format	
• Some of the figures/images were not properly labeled. Kindly check the encircled labels and correct them. • Make the font size consistent throughout the modules. For narratives inside the boxes, you can simply italicize the font, but do not reduce its size. It would be difficult for some students to read words with smaller font sizes. • Font styles are good and easy to read. • There were images that could not easily be recognized. I suggest you use higher resolutions for those images. • Use and choose visually appealing color schemes to highlight key concepts, discussion of the SSI, summary, and other essential elements within the learning modules.	• Corrected improper labeling of figures/images. • Ensured consistency of font size throughout the modules. • Used higher resolutions of images in the modules. • Incorporated visual cues and used color schemes to highlight different parts of the module.
Factor 3: Presentation and Organization	
• The presentation and organization of the discussion in the three modules follow a sequential flow. • Some sentences are too lengthy. Consider revising them. • You started the modules with an engaging introduction that can stimulate students' attention and establish the relevance of the socioscientific issues presented. If possible, can you add links to other news articles that students can read further in, guiding them to their decisions at the 'Share your thoughts' portion of the modules.	• Revised too lengthy sentences. • Added links to other news articles related to the presented SSI.
Factor 5: Accuracy and Up-to-datedness of Information	
• There are some misspelled words. • Check the typographical errors in the module. I encircled some of them. • Double-check the historical dates presented in module 1. • Minor grammar refinements can be done to ensure easier comprehension by students.	• Corrected misspelled words and typographical errors. • Ensured the correctness of historical dates. • Improved the modules for easier comprehension.
Factor 6: Socioscientific Issues	
• Keep the module up to date with the latest developments related to socioscientific issues being discussed. Incorporate recent research findings and news articles. • In module 3, aside from asking students whether or not they would pass a law requiring side and/or rear-view mirrors, you can also ask them for their other suggestions to ensure the safety of bicycle riders. They might suggest ensuring bike lanes in all places, etc., This encourages a multidisciplinary approach to understanding socioscientific issues. • Integrate other collaborative learning opportunities other than group presentations. • Design assignments that require students to analyze and propose solutions to the presented socio-scientific issues. This helps them connect theoretical knowledge with practical decision-making skills. • The issues used in each module are relevant to students, especially the lessons on the applications and uses of different EM waves and mirrors in students' daily lives. • The chosen images in each module would help students feel more relevant to the lesson. The issues presented are timely, especially the issue about mirrors, as many people are now using bicycles as a form of transportation. Students need modules that would help them feel relevant.	• Incorporated recent research findings and news articles into the modules. • Added a portion where students can give other suggestions to ensure the safety of bicycle riders. • Integrated debates, role plays, case studies, and research projects as culminating activities.

Table 4: Results of the SSI-based Modules' evaluation

Criteria	Mean Rating (out of 4.00)			[1]Description
	Module 1	Module 2	Module 3	
Factor 1: Content	3.78	3.87	3.82	Very satisfactory
Factor 2: Format	3.69	3.63	3.71	Very satisfactory
Factor 3: Presentation and organization	3.76	3.72	3.76	Very satisfactory
Factor 4: Readability	3.83	3.80	3.87	Very satisfactory
Factor 5: Accuracy and up-to-datedness of Information	4.00	4.00	4.00	Very satisfactory
Factor 6: Socioscientific issues	3.85	3.83	3.85	Very satisfactory
Overall mean rating	3.82	3.81	3.84	Very satisfactory

[1]Reference: 1.00–1.50=Not Satisfactory; 1.51–2.50=Poor; 2.51–3.50=Satisfactory; 3.51–4.00=Very Satisfactory

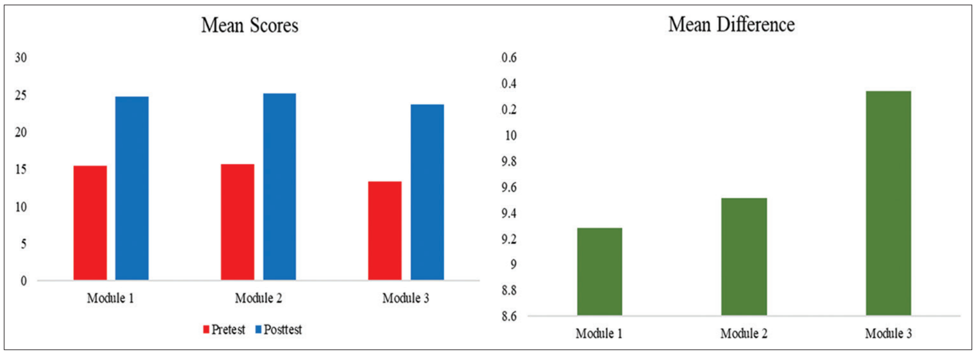

Figure 3: Mean scores and mean difference in the three modules

> *"I appreciate how the learning modules encourage students to gather evidence, evaluate information, and make informed decisions. These skills are crucial in today's information-rich world, where everything is available in just one click on the internet." – E4*
> *"The modules provide opportunities for students to explore the connections between scientific concepts and societal issues." – E5*

Effects of SSI-based Learning Modules in Enhancing Students' Physics Knowledge

In describing the overall effect of the SSI-TLP on students' physics knowledge before and after the instruction, the results obtained from the pre-test and post-test on the three modules were analyzed. The succeeding discussions showed the results of the analyzed data to describe the effect of SSI-based learning modules on students' physics knowledge. Figure 3 shows the frequency distribution of scores of students in the pre-test and post-test, and the mean difference for the three modules.

Figure 3 shows that in the three modules, Module 2 obtained the highest pre-test (red) and post-test (blue) mean score, whereas Module 3 obtained the lowest pre-test and post-test mean score. It can also be seen from the figure that the post-test means scores in all three modules increased compared with the pre-test. Moreover, students had around 9.2% to 10.4% learning gain, as depicted from the mean difference between the pre-test and post-test scores in the three modules.

In determining whether there is a significant difference between the pre-test and post-test scores of the students in the three modules, a paired sample t-test was carried out. However, before conducting this test, the researchers examined again whether the gathered dataset satisfied the four assumptions for the paired t-test. It can be noted that the dependent variable is students' pre-test and post-test scores, classified as continuous variables. Thus, the first assumption is already met. The second assumption is also met as the test scores hold independent observations per module. Meanwhile, the third and fourth assumptions require data processing using SPSS. The normality test using SPSS was conducted to determine whether the paired difference between the pre-test and post-test for each module satisfied the third and fourth assumptions. The results of the normality test are shown in Table 5.

For the paired difference between the pre-test and post-test, the computed z-scores for skewness and kurtosis were 0.28 and −0.49 for Module 1, 0.56 and 0.49 for Module 2, and −0.76 and −0.91 for Module 3. The computed z-scores for skewness and kurtosis for all three modules fall within the acceptable range to pass the normality assumption. Moreover, the results for both Kolmogorov–Smirnov and Shapiro–Wilk tests in the three modules yielded not significant results (Sig.> 0.05). This means that the difference between the pre-test and post-test scores for the three modules passed the test of normality. The histogram and Normal Q-Q plot shown in Figure 4 below support numerical results obtained from the normality test.

The multiple box-and-whisker plots for the paired difference between the pre-test and post-test scores in the three modules are

Table 5: Results of normality test for pre-test and post-test in three modules

Paired difference	Skewness		Kurtosis		Kolmogorov–Smirnov[a]		Shapiro–Wilk	
	Statistics	SE	Statistics	SE	Statistic	Sig.	Statistic	Sig.
Module 1: Paired Difference	0.098	0.347	−0.333	0.681	0.115	0.142	0.974	0.383
Module 2: Paired Difference	0.195	0.347	−0.335	0.681	0.110	0.200*	0.976	0.436
Module 3: Paired Difference	−0.265	0.347	−0.621	0.681	0.100	0.200*	0.972	0.311

SE: Standard error. *This is a lower bound of the true significance. [a]Lilliefors Significance Correction

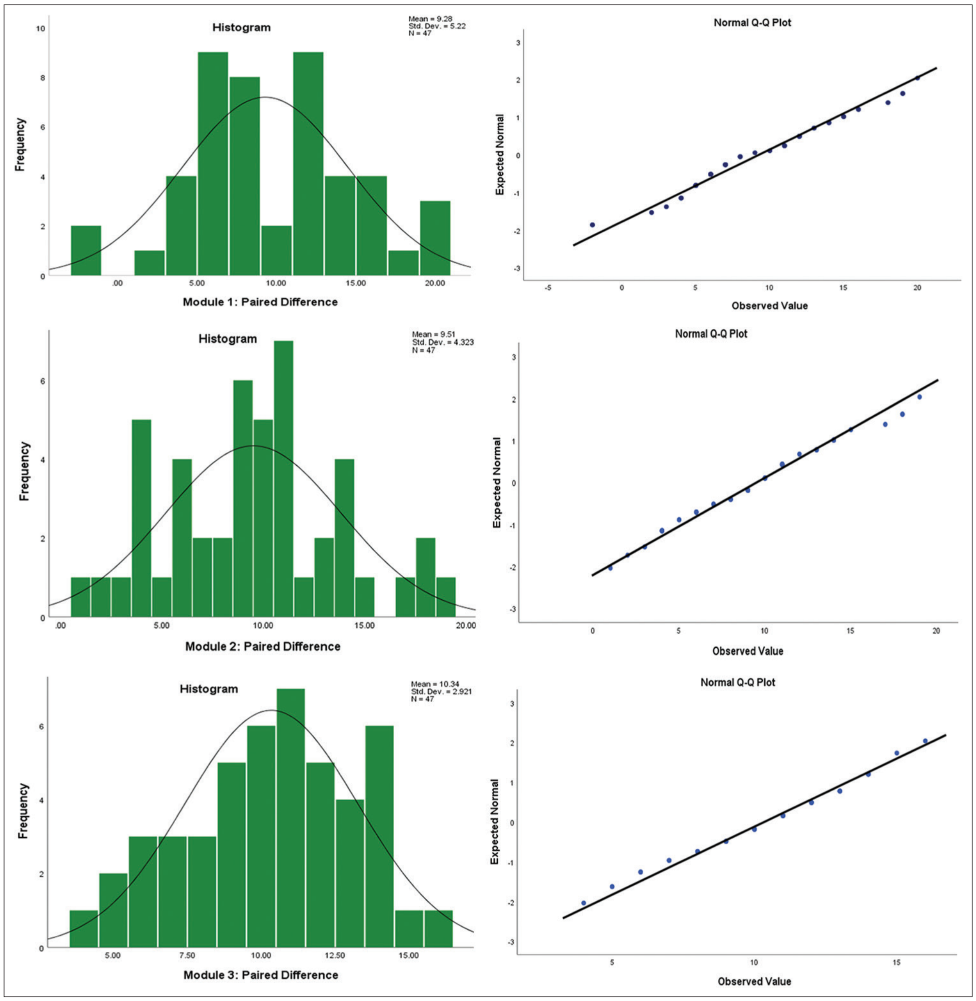

Figure 4: Histogram and normal Q-Q plot for the paired difference in the three modules

shown in Figure 5. It can be seen from the figure that there are no outliers in students' scores for the three modules. This means that the pre-test and post-test scores met the fourth assumption. It can also be observed that the spread in the difference of scores was biggest in Module 1, as indicated by the longest whisker plot, while the smallest spread in the difference of scores was for Module 3, as indicated by the shortest whisker plot. The box-and-whisker plot for Module 1 also shows that a student obtained a lower score in the post-test than in the pre-test, as suggested by the lowest whisker indicating a negative difference in score. There was also a student whose difference between the pre-test and post-test scores increased by 20.00 points in Module 1. For Module 2, the lowest score difference was 1.00 point, and the highest was 19.00 points. For Module 3, the lowest score difference was 4.00 points, and the highest was 16.00 points. Finally, the median scores for the three modules were 8.00 (Module 1), 10.00 (Module 2), and 11.00 (Module 3), as indicated by the solid black line on the box plots.

Given that all four assumptions were already met, a paired sample t-test was conducted using SPSS. Tables 6-8 show the results of the paired sample t-test for the three modules separately.

The interpretation of the mean score in Table 6 showed that the mean score for the Module 1 pre-test is categorized as "Average," while the post-test mean score is categorized as

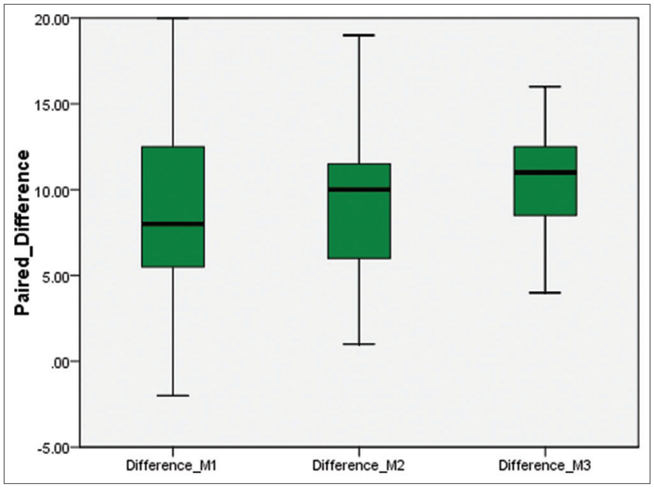

Figure 5: Multiple box-and-whisker plots

Table 6: Results of paired sample t-test for pre-test and post-test in Module 1

Paired sample t-test	Mean	SD	MD	SD	t	df	p	Effect size (d)
Module 1								
Pre-test	15.45	3.96	9.28	5.22	12.18	46	0.000	0.67
Post-test	24.72	5.99						

SD: Standard deviation, df: Degrees of freedom, MD: Mean difference. *p<0.05

Table 7: Results of paired sample t-test for pre-test and post-test in Module 2

Paired sample t-test	Mean	SD	MD	SD	t	df	p	Effect size (d)
Module 2								
Pre-test	15.68	3.44	9.51	4.33	15.08	46	0.000	0.72
Post-test	25.19	5.45						

SD: Standard deviation, df: Degrees of freedom, MD: Mean difference. *p<0.05

Table 8: Results of paired sample t-test for pre-test and post-test in module 3

Paired sample t-test	Mean	SD	MD	SD	t	df	p	Effect size (d)
Module 3								
Pre-test	13.36	2.81	10.34	2.92	24.27	46	0.000	0.80
Post-test	23.70	4.78						

SD: Standard deviation, df: Degrees of freedom, MD: Mean difference. *p<0.05

"Above Average." Table 6 shows the results of the paired sample t-test for Module 1. It can be seen from the table that there is a significant change in students' science knowledge, as revealed in the difference between the pre-test and post-test scores. For Module 1, a significant change ($t(46) = 12.18$, $p < 0.05$) was revealed in the difference between the pre-test scores (M = 15.45, SD = 3.96) and post-test scores (M = 24.72, SD = 5.99). Furthermore, the effect size was determined using Cohen's d. The yielded effect size for this analysis was 0.67 for Module 1, indicating a medium effect size.

Students performed different activities in Module 1. They were asked to make their own timeline showing the development of cell phones and EM waves, and they prepared a role play explaining whether or not cell phones cause health hazards to humans. Figure 6 shows a sample of student output regarding the timeline of the development of cell phones.

Given that students were able to make their own timeline of the development of cell phones and EM waves, and they prepared a role play explaining whether or not cell phones cause health hazards to humans, the MELCs for the topic of EM waves were achieved. Students were able to compare the relative wavelengths of different forms of EM waves in presenting their timeline of the EM waves development. Moreover, they were able to cite examples of practical applications of the different regions of EM waves, such as the use of radio waves in telecommunications. In presenting students' decisions whether or not cell phones cause health hazards to humans, they made use of role play, which is considered one of the learning activities in the teaching and learning of physics and SSI. Some of the students' responses during the FGD as to how the use of SSIs helped them gain a better understanding of the EM waves are as follows:

"I never really thought about how my phone works until we talked about electromagnetic waves in class. These waves are responsible for all the communication." – S2

"Learning about electromagnetic waves and cell phones was cool because it is something we use every day without really understanding them deeply." – S13

Following the interpretation of the mean score in Table 7, it can be deduced that the obtained mean score for the Module 2 pre-test could be categorized as "Average." In contrast, the post-test mean score could be categorized as "Above Average." Table 7 shows the results of the paired sample t-test for Module 2. It can be seen from the table that there is a significant change in students' science knowledge, as shown through the difference in pre-test and post-test outcomes. For module 2, a significant change ($t(46) = 15.08$, $p < 0.05$) was revealed in the difference between the pre-test scores (M = 15.68, SD = 3.44) and post-test scores (M = 25.19, SD = 5.45). Furthermore, the effect size was determined using Cohen's d. The yielded effect size for this analysis was 0.72 for Module 2, indicating a medium effect size. Figure 7 shows some of the students' outputs for Module 2 and their performance activity presentations.

In Module 2, the competency achieved as a result of the significant change between students' pre-test and post-test scores was explaining the effects of EM radiation on living things and the environment. From the students' EM wave diary, they were able to list down their daily activities where

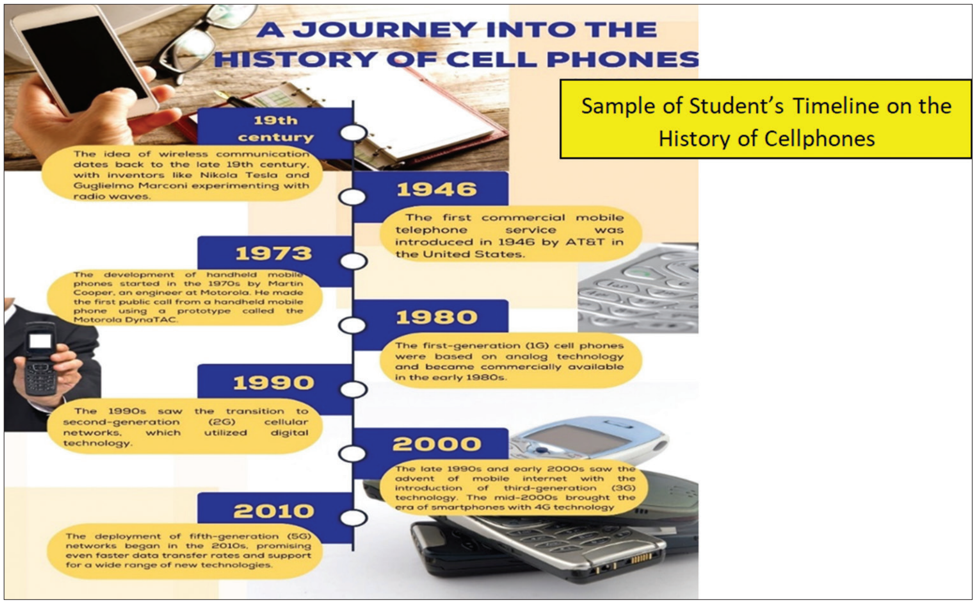

Figure 6: Samples of student outputs in Module 1

EM waves were involved, including how much time they were exposed and the source of the EM wave. As they reflect on these activities, they identified which among their daily activities exposed them too much on EM waves and its possible effects. Moreover, students were also able to determine ways that could minimize their exposure. Doing this activity helped them explain the effects of EM radiation on living things and the environment. Some of the students' responses during the FGD as to how the use of SSIs helped them gain a better understanding of the EM waves are as follows:

> *"Learning about radiation from electromagnetic waves was eye-opening. It is everywhere, and it made me think about how much we are exposed to without even realizing it." – S7*
>
> *"The discussion on radiation got me questioning the long-term effects of our constant exposure. I never really thought about the impact of Wi-Fi and cell signals on our bodies, so it is important to be informed." – S29*

Following the interpretation of the mean score in Table 8, it can be deduced that the obtained mean score for the Module 3 pre-test could be categorized as "Average," whereas the post-test mean score is "Above Average." Table 8 shows the results of the paired sample t-test for Module 3. It can be seen from the table that there is a significant change in students' science knowledge, as apparent in the score change from pre-test to post-test. For Module 3, a significant change ($t(46) = 24.27$, $p < 0.05$) was revealed in the difference between the pre-test scores ($M = 13.36$, $SD = 2.81$) and post-test scores ($M = 23.70$, $SD = 4.78$). Furthermore, the effect size was determined using Cohen's d. The yielded effect size for this analysis was 0.80 for Module 3, indicating a large effect size. Figure 8 shows some of the students' outputs for Module 3.

Module 3 obtaining a large effect size can be accounted to the fact that many students are active cyclists who use bicycles as a means of transportation to school. As shared by the students, they usually encounter various traffic situations while riding, and safety becomes a primary concern. Highlighting the importance of side mirrors as a safety feature can resonate with students, as it directly relates to their own well-being. With the socioscientific issue posed on bicycles should be required to install side mirrors, the competency of predicting the qualitative characteristics (orientation, type, and magnification) of images formed by plane and spherical mirrors was achieved by the students. Other than this, they were also able to propose other ways to ensure the safety of bicycle riders. These ways also alert other road users of the bicycle's presence, including wearing reflective clothing, installing bicycle reflectors, safety devices found on the rear, front, and wheels of bicycles, and staying on the bike lanes. A student's response during the FGD as to how the use of SSIs helped them gain a better understanding of the images formed in plane and spherical mirrors is as follows:

> *"I really enjoyed reading Module 3 as it made me realize the importance of mirrors on the road. I frequently used my bike going to school, and I did not just learn about mirrors but also the importance of road safety." – S15*

DISCUSSION

A long history of attempts to improve science education for the vast majority of students has shaped the creation of socioscientific issues-based instruction (Strømsø et al., 2017). In identifying whether a particular issue can be categorized as SSI, the two common elements must be considered: (1) A connection to science and (2) a level of social significance as identified by the community (Zeidler, 2016). Moreover,

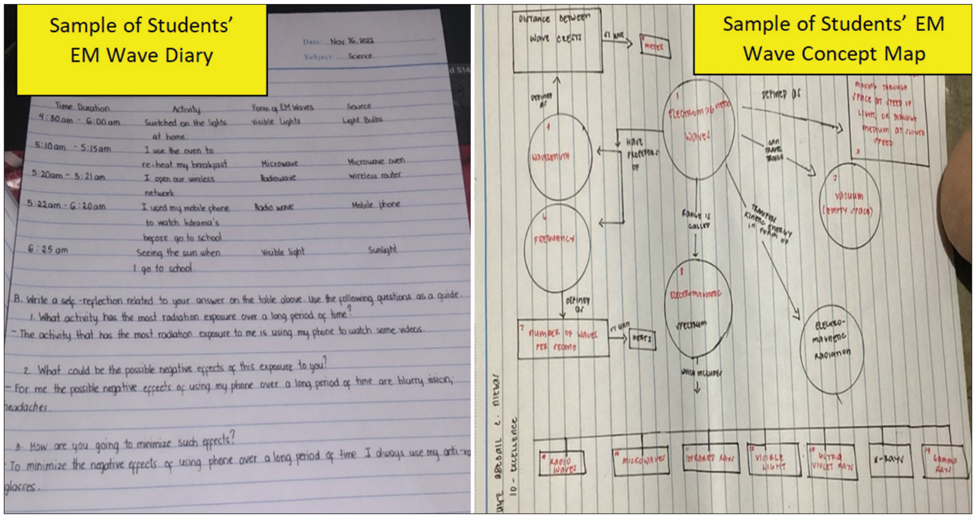

Figure 7: Samples of student outputs in Module 2

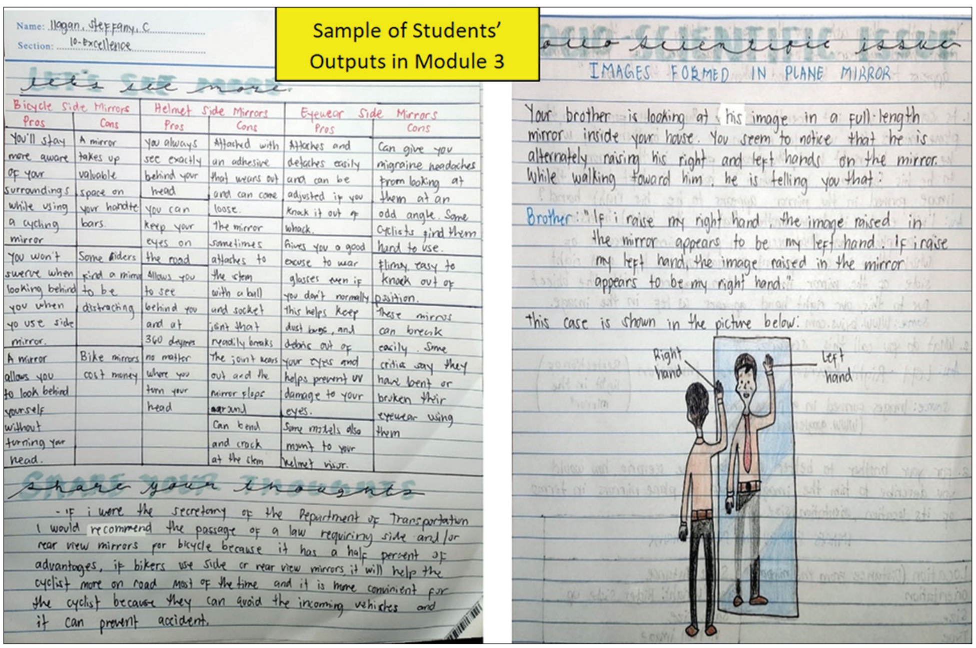

Figure 8: Samples of student outputs in Module 3

Romine et al. (2017) listed three attributes of what makes a good SSI for science instructional purposes: (1) The issue must be relevant and interesting to students, (2) students can potentially draw the connection of the issue to science, and (3) teachers and students can access the underlying ethical tension of the issue.

When many people argue about an issue arising in society without reaching a consensus, this dilemma is considered a controversial issue (Oulton et al., 2007). While controversial issues stem from social conflicts, many have a basis in science and are characterized as SSI (Sadler, 2011). SSI is an ill-structured, controversial, and societal issue with conceptual or procedural connections in science and technology (Sadler et al., 2016). It is usually an open-ended issue with no clear answer or with many plausible solutions (Sadler and Zeidler, 2019). For successful SSI-based instruction to happen in science classrooms, the roles of teachers and students must be examined. Teachers must draw upon pedagogical content and subject matter knowledge, multi-disciplinary practices, and resources to direct a science class discussion involving SSI. Teachers need to develop modules and design teaching strategies for gathering reliable information that students can use to become more informed about the issue (Subiantoro et al., 2021). Meanwhile, the roles of students include collecting information, participating in the discussion, and forming views. Students combine their subject content knowledge with their life experiences, moral reasoning, argumentation, judgment, decision-making, and reasoning skills to investigate, reflect, and form their views regarding the issue (Kahn and Zeidler, 2016).

Several studies have highlighted the potential of SSI-based learning to foster deeper engagement with scientific content, enhance motivation, and promote the application of knowledge to societal contexts (Genisa et al., 2020). Furthermore, by integrating SSI, students gain opportunities to explore the relevance of physics in solving real-world problems, such as climate change, energy consumption, and technological innovations (Alcaraz-Dominguez and Barajas, 2021). In this study, three SSI-based learning modules were developed and used in classrooms. The validation by experts on the developed modules in this study suggests that the content and information presented in the learning modules are accurate. The development and validation of SSI-based learning modules have been a subject of increasing interest in science educational research (Öztürk and Erabdan, 2019). It has been found that the development of SSI-based learning modules brings real-world issues into the science classroom, making the content more relevant and relatable to students (Eilks, 2020). Moreover, these modules have been shown to enhance students' ability to analyze complex issues, evaluate evidence, and make informed decisions, thereby promoting science literacy among students (Topçu, 2020).

Science knowledge has been regarded as content knowledge in an SSI-based instruction (Sadler et al., 2016). Content knowledge is related to understanding science concepts and principles outlined in the science curriculum, which is considered the main component for a basic understanding of an issue (Zeidler et al., 2019). Engaging in the science content through its application to societal issues can help provide a valuable context for learning (Yoo et al., 2020). The result of this study agrees with Yerdelen et al. (2018) and Ture et al. (2020) that positive outcomes on students' physics knowledge have been reported using SSI. Different media types can be used to incorporate SSIs into the course curriculum. Urban et al. (2017) incorporated SSIs into a 1st-year physics course using videos and online quizzes. Pelch and McConnell (2017) used specially designed modules about nuclear energy from the InTeGrate: Interdisciplinary Teaching about Earth for a Sustainable Society, which mainly revolves around distributing worksheets that students complete in groups. Zowada et al. (2018) created learning environments made by the Prezi presentation software. They incorporated a web-based module to discuss Newton's Laws of Motion as a socioscientific issue that engages students. Gulacar et al. (2020) integrated the socioscientific issue on the different sources of energy and electricity using a digital learning environment developed by the Prezi software.

CONCLUSION AND RECOMMENDATION

Three SSI-based learning modules were designed and developed by mapping the construct with the current module features of DepEd. This is followed by creating the instructional design of the module and subjecting the module to the experts' evaluation. The developed modules were sent for experts' review using a criterion-based reference module evaluation tool in a Google format adapted from DepEd. The modules were evaluated for compliance with standards indicated in the criterion items under six (6) factors: Content, format, presentation and organization, readability, accuracy, up-to-datedness of information, and SSI. The developed SSI-based learning modules follow this format: Instruction on how to use the module, parts of the module, expectations, pre-test, tune-up, generating ideas, restructuring of ideas, Let's see more, share your thoughts, and post-test. The experts' evaluation of the SSI-based learning module in EM Waves (M = 3.82, SD = 0.13), Applications and Uses of EM Waves (M = 3.81, SD = 0.08), Images formed in Plane and Spherical Mirrors (M = 3.84, SD = 0.08) garnered "Very Satisfactory" evaluation results. This implies that the developed modules can now be implemented in classrooms and used by students in their learning.

A lesson was designed based on the content of the developed SSI-based learning modules and delivered through a hybrid mode: 2-day online synchronous sessions and 3-day face-to-face classes. A purposive one-group pre-test–post-test approach was utilized to describe the changes in students' knowledge before and after being exposed to SSI-based teaching and learning physics. Students' changes in physics knowledge in class were measured by evaluating the learning gained from the pre-test and post-test scores in the three developed modules.

The empirical evidence showed that the use of SSI-based learning modules enhanced students' knowledge, as seen in the difference in their scores between the pre-test and post-test per module. A significant change was revealed between the pre-test and post-test scores for Module 1 ($t(46) = 12.18$, $p < 0.05$), Module 2 ($t(46) = 15.08$, $p < 0.05$), and Module 3 ($t(46) = 24.27$, $p < 0.05$). The yielded effect sizes for this analysis were 0.67 for Module 1, 0.72 for Module 2, and 0.80 for Module 3. This indicates that there were medium effects on students' knowledge in Modules 1 and 2, whereas there was a large effect in Module 3. The implementation of SSI-based learning modules in class sparked interest in students to explore the connection of the SSI to the presented physics topics. It builds students' curiosity and promotes critical thinking as students analyze the issues presented, evaluate evidence, and consider multiple perspectives to make an informed decision.

Further research may be done by expanding the topics, fields, or learning competencies covered in the SSI-based learning modules to include other topics that might be difficult for the students to understand. Other SSI-based learning modules can be made for different branches of science (biology, chemistry, earth science, and even other parts of physics), and different grade levels can also be considered. Research may also be carried out the study on a larger scale and may conduct experimental studies, as this study involved only one Grade 10 section.

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