



Enhancing Students' Understanding of Image Formation in Optics through a Bilingual Electronic Science Module (e-BiSciMo)

LACISTE, Candy⁽¹⁾; SOMORAY, Ellaine⁽²⁾; LASALA, Nestor Jr⁽³⁾

⁽¹⁾ 0009-0007-6199-4925; Sorsogon State University, Sorsogon City, Philippines, candylaciste279@gmail.com

⁽²⁾ 0009-0000-8140-2789; Sorsogon State University, Sorsogon City, Philippines, ellainesomoray8@gmail.com

⁽³⁾ 0000-0002-8910-9613; Sorsogon State University, Sorsogon City, Philippines, nestor.lasala@sorsu.edu.ph

The content expressed in this article is the sole responsibility of its authors.

ABSTRACT

Many secondary students continue to face conceptual challenges in understanding image formation by mirrors and lenses, often attributed to the topic's abstract and spatial nature. This study developed and evaluated an electronic-based science module (e-BiSciMo) aligned with the Grade 10 K to 12 Science Competency S10FE-IIg-50. The module was designed to support independent learning using principles of multimedia instruction. A one-group pretest-posttest design involving 40 Grade 10 students was employed to examine changes in conceptual understanding following the implementation of the module. Quantitative data were analyzed using a paired-sample t-test and Cohen's d. Results showed a statistically significant improvement in post-test scores ($p = .0041$), with a large effect size (Cohen's $d = 2.25$), suggesting a meaningful gain in student performance. Expert validation using the DepEd LRMDs evaluation tool rated the module as "Very Satisfactory" in content, instructional quality, technical aspects, and accuracy. While the study was limited in scope, initial findings indicate the potential value of e-BiSciMo as a supplementary instructional tool in secondary science education.

RESUME

Muchos estudiantes de secundaria continúan enfrentando desafíos conceptuales para comprender la formación de imágenes mediante espejos y lentes, a menudo atribuidos a la naturaleza abstracta y espacial del tema. Este estudio desarrolló y evaluó un módulo de ciencias en formato electrónico (e-BiSciMo) alineado con la competencia de Ciencia de Grado 10 del currículo K a 12 (S10FE-IIg-50). El módulo fue diseñado para apoyar el aprendizaje independiente utilizando principios de instrucción multimedia. Se empleó un diseño de preprueba y postprueba con un solo grupo, que involucró a 40 estudiantes de décimo grado, para examinar los cambios en la comprensión conceptual tras la implementación del módulo. Los datos cuantitativos se analizaron mediante una prueba t para muestras relacionadas y el estadístico d de Cohen. Los resultados mostraron una mejora estadísticamente significativa en los puntajes de la postprueba ($p = .0041$), con un tamaño del efecto grande (d de Cohen = 2.25), lo que sugiere una mejora significativa en el desempeño estudiantil. La validación experta, utilizando la herramienta de evaluación del LRMDs del Departamento de Educación, calificó el módulo como "Muy Satisfactorio" en contenido, calidad instruccional, aspectos técnicos y precisión. Aunque el estudio tuvo un alcance limitado, los hallazgos iniciales indican el valor potencial del e-BiSciMo como recurso instruccional complementario en la educación científica secundaria.

ARTICLE INFORMATION

Article process:

Submitted: 07/06/2025

Approved: 10/12/2025

Published: 10/13/2025



Keywords:

Bilingual Science
Instruction; Multimedia
Learning; Physics
Education; Image
Formation; Conceptual
Understanding

Keywords:

Enseñanza bilingüe de
ciencias; Aprendizaje
multimedia; Educación en
física; Formación de
imágenes; Comprensión
conceptual

Introduction

Science education is widely recognized for its role in developing learners' critical thinking, problem-solving abilities, and capacity for informed engagement with real-world issues. Yet in the Philippine context, persistent underperformance in science remains a pressing concern. The 2022 Programme for International Student Assessment (PISA) revealed that Filipino students continue to rank among the lowest globally in science, mathematics, and reading, with notable difficulty applying scientific concepts to everyday contexts (OECD, 2023). Likewise, results from the National Achievement Test (NAT) consistently reflect low proficiency levels across many regions, underscoring systemic challenges in delivering effective science instruction (SEI-DOST & PNU, 2019).

Among the most conceptually difficult topics in secondary physics is image formation by mirrors and lenses. Research indicates that students often hold persistent misconceptions about ray behavior, image orientation, and magnification due to the abstract and non-observable nature of light phenomena (Galili & Hazan, 2000; Goldberg & McDermott, 1987). Traditional approaches, typically reliant on static visuals and procedural formulas, fail to provide the dynamic, sensory-rich experiences needed to build coherent mental models (Duit & Treagust, 2003).

Multimedia-based instructional tools offer promising solutions. Grounded in Mayer's (2005) cognitive theory of multimedia learning, well-designed electronic modules can reduce cognitive overload, promote dual coding of information, and support engagement through interactive, multisensory inputs. Such affordances are especially relevant to physics topics like optics, which benefit from animated representations and iterative feedback (Clark & Mayer, 2016; Moreno & Mayer, 2007). However, in Philippine public schools, access to localized, standards-aligned, and technology-supported resources remains limited and uneven.

In parallel, the language of instruction poses additional challenges. While the Philippines' bilingual education policy promotes both English and Filipino in science education, many students struggle with comprehension due to the abstract nature of scientific terminology in a second language. Emerging research on bilingual and translanguaging pedagogies suggests that integrating learners' first language in science instruction can support understanding and discourse (Airey, 2012; Probyn, 2015; Setati & Adler, 2000).

In response to these overlapping challenges, conceptual difficulty in optics, lack of contextualized digital resources, and language-related barriers, this study developed and evaluated the Electronic Bilingual Science Module (e-BiSciMo). The module integrates bilingual (English Filipino) explanations, visual and auditory scaffolds, and interactive checkpoints within a PowerPoint-based platform designed for accessibility in low-tech environments. Anchored on the K to 12 Science Competency S10FE-IIg-50, it applies

principles from multimedia learning and bilingual science instruction to enhance conceptual understanding of image formation in light and mirrors.

Thus, this study aimed to determine the effects of the e-BiSciMo on students' conceptual understanding using a pretest-posttest design, complemented by expert validation guided by the Department of Education's Learning Resources Management and Development System (LRMDS) rubric. The results offer insights into the potential of curriculum-aligned, bilingual, multimedia resources to address persistent challenges in science learning as reported in the Philippine secondary education context.

Methodology

This study employed a descriptive-developmental research design, combining both descriptive and developmental approaches to create and evaluate a learning resource systematically. This design is suitable for studies that aim to design, implement, and evaluate the effectiveness of an instructional product (Lasala, 2022; Richey & Klein, 2007). In particular, this study focused on the development and evaluation of the Electronic Bilingual Science Module (e-BiSciMo), which is tailored to improve the performance of Grade 10 students in Physics, specifically in the area of image formation using mirrors and lenses—a consistently challenging topic in the curriculum. To guide the instructional design process, the ADDIE Model (Analysis, Design, Development, Implementation, Evaluation) was employed. This widely used framework ensures that the module meets quality criteria in terms of content relevance, instructional effectiveness, and technical delivery (Molenda, 2003). Following the ADDIE phases, the module was designed using bilingual scaffolds, interactive checkpoints, and multimedia elements, then subjected to iterative evaluation involving expert validation, pilot testing, and classroom implementation.

Additionally, a one-group pretest–posttest experimental design was employed to evaluate the impact of e-BiSciMo on students' academic performance. The same group of 40 Grade 10 students took a 30-item test before and after using the module. Student journals were also collected to enrich the data with qualitative feedback. The design is represented as:

O1 X O2

Where: X- Bilingual Multimedia Instructional Module ; O1- Pretest; O2- Posttest

While this design provided preliminary evidence of effectiveness, it did not include a control or comparison group. Thus, observed gains may partly reflect testing effects, classroom exposure, or other extraneous factors. This limitation was acknowledged in the interpretation of the findings.

Quantitative data obtained from the pretest and posttest were analyzed using both descriptive and inferential statistics, processed through Microsoft Excel and the JASP

statistical software. The mean and standard deviation were calculated to describe the central tendency and variability of students' scores before and after the intervention. In addition, the median and interquartile range (IQR) were examined to account for potential skewness in the distribution of scores, given the relatively small sample size ($n = 40$). The pretest scores had a median of approximately 47 with an IQR of 6, while the posttest scores had a median of approximately 80 with an IQR of 4. A paired-sample t -test was conducted to determine whether the observed differences in scores were statistically significant, with a significance level of $p < .05$. The paired-sample t -test assumes that the difference scores are approximately normally distributed. Although formal normality testing (e.g., Shapiro–Wilk) was not conducted, the sample size of 40 supports the robustness of the t -test under the Central Limit Theorem. Visual inspection of score distributions suggested no severe departures from normality, thereby justifying its use (Blanca et al., 2017; Blanca et al., 2023).

To complement the inferential analysis, Cohen's d was calculated to determine the effect size of the intervention, enabling the interpretation of the practical significance of the learning gains. According to Cohen (1988), effect sizes were categorized as small (0.2), medium (0.5), or large (≥ 0.8). These were followed in interpreting the study's results. Likewise, the study involved two groups of participants: (1) five expert science teachers who validated the instructional material, and (2) forty (40) Grade 10 students enrolled at one of the Secondary Schools here in Sorsogon, Philippines, during the 2022–2023 school year. Purposive sampling was employed to select the student participants, ensuring their readiness for the targeted learning competencies. However, the paper acknowledges that while purposive sampling ensured alignment with the target learning competencies, it also introduces potential selection bias and limits generalizability to other student populations, making it one of the study's limitations. The expert validators were selected based on their specialization in science education and familiarity with the Department of Education's resource evaluation standards.

A pilot implementation was initially conducted with a separate group of students to refine the module prior to full deployment. The final implementation involved a different intact class to prevent contamination of results. To ensure the validity, relevance, and effectiveness of the study, a set of rigorously designed and validated instruments was employed. These tools were either developed or adapted to align with the learning objectives and to provide reliable data for assessing both the learning material and the outcomes of its implementation.

The identification of target content for the e-BiSciMo began with a thorough analysis of the curriculum, supported by insights from existing literature, which identifies image formation as one of the most conceptually challenging topics in secondary physics education (Galili & Hazan, 2000). This topic, commonly misunderstood by students due to its abstract nature and representational complexity, became the focus of the module. Two Most Essential Learning Competencies (MELCs) guided the scope and content of the intervention: (1)

predicting the qualitative characteristics—orientation, type, and magnification—of images formed by plane and curved mirrors and lenses (S10FE-IIg-50), and (2) identifying how the properties of mirrors and lenses determine their use in optical instruments, such as cameras and binoculars (S10FE-IIh-52). These competencies fall under the content standard that addresses image formation in mirror and lens systems and are central to developing foundational understanding in optics.

The instructional intervention, the Electronic Bilingual Science Module (e-BiSciMo), was developed in both English and Filipino to support bilingual instruction. Content was initially crafted in English and manually translated into Filipino to maximize accessibility. Online translation platforms, such as EasyFilipinoTranslation.com and Lingvanex.com, were used as auxiliary tools, though all translations were carefully reviewed by the researchers to ensure scientific and linguistic fidelity. The module was designed as an interactive learning resource using PowerPoint format, enriched with embedded audio narration, visual illustrations, guided explanations, digital checkpoints, and formative quizzes. This multimedia design was intended to stimulate multimodal engagement and deepen conceptual understanding, in line with multimedia learning theory (Mayer, 2005).

To measure the effect of the module on students' conceptual understanding, a 30-item multiple-choice test was constructed and administered as both pretest and posttest. The test items were developed in direct alignment with the two MELCs, ensuring construct validity, and were subjected to expert validation by science educators. Prior to full implementation, the test underwent pilot testing with a separate group of students to establish clarity, content alignment, and psychometric reliability. The instrument achieved a Cronbach's alpha of 0.81, indicating high internal consistency. The interval between the pretest and posttest was one week, deemed sufficient to capture the effects of the intervention while minimizing external confounding factors.

To contextualize scores, a Performance Level (PL) was computed as the percentage of the mean score relative to the total possible score. The descriptive categories—*Full Mastery* ($\geq 92\%$), *Near Full Mastery* (83–91%), *Mastery* (75–82%), *Near Mastery* (51–74%), *Low Mastery* (25–50%), and *No Mastery* ($\leq 24\%$)—were adapted from DepEd/National Achievement Test (NAT) mastery descriptors. Since DepEd issuances show similar but not identical cutoffs, the thresholds used here represent a study-specific adaptation for consistency in reporting (DepEd, 2015; DepEd, n.d.).

To ensure the instructional soundness of the e-BiSciMo, the researchers utilized an Expert Validation Sheet adapted from the DepEd Learning Resources Management and Development System (LRMDS, 2009). This validation tool assessed four core dimensions: content quality, instructional quality, technical quality, and other findings, which included

factual, conceptual, and grammatical accuracy. Each criterion was supported by several indicators rated on a 4-point Likert scale ranging from Strongly Disagree (1) to Strongly Agree (4). The instrument also provided space for narrative comments, allowing validators to suggest areas for revision. Expert feedback emphasized the need for clearer diagrams, simplification of complex Filipino scientific terms, and refinement of audio narration. All comments and recommendations were integrated into the final version of the module prior to student implementation. Similar validation protocols were used in other recent material development studies in Physics and Ecology, which likewise relied on expert review using DepEd LRMS standards to ensure content, instructional, and technical quality (Candia et al., 2025; Gestida et al., 2025).

To complement the quantitative data and gain deeper insight into students' learning experiences, reflective student journals were collected. These journals were written during and after the module engagement, guided by prompts that encouraged learners to articulate their understanding, evaluate the clarity of bilingual explanations, identify challenges they encountered, and propose improvements to the module. These qualitative responses enriched the evaluation process by highlighting learner perceptions and helping assess the effectiveness of the bilingual and multimedia components of the instructional design.

Meanwhile, data collection in this study was systematically structured, following the five phases of the ADDIE instructional design model: Analyze, Design, Develop, Implement, and Evaluate. Each phase made a unique contribution to the comprehensive development, deployment, and assessment of the e-BiSciMo.

In the Analyze phase, the researchers conducted curriculum content analysis and stakeholder consultations to identify image formation as a least-mastered topic in Grade 10 Physics. Formal communication letters were sent to expert science teachers to secure their participation in validating the instructional material. The needs analysis and literature review confirmed the conceptual complexity of optics topics and guided the selection of the Most Essential Learning Competencies (MELCs) to be addressed.

During the Design phase, the structure and content framework of the e-BiSciMo were conceptualized, along with its accompanying assessment tools. The pretest and posttest instruments were designed to align strictly with the target MELCs, while the expert validation instrument was adapted from the DepEd Learning Resources Management and Development System (LRMS) framework. These tools were reviewed for alignment, clarity, and appropriateness for Grade 10 learners.

The Development phase involved creating the initial draft of the bilingual module. This version was submitted to expert validators, who rated it using a 4-point Likert scale and provided qualitative feedback. Based on the evaluators' suggestions—such as refining diagrams

and simplifying scientific terms in Filipino—substantive revisions were made. A pilot test with a separate group of students was conducted to evaluate the clarity, usability, and pedagogical effectiveness of the module. Observations from this trial helped refine both the instructional flow and the language structure of the content.

Upon completion of the revisions, the Implementation phase commenced. A new set of Grade 10 students, different from those involved in the pilot test, participated in the full deployment of the e-BiSciMo. These students first completed a pretest to establish baseline performance levels. The module was then administered over the course of four classroom sessions, followed by a posttest to evaluate learning gains. Students were also asked to write reflective journals to document their learning experiences, challenges, and insights about the bilingual and digital format of the module.

Finally, in the Evaluation phase, the study analyzed data from three primary sources: the pretest and posttest scores, expert validation sheets, and student journal entries. Paired-sample t-tests were conducted to determine whether the differences between pre- and post-intervention scores were statistically significant. Thematic analysis of the journals provided qualitative insight into student experiences and engagement, while synthesis of expert validation data confirmed the instructional soundness of the module in terms of content, pedagogy, and technical design.

Moreover, ethical clearance for the study was granted by the secondary school where the study is conducted. All participants were thoroughly briefed on the objectives, procedures, and voluntary nature of the study. Students and teachers provided informed consent, with assurances that participation or performance would not influence academic standing. Measures were strictly observed to uphold the confidentiality and anonymity of data, in line with ethical standards in educational research. Participation was entirely voluntary, and students retained the right to withdraw from the study at any point without penalty.

While the chosen descriptive–developmental and one-group pretest–posttest design was appropriate for evaluating the initial effectiveness of the e-BiSciMo, several methodological constraints must be acknowledged. The absence of a control or comparison group limits causal attribution of observed gains solely to the intervention, and the relatively small sample of 40 students from a single school reduces generalizability. Additionally, the primary reliance on multiple-choice test items may have emphasized recall and recognition over capturing deeper reasoning processes, although student journals were included to provide qualitative insights. Finally, the one-week interval between pre- and post-tests was sufficient for examining immediate effects but did not permit evaluation of long-term retention. These limitations suggest that subsequent studies should employ larger and more diverse samples, integrate open-ended and performance-based assessments, extend the implementation period

to measure sustained learning, and compare outcomes with those of teacher-led or blended instructional approaches.

Results and Discussion

Development of Electronic Bilingual Science Module (e-BiSciMo) in teaching Physics 10

The researchers developed an Electronic Bilingual Science Module that is used as a tool to enhance students' academic performance in the identified difficult topic Physics. The e-BiSciMo that was developed was based on the DepEd Most Essential Learning Competencies for Grade 10 Physics Second Quarter. As such, the researchers developed three interconnected e-BiSciMo for one learning competency under the chosen topic which is Light: Mirrors and Lenses.

Table 1:

Summary of Learning Competencies and Mirrors and Lenses Concept used in the Development of the e-BiSciMo

Developed e-BiSciMo/ Topics	Learning Competency	Mirrors and Lenses Concepts
Properties of Light and Image Formation in Plane Mirrors: Part 1 (Quest 1-Quest 3)	Predict the qualitative characteristics (orientation, type, and magnification) of images formed by plane and curved mirrors and lenses (S10FE-IIg-50)	What's In - Properties and behaviors of light What's New - Reflective Surfaces - Specular and Diffuse Reflection - Law of Reflection - Mirror Left-Right Reversal
LImage Formation in Curved Mirrors and Lenses: Part 2 (Quest 4-Quest 7)	Identifying how the properties of mirrors and lenses determine their use in optical instruments, such as cameras and binoculars (S10FE-IIh-52).	- Three Types of Mirrors - Two Types of images formed What's More - L-O-S-T (Location, Orientation, Size, Type) - Plane Mirror Edition (Ray Diagramming) - Curved Mirror Edition (Ray Diagramming)
Applications of Mirrors and Lenses in Optical Devices: Part 3 (Quest 8- Last Quest)		What Have I Learned - Concave and Convex Lens What I Can Do - Application in Real Life

Table 1 presents the foundation of the developed Electronic Bilingual Science Module based on the DepEd Most Essential Learning Competencies for Grade 10 Physics in the Second Quarter. As shown in the table, the concepts were divided into three interconnected learning materials. The 1st e-BiSciMo encompasses Quest 1, Quest 2, and Quest 3, which include Properties and behaviors of light, Types and Laws of Reflection, and Mirror Left-Right Reversal. Meanwhile, the 2nd e-BiSciMo encompasses Quest 4, Quest 5, Quest 6, and Quest 7, which cover the three types of mirrors and the images formed using the L-O-S-T (Location, Orientation, Size, and Type) principles. The 3rd e-HiSciMo contains the importance and Applications of Mirrors and Lenses in optical devices and everyday life.

Meanwhile, Table 2 presents the essential features of the developed e-BiSciMo. As shown in the table, the e-BiSciMo contains a Multisensory simulation in which the students will be able to acquire knowledge through reading and listening. Additionally, the material includes two embedded human-read audio files: one in English and one in Tagalog. This is to aid the learners in understanding complex concepts by checking the information they have comprehended in two different languages. Another feature of e-BiSciMo is the immediate feedback system. With this, the learners are able to monitor their progress throughout the module. Lastly, the e-BiSciMo is convenient because it is accessible on both laptops and phones. In this way, students can learn at their own pace and from anywhere they want, anytime they want. As such, this can help students develop into independent learners.

Moreover, to ensure engagement, the developed materials are produced using Microsoft PowerPoint software, which is enhanced with hyperlinks, animations, and other special features, such as narration, sound effects, animated images, and interactive designs. Aside from this, PowerPoint presentations are also accessible on mobile phones, making it easier for students to use them. Furthermore, the researchers did not add any features that require an internet connection, given the slow internet connectivity in the Philippines. Most interactive learning tools, such as Edmodo, require an internet connection to access and also require a stable or high-bandwidth internet connection to avoid intermittent access to the learning platform. With that, the researchers decided to use a PowerPoint presentation as a tool to develop the e-BiSciMo as it is more accessible compared to other online educational platforms.

The three e-BiSciMos developed consist of 10 quests of game-based activities that enhance students' academic performance on the topic Light: Mirrors and Lenses. Recent evidence shows that game-based and interactive modules can significantly enhance students' motivation and conceptual engagement in science, particularly when lessons are contextualized and learner-centered (Lasala, 2024). The first part has a title page, which indicates the title of the E-SIM; a content page, which indicates the content standard, and the most essential learning competencies; A preface that indicates the purpose of the e-BiSciMo, the name of the developer, and the instructions for using the e-BiSciMo; the reference page that indicates the list of sources of information, graphics, and design used in the e-BiSciMo. The second and third part is the continuation of the module's audio-embedded interactive activities.

Table 2.

Developed e-BiSciMo	FEATURES			
	Multisensory Simulation	Bilingual	Immediate Feedback System	Student Centered
Light: Mirrors and Lenses Part 1, 2, and 3	The developed material stimulates the visual and auditory organs of the user.	The material contains embedded English (blue speaker symbol) and Filipino (yellow speaker symbol) human-read audio. Both of which are accessible through the symbols placed.	Each activity contains an immediate feedback system to show the students' progress	The learners are encouraged to be autonomous and independent by self-data manipulation.

Matrix of the Developed E-SIM highlighting the four features

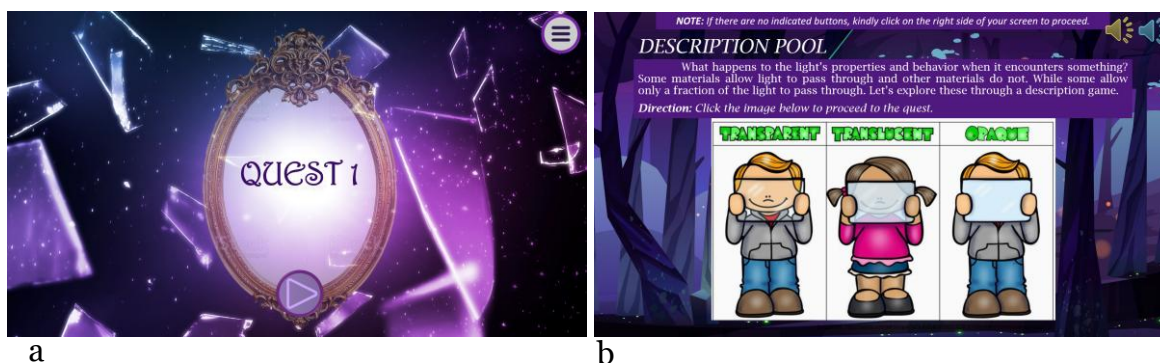
A. e-BiSciMo Part 1 - Light: Mirrors and Lenses

The e-BiSciMo part one is composed of three quests. Each level contained different bilingual audio-embedded types of games that will boost their academic performance in learning mirrors and lenses. After completing each quest, the students will gain enchanted items.

Figure 1.

(a) Introduces the magic mirror to know the first quest. (b) The students described the three different media and the lights' behavior in response to encountering various types of media. This quest required the students to describe the given medium type by clicking on the corresponding options.

Quest 1: Behavior and Properties of Light



Quest 2: Two Types of Reflection

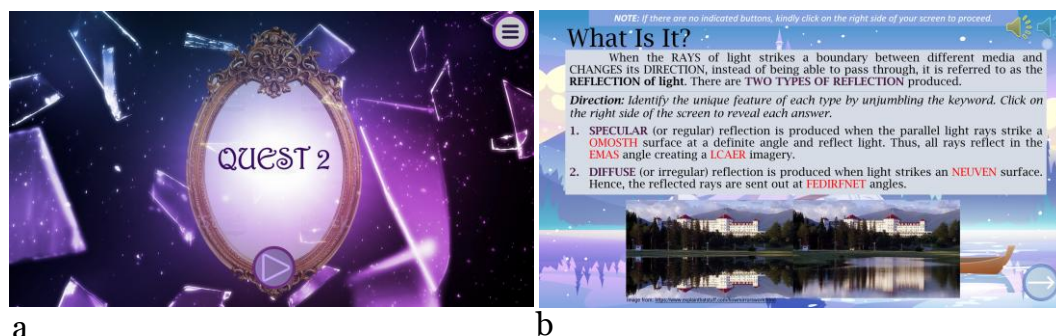
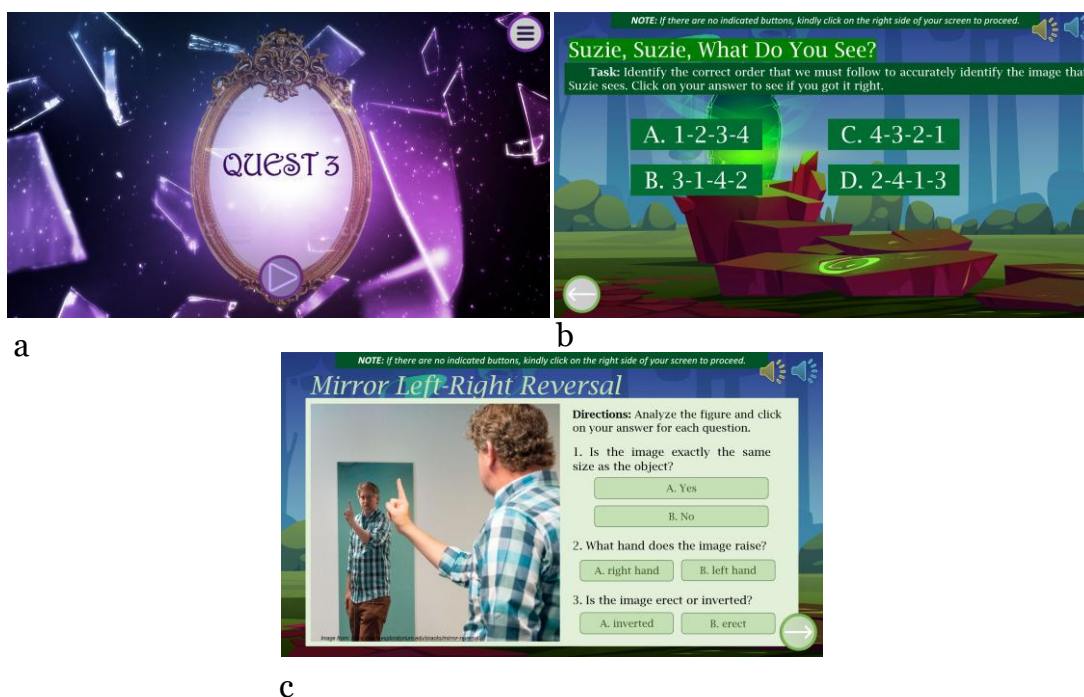


Figure 2.

(a) Shows the magic mirror to enter the second quest. (b) The learners identified the key characteristics of each type of reflection produced after the behavior of the rays of light after striking the boundary between different media.

Quest 3: Ray Diagramming of Plane Mirrors

**Figure 3.**

(a) Presents the magic mirror to the third quest. (b) Students learned the step-by-step process of making a ray diagram due to the utilization of the line-of-sight principle in respect to the law of reflection. Upon the given choices of arranged chronology of the given step-by-step process, the learners chose the accurate one. (c) The learners described the type of image formed by a plane mirror.

B. e-BiSciMo Part 2 - Light: Mirrors and Lenses

The e-BiSciMo part two is composed of four quests. Each level contained different bilingual audio-embedded types of games that will boost their academic performance in learning mirrors and lenses. After completing each quest, the students will gain enchanted items.

Quest 4: Examples of the Two Types of Curved Mirrors



a

b

Figure 4.

(a) Depicts the magic mirror to see the fourth quest. (b) The learners studied the two types of curved or spherical mirrors – the concave and the convex mirror. Conversely, the learners identified the concave mirror among the selections given.

Quest 5: What is my L-O-S-T? (Plane Mirror Edition)



a

b

Figure 5.

(a) Presents the magic mirror to open the fifth quest. (b) The students analyzed the ray diagram model of a given object placed in front of a plane mirror, from which they identified the L-O-S-T (Location, Orientation, Size, and Type).

Quest 6: What is my L-O-S-T? (Concave Mirror Edition)



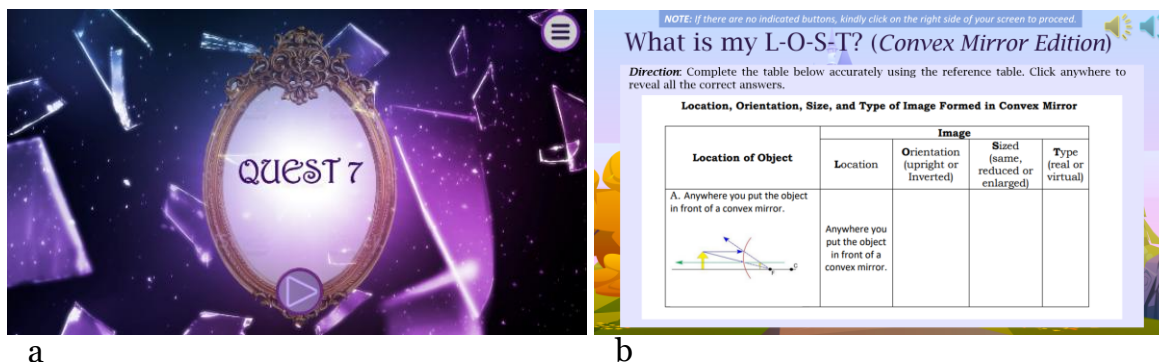
a

b

Figure 6.

(a) Displays the magic mirror for the sixth quest. (b) At this level, the students described the image formed of the object placed in front of a concave mirror by identifying the L-O-S-T (Location, Orientation, Size, and Type).

Quest 7: What is my L-O-S-T? (Convex Mirror Edition)

**Figure 7.**

(a) Reveals the magic mirror to enter the seventh quest. (b) At this level, the students described the image formed of the object placed in front of a convex mirror by identifying the L-O-S-T (Location, Orientation, Size, and Type).

C. e-BiSciMo Part 2 - Light: Mirrors and Lenses

The e-BiSciMo part three is composed of three quests. Each level contained different bilingual audio-embedded types of games that will boost their academic performance in learning mirrors and lenses. After completing each quest, the students will gain enchanted items.

Quest 8: Indicators of Spherical Mirrors

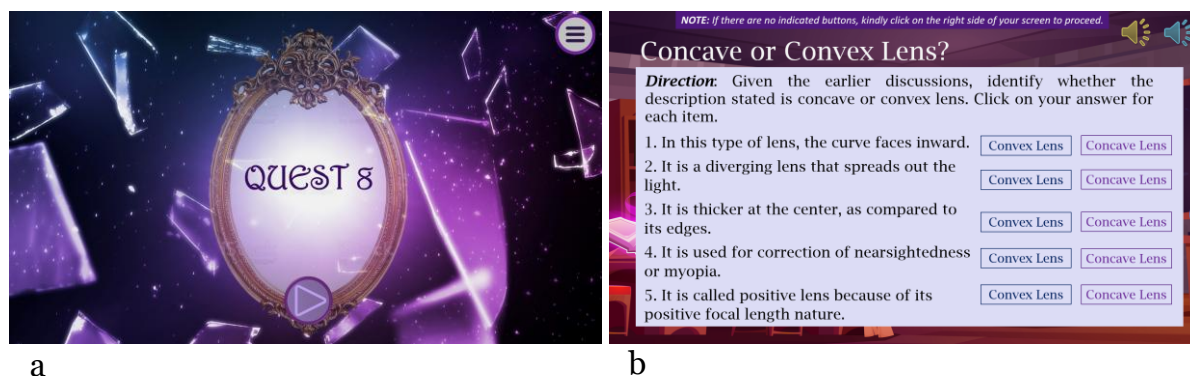
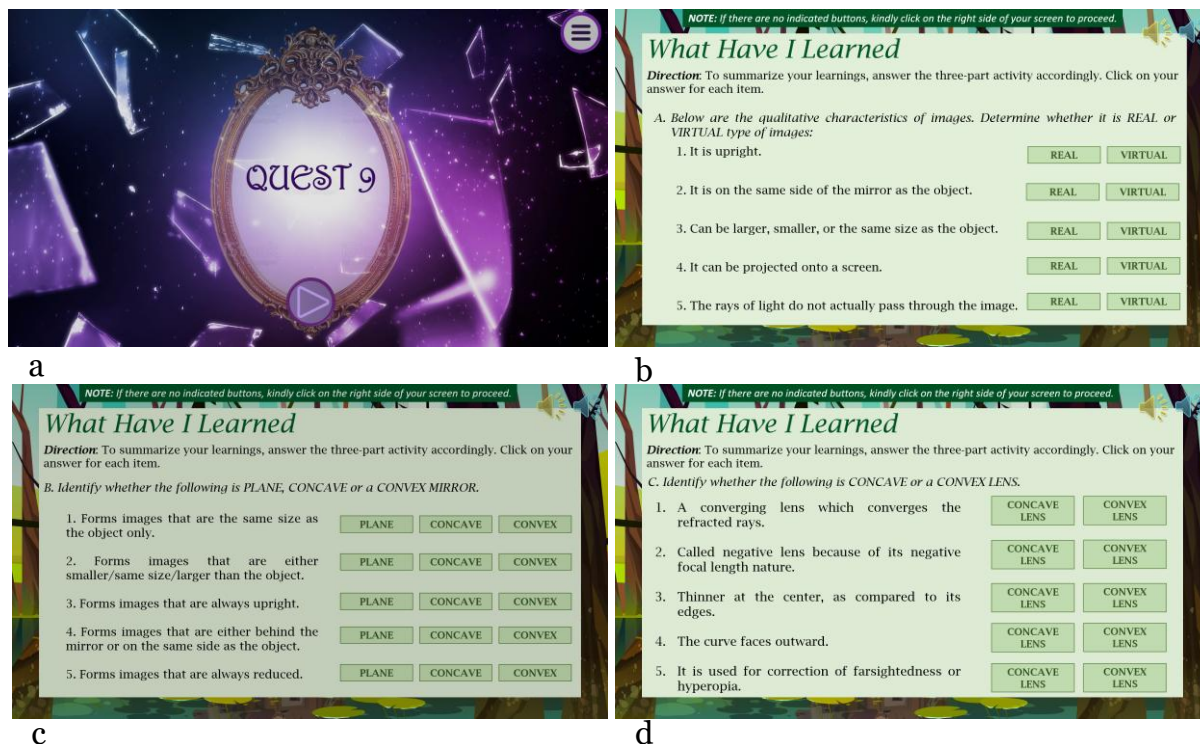


Figure 8.

(a) Portrays the magic mirror to execute the eighth quest. (b) At this level, the students identified the type of spherical or curved mirror based on the descriptions given.

Quest 9: What Have I Learned

**Figure 9.**

(a) Depicts the magic mirror that will lead to the ninth quest. The students tested the knowledge they had acquired by utilizing the three-part e-BiSciMo, accomplishing the three-part test. (b) The first test focused on identifying real and virtual images. (c) The second test emphasized which type of mirror is used. (d) The last test highlighted the difference between concave and convex lenses.

Last Quest: Application in Real Life

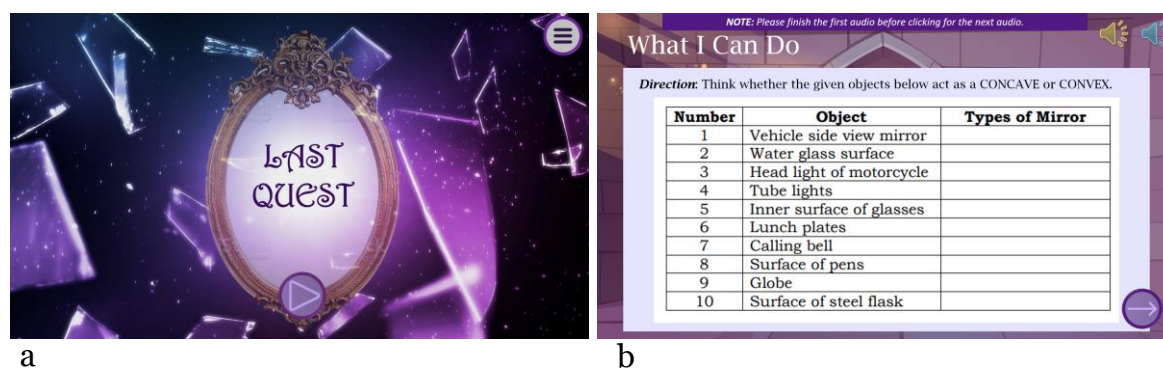


Figure 10. (a) Highlights the magic mirror to answer the last quest of e-BiSciMo. (b) At this level, the learners expanded on the real-life application of spherical or curved mirrors. In this last quest, they analyze the use of each object given and cite the type of mirror.

Experts Evaluation of the developed e-BiSciMo for Grade 10 Physics

To ensure that the e-BiSciMo met the standards for quality and effectiveness as an instructional resource, it was subjected to a comprehensive expert validation using the Department of Education's Learning Resources Management and Development System (DepEd LRMS) tool for non-print materials. Five experts in science education and instructional design evaluated the module across four essential factors: Content Quality, Instructional Quality, Technical Quality, and Accuracy and Up-to-datedness. Their quantitative ratings and qualitative feedback served as the basis for refining the module prior to its classroom implementation. The results of their evaluation are summarized in Table 3.

Table 3.

Experts' summary of points of developed e-BiSciMo evaluations

Factors	Point to pass (DepEd, 2009)	Mean Scores of Experts' Evaluation					Average Score
		E1	E2	E3	E4	E5	
a. Content Quality	At least 30 of 40	39	38	38	39	39	38.6
b. Instructional Quality	At least 30 of 40	39	38	39	39	38	38.6
c. Technical Quality	At least 39 of 52	49	49	49	50	48	49
d. Accuracy and Up-to-datedness	At least 16 of 16	16	16	16	16	16	16

Note: E-Expert

Based on the table 3, the first factor, Content Quality, received an average score of 38.6 out of 40, surpassing the minimum required score of 30. This high rating suggests that the e-BiSciMo's content was deemed accurate, coherent, comprehensive, and aligned with the K–12 Grade 10 Science Curriculum. The evaluators recognized that the concepts presented—particularly those involving image formation by mirrors and lenses—were well contextualized and scaffolded to address common student misconceptions. This finding is consistent with previous research emphasizing that high-quality instructional content must be both scientifically accurate and pedagogically coherent to support deep conceptual understanding (Harlen, 2010; Duit & Treagust, 2003). The inclusion of localized examples and visual models within the module likely contributed to its effectiveness, as supported by studies showing that contextualization enhances learners' engagement and comprehension in science (Aikenhead, 2006).

Under the Instructional Quality domain, the e-BiSciMo again received a high average rating of 38.6 out of 40, indicating that the module's structure and pedagogy were viewed as highly supportive of meaningful learning. Experts noted that the instructional flow—from concept activation to guided inquiry and self-assessment—aligned with constructivist

principles, allowing learners to explore abstract physics concepts in accessible ways. This supports the findings of Mayer (2005), who emphasized the importance of guided discovery and multimodal input in fostering retention and transfer of learning in science education. Moreover, the module's use of interactive questioning, reflection prompts, and differentiated tasks reflected best practices in learner-centered instruction (Bransford et al., 2000), supporting diverse learner needs in a self-directed setting (Lasala, Ricafort, & Prado, 2025b)

For Technical Quality, the module achieved an average score of 47 out of 52, well above the 39-point passing requirement. This result highlights the e-BiSciMo's functional layout, multimedia integration, and user-friendly navigation. According to Clark and Mayer (2016), well-designed e-learning materials must minimize extraneous cognitive load through coherent visual and interactive elements. The expert raters specifically cited the clarity of the interface, appropriate font usage, and responsiveness of the embedded elements (e.g., simulations, clickable self-tests) as contributors to its strong technical performance. However, minor comments were made on the need to improve visual spacing and image resolution in earlier versions of some slides and activity pages. These suggestions align with research indicating that interface consistency and visual clarity are essential to maintaining cognitive flow in digital learning environments (Lasala, Prado, Doringo, & Ricafort, 2025a; Moreno & Mayer, 2007).

In the final category, Accuracy and Up-to-dateness, the module received a perfect score of 16 out of 16, affirming that its content was free of factual, grammatical, and conceptual errors, and that all examples and terminology reflected current scientific standards. Experts found that the module adhered closely to DepEd's curriculum guide and incorporated accurate scientific representations, an essential requirement for credibility and learning efficacy (Taber, 2014). This result further supports the e-BiSciMo's readiness for integration into formal science instruction.

In addition to the numerical ratings, the validators provided qualitative feedback that was crucial in shaping the final version of the e-BiSciMo. Positive remarks highlighted the module's engaging format, alignment with learning competencies, clear learning outcomes, and ability to support independent learning. Experts appreciated how the module demystified complex topics in optics through step-by-step visuals, formative checks, and contextual tasks. Meanwhile, constructive feedback included minor issues such as typographical inconsistencies, inconsistent spacing, and suggestions for more precise ray diagrams. One expert recommended integrating more scaffolded prompts in the self-assessment sections to guide student reflection.

Importantly, all comments and recommendations were reviewed and addressed prior to implementation. The necessary revisions were incorporated to enhance layout consistency, correct textual and graphical issues, and improve the clarity of key illustrations. These

refinements ensured that the final version of the e-BiSciMo reflected not only instructional and technical quality but also responsiveness to expert input.

Taken together, these findings confirm that the developed e-BiSciMo is a valid and high-quality instructional resource aligned with DepEd's standards for non-print materials. The expert validation process, supported by strong quantitative ratings and constructive feedback, affirms that the module can be confidently used to support students' conceptual understanding in Grade 10 Physics, particularly in learning about light, mirrors, and lenses through guided, self-paced, and technology-enhanced instruction.

Effects of e-BiSciMo on Students' Conceptual Understanding

To assess the effectiveness of the e-BiSciMo in improving students' conceptual understanding of light and mirror-related concepts, a pretest and posttest were administered to Grade 10 students. The assessment targeted three specific content areas: image formation in plane mirrors, curved mirrors (concave and convex), and lenses (converging and diverging), each designed to align with the learning competency S10FE-IIg-50. The performance in each topic was measured out of 30 points, with mastery levels determined through percentage-based performance level (PL) interpretations. Table 4 summarizes the descriptive and inferential results of the students' performance before and after exposure to the developed e-learning material.

Table 4.

Paired sample t-test result of the pre-test and post-test achievement scores of students

Topics	No. of Items	No. of Points	Pre-Test			Post-Test		
			Raw Mean Scores	PL (%)	Interpretation	Raw Mean Scores	PL (%)	Interpretation
Properties of Light and Image Formation in Plane Mirrors	10	30	18	60%	NM	27.56	91.9%	FM
Image Formation in Curved Mirrors and Lenses	10	30	14	47%	LM	25.84	86.13%	NFM
Applications of Mirrors and Lenses in Optical Devices	10	30	15	50%	LM	26.43	88.1%	NFM
Overall	30	90	47	52.2%	NM	79.83	88.7%	NFM
SD				5.98			3.4	
Degree of freedom					39			
Cohen's d	2.25							
p-value	0.0041							

Note: Significant at 0.05 level; Cohen's d indicates a very large effect size.

Legend: PL- Performance Level; NM- Near Mastery; LM- Low Mastery; NFM- Near Full Mastery.

FM- Full Mastery

Table 4 presents the comparative results of the pre-test and post-test assessments administered to evaluate the effectiveness of the e-BiSciMo in enhancing students' understanding of image formation concepts, particularly under the physics topic of light behavior in mirrors and lenses. The assessment was conducted among 40 Grade 10 students using a one-group pretest-posttest design. The test items were organized into three content areas: image formation in plane mirrors, concave and convex mirrors, and converging and diverging lenses, each with a maximum of 30 points.

In the pre-test, students demonstrated limited understanding across all three domains. The mean scores were 18 (60%) for plane mirrors, 14 (47%) for curved mirrors, and 15 (50%) for lenses. These values correspond to performance level interpretations of Near Mastery (NM) for plane mirrors and Low Mastery (LM) for the other two topics, indicating that most students had not yet developed sufficient conceptual understanding in image prediction. These results are consistent with prior research, which shows that secondary students often struggle with optics topics, particularly in representing and interpreting image characteristics through ray diagrams (Galili & Hazan, 2000; Goldberg & McDermott, 1987).

Following the intervention, students showed marked improvements. The post-test scores increased across all three topics, with mean values of 27.56 (91.9%) for plane mirrors, 25.84 (86.13%) for curved mirrors, and 26.43 (88.1%) for lenses. These corresponded to performance levels of Full Mastery (FM) and Near Full Mastery (NFM), suggesting significant conceptual gains. The highest post-test performance was observed in image formation in plane mirrors, which may be attributed to the relative familiarity and intuitiveness of image properties such as orientation and size in flat reflective surfaces. In contrast, although significant improvements were also evident in curved mirrors and lenses, these topics remained slightly below complete mastery, possibly due to their more abstract nature. Students must visualize focal points, apply the mirror and lens equations qualitatively, and understand how the type of image changes with the position of the object—concepts that are typically more cognitively demanding (Singh, 2000).

The overall performance level increased from 52.2% (Near Mastery) in the pre-test to 88.7% (Near Full Mastery) in the post-test. A paired-sample t-test revealed a statistically significant result, $t(39) = 9.12$, $p = .0041$. Assumptions of the paired-sample t-test were considered. With $n = 40$, the Central Limit Theorem supports robustness to moderate non-normality, and visual inspection suggested no severe departures from normality (Blanca et al., 2017; Blanca et al., 2023). The Cohen's d of 2.25 denotes a very large effect size (Cohen, 1988), confirming the potential of e-BiSciMo when used in learning delivery. Notably, the standard deviation decreased from 5.98 in the pre-test to 3.4 in the post-test, suggesting that the

intervention not only improved overall performance but also led to more consistent learning outcomes across the group.

While the Cohen's d of 2.25 indicates a very large effect, this value may be somewhat inflated due to the one-group pretest–posttest design, where test familiarity and short intervention intervals can amplify measured gains (Morris & DeShon, 2002). Nonetheless, such an effect is not implausible in this context, given the novelty of the bilingual, interactive module, the strong scaffolding provided, and the alignment with students' linguistic resources, which likely produced substantial immediate learning gains.

These findings suggest that the e-BiSciMo successfully supported conceptual change and meaningful learning in the domain of optics. The module's interactive design, localized contexts, and structured visual explanations may have addressed common student misconceptions and enhanced cognitive engagement, consistent with various research (Jalmasco et al., 2025; Lasala, 2023) and Mayer's (2005) cognitive theory of multimedia learning and Duit and Treagust's (2003) views on conceptually focused science instruction.

Nonetheless, several limitations must be acknowledged. First, the use of a one-group pretest-posttest design without a control group limits the ability to isolate the effects of the e-BiSciMo from other influencing variables such as classroom instruction, peer discussions, or test-retest familiarity. Second, the study's sample was drawn from a single class in one school, thus limiting the generalizability of the findings to broader populations. Third, the assessment relied on multiple-choice items, which, while helpful in measuring recall and recognition, may not fully capture students' reasoning processes or more profound understanding. Finally, potential short-term memory effects cannot be ruled out, particularly if the interval between pre- and post-testing was relatively short.

Despite these limitations, the data provide strong evidence that the e-BiSciMo is an effective supplementary instructional tool for improving students' understanding of light and mirrors. The combination of statistically significant improvement, large effect size, and elevated mastery levels across topics supports its potential for wider classroom use, especially in addressing persistent difficulties in optics learning among secondary students.

Conclusion

The development and implementation of the e-BiSciMo aimed to support students' conceptual understanding of image formation using mirrors and lenses. Quantitative results from a pretest-posttest design involving Grade 10 learners indicated statistically significant gains following the module's use. The large effect size observed suggests that the learning experience may have contributed to improved performance in the targeted physics concepts. Expert evaluation using an established DepEd rubric rated the module highly in terms of content quality, instructional design, technical features, and factual accuracy.

The findings suggest that a well-structured electronic module may serve as a useful supplement to classroom instruction in physics, particularly when addressing abstract topics like light behavior. The design elements of the e-BiSciMo—such as embedded self-assessment, visual scaffolds, and interactive elements—may have played a role in helping learners engage with and reflect on core concepts. However, the absence of a control group and the relatively small, context-specific sample limit the generalizability of the results. Further research involving broader implementation, control-comparison designs, and qualitative feedback from users would help establish the effectiveness and adaptability of the module more conclusively.

REFERENCES

- Aikenhead, G. S. (2006). 9. Cross-Cultural Science Teaching: Rekindling Traditions for Aboriginal Students. *University of Toronto Press EBooks*.
<https://doi.org/10.3138/9781442686267-012>
- Airey, J. (2012). “I don’t teach language”: The linguistic attitudes of physics lecturers in Sweden. *AILA Review*, 25, 64–79. <https://doi.org/10.1075/aila.25.05air>
- Blanca, M. J., Alarcón, R., Arnau, J., Bono, R., & Bendayan, R. (2017). Non-normal data: Is ANOVA still a valid option? *Psicothema*, 29(4), 552–557.
<https://doi.org/10.7334/psicothema2016.383>
- Blanca, M. J., Arnau, J., Bono, R., & Bendayan, R. (2023). Non-normal data in repeated measures ANOVA: Impact on Type I error and power. *Psicothema*, 35(1), 132–139.
<https://doi.org/10.7334/psicothema2022.239>
- Bransford, J. D., Brown, A. L., & Cocking, R. R. (2000). *How People Learn: Brain, Mind, Experience, and School*. Washington DC: National Academy Press.
- Candia, R., Glomar, G., Joven, C., & Lasala Jr, N. (2025). Home-Based Learning Activities (H-BLA) in Teaching Physics Topics for Elementary School Students.
<https://doi.org/10.37251/jber.v6i2.1738>
- Clark, R. E., & Mayer, R. E. (2016). *E-Learning and the Science of Instruction: Proven Guidelines for Consumers and Designers of Multimedia Learning*. John Wiley & Sons.
<https://doi.org/10.1002/9781119239086>
- Cohen, J. (1988). *Statistical Power Analysis for the Behavioral Sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates, Publishers.
- Department of Education (DepEd). (2015). DepEd Order No. 8, s. 2015: Policy guidelines on classroom assessment for the K to 12 Basic Education Program. Department of Education, Philippines.
- Department of Education (DepEd). (n.d.). Annex E: Criteria for proficiency/achievement level [Additional requirements]. Department of Education, Philippines. Retrieved

- from https://www.deped.gov.ph/wp-content/uploads/ANNEX-E_ADDITIONAL-REQUIREMENTS-1.pdf
- Duit, R., & Treagust, D. F. (2003). Conceptual change: A powerful framework for improving science teaching and learning. *International Journal of Science Education*, 25(6), 671–688. <https://doi.org/10.1080/09500690305016>
- Galili, I., & Hazan, A. (2000). Learners' knowledge in optics: interpretation, structure and analysis. *International Journal of Science Education*, 22(1), 57–88. <https://doi.org/10.1080/095006900290000>
- Gestiada, R. J., Tisoy, F. J., & Lasala Jr, N. (2025). The 360 view: Contextualized virtual reality tours as innovative teaching tool in ecology for elementary school students. <https://doi.org/10.37251/jber.v6i1.1213>
- Goldberg, F. M., & McDermott, L. C. (1987). An investigation of student understanding of the real image formed by a converging lens or concave mirror. *American Journal of Physics*, 55(2), 108–119. <https://doi.org/10.1119/1.15254>
- Harlen, W. (2010). The royal society's report on primary school science. *Primary Science*, 115, 25–27.
- Jalmasco, A. C., Loberes, J. M., & Lasala, N. J. (2025). Interactive story for teaching ecosystem topics using twine application for elementary school students. *Journal of Basic Education Research*, 6(2), 66–78. <https://doi.org/10.37251/jber.v6i2.1480>.
- Lasala Jr, N. (2023). EDUTainment: Effectiveness of game-based activities in teaching ecosystem topics. *Recoletos Multidisciplinary Research Journal*, 11 (2), 69–83. <https://doi.org/10.32871/rmrj2311.02.07>
- Lasala Jr, N. L. (2022). Validation of game-based activities in teaching Grade 7-Biology. *Jurnal Pendidikan IPA Indonesia*, 11(4), 519–530. <https://doi.org/10.15294/jpii.v11i4.39185>
- Lasala Jr, N. L. (2024). STUDENTS ' INTRINSIC MOTIVATION USING GAME-BASED ACTIVITIES. *Dalat University Journal of Science*, 50–70. [https://doi.org/10.37569/DalatUniversity.14.2.1161\(2024\)](https://doi.org/10.37569/DalatUniversity.14.2.1161(2024))
- Lasala Jr, N., Prado, J., Doringo, N., & Ricafort, J. (2025a). BEsMART: Board Examinations Mobile Application Reviewer for Pre-Service Science Teachers using Space Repetition and Hypercorrection. *Pakistan Journal of Life and Social Sciences*, 23 (1), 7274–7290. <https://doi.org/10.57239/PJLSS-2025-23.1.00564>
- Lasala Jr, N., Ricafort, J., & Prado, J. (2025b). Effect of E-learning Self-directed Interactive Module (E-SelfIMo) on Students' Understanding of Earth Science Concepts
- Mayer, R. E. (2005). Cognitive Theory of Multimedia Learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 31–48). Cambridge University Press. <https://doi.org/10.1017/CBO9780511816819.004>

- Molenda, M. (2003). In Search of the Elusive ADDIE Model. *Performance Improvement*, 42, 34-36. <https://doi.org/10.1002/pfi.4930420508>
- Moreno, R., & Mayer, R. (2007). Interactive Multimodal Learning Environments. *Educational Psychology Review*, 19, 309-326. <http://dx.doi.org/10.1007/s10648-007-9047-2>
- Morris, Scott B., & DeShon, Richard P. (2002). *Combining effect size estimates in meta-analysis with repeated measures and independent-groups designs*. *Psychological Methods*, 7(1), 105-125. DOI: 10.1037/1082-989X.7.1.105
- OECD. (2023). PISA 2022 results (Volume I). OECD Publishing. https://www.oecd.org/en/publications/pisa-2022-results-volume-i_53f23881-en.html
- Probyn, M. (2015). Pedagogical translanguaging: bridging discourses in South African science classrooms. *Language and Education*, 29(3), 218–234. <https://doi.org/10.1080/09500782.2014.994525>
- Richey, R. C., & Klein, J. (2007). *Design and Development Research: Methods, Strategies, and Issues*. Mahwah, NJ: Lawrence Erlbaum Associates, Publishers.
- Setati, M., & Adler, J. (2000). Between languages and discourses: Language practices in primary multilingual mathematics classrooms in South Africa. *Educational Studies in Mathematics*, 43(3), 243–269. <https://doi.org/10.1023/a:1011996002062>
- Taber, K. S. (2014). Methodological issues in science education research: A perspective from the philosophy of science. In M. R. Matthews (Ed.), *International handbook of research in history, philosophy and science teaching* (Vol. 3, pp. 1839–1893). Springer. https://doi.org/10.1007/978-94-007-7654-8_57