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Physics Learning Gaps: Spherical Mirrors and Lenses in Focus

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Index Terms:

instructional delivery, optics, problem solving, science teachers, spherical mirrors, thin lenses

Abstract. The study sought to evaluate the level of students' understanding, problem-solving skills, practical application, and difficulties encountered in their learning of spherical mirrors and thin lenses, as well as their perceptions of how their science teachers deliver their lessons in the classroom setting. The study adopted a quantitative descriptive correlational research design to systematically examine the relationships among these variables. The researcher also employed a two-stage cluster sampling technique to ensure a representative selection of participants. The respondents of this study were 165 Grade 10 students from three randomly selected schools in Santa Catalina District 2. The researcher utilized a 30-item test questionnaire to measure students' level of knowledge and a Likert scale survey to gather their perceptions regarding instructional delivery. The data analysis used in this study included mean, standard deviation, and composite scoring to provide a clear interpretation of the results. The study found that the Grade 10 students had a satisfactory level of understanding of spherical mirrors and lenses, particularly in practical application and ray diagram interpretation. However, the students demonstrated their lowest performance in problem-solving and conceptual understanding, especially when they were required to explain concepts without relying on formulas. This indicates a tendency to depend on procedural knowledge rather than deep conceptual reasoning. The students also encountered some difficulties in applying formulas accurately, constructing ray diagrams, and understanding light behavior in mirrors and lenses. On the other hand, the students perceived the instructional delivery of their science teachers as very effective, as clear explanations, real-life examples, and hands-on learning activities significantly helped them understand concepts and solve problems more effectively.

Introduction

Globally, optics education holds a critical role in scientific and technological progress, as it supports innovations in fields such as imaging, communication, and medicine. Despite its importance, students still experience learning gaps in understanding fundamental optics concepts, especially those related to image formation, reflection, and refraction using spherical mirrors and thin lenses (Sebald et al., 2022). Students struggle to apply optical fundamentals like reflection and refraction to problem-solving and real-world scenarios. This is particularly evident among Filipino students, who ranked 79th out of 81 countries on the 2022 PISA exam, which reflects a marginal decline from their 2018 performance (OECD, 2023). Such ongoing underperformance points to systemic problems in science education. As noted by Acido and Caballes (2024), the Philippines' PISA scores significantly lag behind those of other countries, and this gap could be attributed to broader educational and developmental factors. In response, scholars emphasize the need for technology-based learning tools and a stronger focus on critical thinking and intellectual activity to address learning gaps and improve students' interest and understanding of physics (Faridi et al., 2021; Wu et al., 2024; Zhang et al., 2022).

In the Philippines, optics remains one of the most difficult science topics for secondary students due to its abstract and representational demands. Studies show that Filipino learners often misinterpret key concepts like refraction and image formation, especially when using diagrams or symbolic formats (Tadeo & Yoo, 2022). Although some research supports the benefits of guided simulations (Arboiz & Malayao, 2024), implementation across schools is uneven due to limited resources and teacher readiness. Acosta (2021) noted the scarcity of validated, localized learning materials, while Cabural (2024) linked poor PISA results to poor instructional quality. Additionally, Canuto et al. (2024) found that student performance in physics is strongly influenced by teacher competence and content mastery. These issues show that while innovative tools exist, the effectiveness of optics instruction in the country is still constrained by access, training, and curricular support.

Despite a growing body of research on optics education, there is limited focus on students' conceptual understanding and problem-solving abilities specifically related to spherical mirrors and thin lenses. Existing studies tend to examine general optics topics or the effects of educational technologies without isolating these particularly difficult subtopics. For example, Wörner et al. (2022) found persistent misconceptions in how students view image formation through lenses, while Sebald et al. (2022) reported flawed mental models of how lenses and mirrors work. In the local setting, Tadeo and Yoo (2022) found that students' understanding varies widely depending on how content is presented, stressing the need for targeted interventions. Given these gaps, this study aims to examine students' conceptual and procedural understanding of spherical mirrors and thin lenses, identify common difficulties, and recommend teaching strategies that can improve learning outcomes.

This research aligns with Sustainable Development Goal 4: Quality Education, which emphasizes inclusive and equitable access to effective learning. In the context of Santa Catalina District II, the study addresses a critical need to improve students' comprehension of optics concepts foundational to science literacy and STEM readiness. By identifying specific misconceptions and proposing actionable teaching strategies, the study aims to enhance the quality of physics instruction and support teachers in delivering more effective lessons. In the end, the findings contribute to broader education goals by ensuring that students, regardless of location or context, can access meaningful, high-quality science learning opportunities that prepare them for a knowledge-based society.

Statement of the Problem

The study is designed to evaluate the students' understanding and skills in mirrors and lenses, identify the learning gaps encountered in learning these topics, and provide specific insights into students' learning progress.

Specifically, the study seeks to answer the following questions:

1. To what level is the students' knowledge of mirrors and lenses in terms of:
   1.1 concept;
   1.1 problem-solving; and
   1.2 practical applications?
2 To what extent are the learning gaps faced by students when learning about mirrors and lenses in terms of the following:
   2.1 conceptual understanding of light behavior;
   2.2 mathematical application of lens and mirror formulas; and
   2.3 difficulty in ray diagram construction?
3 To what extent is the instructional delivery of science teachers as perceived by the students?
4 Is there a significant relationship between the level of students' knowledge of mirrors and lenses and the gaps they face when learning mirrors and lenses?
5 Is there a significant relationship between the extent of the instructional delivery of science teachers and the gaps in learning mirrors and lenses?

Methodology

Research Design

This study employed a quantitative descriptive–correlational research design. It is descriptive in nature because it aims to determine the level of students' knowledge in mirrors and lenses in terms of conceptual understanding, problem-solving, and practical applications, as well as the extent of learning gaps encountered in learning these topics. In addition, the study describes students' perceptions of their science teachers' instructional delivery, including clarity of explanations, teaching strategies, use of visual aids, and promotion of student engagement.

The design is also correlational because it examines the relationships among key variables in the study. Specifically, it investigates the relationship between students' level of knowledge and the gaps encountered in learning mirrors and lenses, as well as the relationship between perceived instructional delivery and the learning gaps experienced by students. This approach determines whether significant relationships exist among the variables without manipulating any variables.

Research environment

The study was conducted in Santa Catalina District II, a school district under the Schools Division of Negros Oriental, Philippines. The district is located in the municipality of Santa Catalina, a rural area in the province of Negros Oriental. Established in 2012, Santa Catalina District II focuses on delivering basic education and promoting community engagement in educational initiatives. The district serves learners from Grade 7 to Grade 12 and includes both elementary and secondary schools. At the senior high school level, it offers both academic and technical-vocational-livelihood (TVL) tracks to address diverse learner needs and career pathways.

The primary research sites of this study were the four public secondary schools within the district. These schools are geographically distributed across different barangays and accommodate students from various socioeconomic backgrounds. Specifically, Cawitan High School, located in Barangay Cawitan, offers both academic and TVL programs, including courses such as horticulture, computer systems servicing, cookery, and beauty care services. Nagbalaye High School, situated in Barangay Nagbalaye, caters to a large population of secondary students and actively implements both academic and TVL programs to enhance students' competencies. Nagbinlod High School, located in Barangay Nagbinlod, provides access to secondary education for students from nearby rural communities. Lastly, Santa Catalina Science High School, also located in Barangay Cawitan along the national highway, is a specialized secondary school known for its strong emphasis on science and technology education.

Research respondents

The participants in this research were Grade 10 students from Santa Catalina District II. Out of the four schools in the district, three were randomly selected using a two-stage cluster sampling method. In the first stage, the schools were grouped into clusters, and Nagbinlod High School was designated for a trial run to establish the reliability of the test questionnaire. In the second stage, specific classes within the selected schools were identified for the final data collection. The distribution of participants included 41 students from SCSHS, 70 students from CHS out of a population of 120, and 54 students from NHS out of a population of 83, resulting in a total sample of 165 students from an overall population of 244.

Research instruments

A structured questionnaire served as the primary research instrument in this study, carefully designed to address the research questions. The instrument consisted of several parts. Part I included a disclosure statement that informed students about the purpose of the research, emphasized that participation was voluntary, and assured that all collected data would remain confidential. It also addressed ethical considerations by allowing anonymous responses and encouraging honest and thoughtful feedback to establish openness and trust. Part II gathered demographic information such as the students' names and their respective schools. Part III assessed students' conceptual understanding, problem-solving skills, and ability to apply optics concepts in real-world situations through ten questions focusing on image formation, the use of formulas such as mirror and lens equations, and their application in practical scenarios. Part IV was organized into three subject themes, each containing ten questions aimed at identifying learning gaps. This section evaluated students' understanding of light reflection and refraction, their ability to solve numerical problems using appropriate equations for spherical mirrors and thin lenses, and their skills in constructing accurate ray diagrams. Part V examined the relationship between student achievement and teacher credentials by capturing students' perceptions of classroom participation, clarity of explanations, and overall teaching effectiveness. Responses were collected using both a 7-point Likert scale ranging from 1 (Excellent) to 7 (Very Poor) and a 5-point Likert scale ranging from 1 (Strongly Disagree) to 5 (Strongly Agree).

To ensure the quality of the instrument, both validity and reliability were rigorously established. Content validity was achieved through evaluation by a panel of experts in curriculum development, testing, and physics education, who assessed whether the questionnaire accurately represented constructs such as conceptual knowledge, problem-solving ability, and understanding of thin lenses and spherical mirrors. Based on their feedback, ambiguous or unnecessary items were revised or removed. Reliability was evaluated through a pilot study involving a small group of students with characteristics similar to the target participants. Cronbach's alpha coefficient was used to determine internal consistency, with a threshold of 0.70 indicating acceptable reliability. The results showed coefficients greater than 0.70 across all constructs, including concept (0.773), problem solving (0.871), practical application (0.867), conceptual understanding (0.775), mathematical application (0.906), difficulty in ray diagram (0.871), and students' insights (0.881), confirming the instrument's reliability. Overall, the use of expert validation and statistical reliability testing ensured that the questionnaire was both valid and reliable, thereby strengthening the credibility of the study's findings regarding students' understanding, learning gaps, and perspectives on spherical mirrors and thin lenses, while maintaining strict confidentiality of all collected data..

Ethical considerations

The conduct of this study was guided by proper ethical principles to protect the dignity of the participants. The following measures were strictly followed for compliance. Consent was formally obtained from the Schools Division Superintendent of Negros Oriental, the District 2 Supervisor, the principal teacher, other teachers involved in the study, and student respondents through the signing of informed consent. All participants were fully oriented on the purpose of the study.

The confidentiality and anonymity of the respondents were guaranteed throughout the research process. Codes were assigned to all respondents to maintain the anonymity and confidentiality of their responses. The respondents were informed of their right to choose participation in the study and that refusing to participate or withdrawing would not result in any penalties.

To ensure data integrity and confidentiality, all collected data were securely stored and accessed only by the researcher. The data were used solely for research purposes, in full compliance with ethical standards related to research methodology. Ethical clearance was obtained from both the Ethics Committee of the Foundation University Research Office and the Schools Division of Negros Oriental, Santa Catalina District II, prior to conducting the research.
The researcher acknowledges the use of AI-assisted tools, specifically ChatGPT and Quillbot, provided by OpenAI, to enhance the clarity and readability of this manuscript. After utilizing these tools, the entire paper was reviewed, validated, and refined by the researcher herself, making her solely responsible for its content. A declaration of AI use can be found in Appendix A.

Research procedure

Upon the endorsement of the dean of the graduate school of Foundation University, a letter of request to conduct the study was sent to the Schools Division Superintendent of the Division of Negros Oriental. The signed and approved requests were presented to the school supervisor, principals, and respective advisers of the students. During the distribution, the researcher explained to the students the purpose and importance of the research. The retrieval of the questionnaires was done right after the students had answered the questions. The results coming from the different schools were organized and then tallied using MS Excel, and were analyzed and interpreted.

Statistical Treatment of the Data

To ensure accurate data analysis, both descriptive and inferential statistical tools were employed in this study. The mean was used to determine the average scores of students' responses for each variable, particularly in assessing their level of knowledge of mirrors and lenses in terms of concepts, problem-solving, and practical applications. It also measured the challenges encountered by students, including their conceptual understanding of light behavior, mathematical application of lens and mirror formulas, and difficulties in constructing ray diagrams, as well as the extent of instructional delivery by science teachers. To examine the distribution of the data, the Shapiro–Wilk test of normality was conducted, which yielded p-values less than 0.05, indicating that the data were not normally distributed. This result justified the use of non-parametric statistical tests for subsequent analysis. Consequently, Spearman's Rank-Order Correlation was utilized to determine the significant relationships between students' level of knowledge of mirrors and lenses and the challenges they encountered, as well as the relationship between the extent of instructional delivery and the challenges experienced by students. This statistical method is particularly appropriate for ordinal data and datasets that do not follow a normal distribution.

Results and Discussion

This section presents the results of the study in a clear and systematic manner, aligned with the research specific problems. It also provides a corresponding discussion of the findings, supported by relevant literature and studies to offer deeper insights and interpretations.

	Indicators	$\bar{x}$	EoK	SD
1.	I can describe how light bends (refracts) in lenses and how this affects image formation.	4.59	G	1.43
2.	I am able to draw and understand ray diagrams to find out how images form in mirrors and lenses.	4.52	G	1.45
3.	I understand how object distance, image distance, and focal length are connected in mirrors and lenses.	4.52	G	1.37
4.	I can easily tell the difference between concave and convex mirrors and lenses by their shape and how they work	4.46	G	1.39
5.	I use the laws of reflection to predict where light will be reflected in curved mirrors, and how this affects the image formation.	4.36	S	1.48

6.	I can explain how an object's position compared to the focal point changes the image's size, direction, and type.	4.35	S	1.47
7.	I find the focal point and focal length of curved mirrors and thin lenses.	4.31	S	1.43
8.	I can explain the difference between real and virtual images formed by mirrors and lenses.	4.30	S	1.33
9.	I can determine the orientation of images formed by spherical mirrors and thin lenses when an object is placed at different distances.	4.26	S	1.55
10.	I feel confident explaining the basic ideas of spherical mirrors and thin lenses without needing to use formulas.	4.21	S	1.48
Composite		4.38	S	1.44

Note: *Level of Knowledge (LoK); 6.15-7.00, Excellent (E); 5.29-6.14, Very Good (VG); 4.43-5.28, Good (G); 3.57-4.42, Satisfactory (S); 2.71-3.56, Fair (F); 1.85-2.70, Poor (P); 1.00-1.84, Very Poor (VP); n = 165*

Table 1.1. Perceived Level of Students' Knowledge on Mirrors and Lenses in terms of Concepts

Table 1.1 shows a composite mean of 4.38 (SD = 1.44), interpreted as Satisfactory, indicating that students have a basic but still developing understanding of mirrors and lenses. While they demonstrate familiarity with key concepts, their understanding remains not fully integrated, which is expected. This is because learning abstract scientific topics, such as optics, requires strong visualization and conceptual reasoning skills (Wang et al., 2021).

The highest mean (4.59, SD = 1.43) is in describing light refraction and image formation, indicating stronger performance in visually supported and observable concepts. In contrast, the lowest mean (4.21, SD = 1.48) is in explaining concepts without formulas, suggesting difficulty in abstract conceptual explanation and independent reasoning. This result reflects challenges in constructing meaningful understanding beyond procedural or guided learning.

The result also suggests that students are more successful in interpreting visual representations than in explaining underlying principles. This aligns with Tadeo and Yoo (2022), who emphasize that understanding optics depends on how well students integrate verbal, visual, and mathematical representations, and that difficulty arises when these connections are weak.

Moreover, the variation in responses (SD = 1.33–1.55) signifies uneven understanding among students, which may be influenced by prior knowledge and misconceptions. Wörner et al. (2022) maintained that persistent misconceptions in light behavior and image formation often interfere with students' ability to develop accurate conceptual frameworks, especially in abstract topics like optics.

Additionally, Royani et al. (2025) stressed that meaningful conceptual understanding requires learners to actively construct knowledge rather than rely on memorization or procedural learning. When this process is not fully achieved, students tend to demonstrate partial understanding, particularly in complex science topics.

	Indicators	$\bar{x}$	EoK	SD
1.	I can figure out whether an image is real or virtual by using mathematical calculations and or by ray tracing.	4.18	S	1.55
2.	I can use problem-solving skills in real-life situations, like designing optical tools or finding a lens's focal length.	4.13	S	1.60
3.	I can check my answers by comparing mathematical results with ray diagrams.	4.10	S	1.53
4.	I know how to use sign conventions correctly when solving problems with mirrors and lenses.	4.02	S	1.65
5.	I can use the mirror equation [$\frac{1}{f} = \frac{1}{do} + \frac{1}{di}$] to find the image distance, object distance, or focal length.	4.01	S	1.58
6.	I can solve numerical problems involving concave and convex lenses, predicting the nature and size of the image formed.	4.01	S	1.46
7.	I can calculate image magnification using the formula Magnification (M) = $\frac{hi}{ho} = -\frac{di}{do}$ and describe if the image is magnified or demagnified.	3.95	S	1.56
8.	I can use the lens formula [$\frac{1}{f} = \frac{1}{do} + \frac{1}{di}$] to find out the properties of images made by thin lenses.	3.92	S	1.64
9.	I can solve math problems with concave and convex mirrors, even when objects are at different positions.	3.88	S	1.52

10.	I feel confident in solving hard problems with spherical mirrors and thin lenses without needing a formula sheet.	3.83	S	1.60
	Composite	**4.00**	**S**	**1.57**

Note: *Level of Knowledge (LoK); 6.15-7.00, Excellent (E); 5.29-6.14, Very Good (VG); 4.43-5.28, Good (G); 3.57-4.42, Satisfactory (S); 2.71-3.56, Fair (F); 1.85-2.70, Poor (P); 1.00-1.84, Very Poor (VP); n = 165*

Table 1.2. Perceived Level of Students' Knowledge on Mirrors and Lenses in terms of Problem Solving

Table 1.2 on the next page shows a composite mean of 4.00 (SD = 1.57), interpreted as Satisfactory, indicating that students have a basic but still developing level of problem-solving skills in mirrors and lenses. Overall, they perform better in guided and structured tasks but struggle with independent and higher-order problem-solving, showing that their skills remain largely procedural rather than fully analytical.

The highest mean (4.18) is seen in determining whether an image is real or virtual using calculations or ray tracing, which suggests strength in solving problems with clear procedures and visual support. In contrast, the lowest mean (3.83) is in solving complex problems without a formula sheet, reflecting difficulty in independent reasoning. This pattern aligns with Apsari et al. (2023), who noted that students often show only moderate problem-solving proficiency in physics due to underdeveloped higher-order thinking skills.

Similarly, Anggraini et al. (2021) posited that students tend to rely on procedural learning rather than deep conceptual understanding, which explains their difficulty in handling unfamiliar or complex problems.

	Indicators	**x̄**	**EoK**	**SD**
1.	I know how concave and convex mirrors are used in everyday things, like car side mirrors and security mirrors.	4.81	G	1.41
2.	I understand how convex mirrors give a wider view and are used for traffic safety and surveillance.	4.49	G	1.51
3.	I know how convex and concave lenses in eyeglasses help fix vision problems like nearsightedness and farsightedness.	4.48	G	1.51
4.	I can explain how concave mirrors are used in devices like telescopes, headlights, and shaving mirrors.	4.47	G	1.44
5.	I understand how magnifying glasses work and can explain why convex lenses make things look bigger.	4.44	G	1.52
6.	I can describe how projectors use lenses to show clear images on a screen.	4.43	G	1.57
7.	I can explain how the human eye works like a natural lens and how eyeglasses help improve vision.	4.38	S	1.52
8.	I understand how light moves through optical fibers by using reflection and refraction.	4.28	S	1.61
9.	I feel sure of myself when explaining how mirrors and lenses work in everyday devices.	4.20	S	1.56
10.	I can explain how lenses work in science equipment like microscopes and cameras.	4.16	S	1.55
	Composite	**4.41**	**S**	**1.52**

Note: Level of Knowledge (LoK); 6.15-7.00, Excellent (E); 5.29-6.14, Very Good (VG); 4.43-5.28, Good (G); 3.57-4.42, Satisfactory (S); 2.71-3.56, Fair (F); 1.85-2.70, Poor (P); 1.00-1.84, Very Poor (VP); n = 165

Table 1.3. Perceived Level of Students' Knowledge on Mirrors and Lenses in terms of Practical Application

Table 1.3 shows the level of students' knowledge about mirrors and lenses in the field of practical application, where the composite mean is 4.41 (SD = 1.52), described as Satisfactory. This shows that students can make connections between the theoretical knowledge learned and the real world, but their knowledge is limited and inconsistent. Similarly, Sebald et al. (2022) argued that learners often struggle to transfer abstract optics concepts into practical applications, especially when the phenomena are not directly observable.

The highest mean (4.81) is in identifying the use of concave and convex mirrors in everyday devices such as car side mirrors and security mirrors, showing a strong understanding of familiar and observable applications. In contrast, the lowest mean (4.16) is in explaining how lenses work in scientific equipment like microscopes and cameras, indicating a weaker understanding of more complex and less visible applications. The results suggest that students are more confident in applying optics concepts in everyday, concrete situations but struggle when these are applied to more abstract or technical contexts (Wang et al., 2021).

This is supported by several studies, which show that the integration of real-life and inquiry-based approaches improves the linking of concepts with practice (Rincón-Flores et al., 2022; Arboiz & Malayao, 2024). Moreover, the use of simulations, virtual labs, and technology-based learning helps improve the practical application and scientific literacy of the students (Arieska et al., 2021; Zhao, 2025; Canino et al., 2024). The results indicate that although the students are able to perform basic applications, there is a need for experiential learning.

Table 2.1 on the next page shows that students experience a moderate level of learning gap ($\bar{x}$ = 3.03, SD = 0.96) in learning mirrors and lenses in terms of conceptual understanding of light behavior. This indicates that the students face a moderate level of difficulty in understanding the concepts of optics. These problems largely result from the abstract and non-observable nature of light. It is essential to visualize light reflection, refraction, and formation of images, where misconceptions are highly prevalent (Banda & Nzabahimana, 2021; Wang et al., 2021; Fliegauf et al., 2022; Putri et al., 2023).

The composite mean scores ranging from 3.08 to 3.15 signify that the students face moderate learning gaps in optics, particularly with abstract concepts like light reflection for spherical mirrors and the relationships among focal length, object distance, and image distance.

	Indicators	$\bar{x}$	EoC	SD
1.	I find it hard to understand how light works when it bounces off spherical mirrors, like concave and convex mirrors.	3.15	M	0.89
2.	I find it hard to understand how focal length, object distance, and image distance are connected.	3.10	M	0.93
3.	I find it hard to tell the difference between real and virtual images made by curved mirrors and thin lenses.	3.08	M	0.88
4.	I find it hard to use the rules of reflection and refraction to predict how light moves in optical systems.	3.05	M	0.96
5.	I find it hard to explain why concave lenses make virtual images, while convex lenses can make both real and virtual images.	3.04	M	1.02
6.	I find it hard to understand how light behaves when it changes direction or is refracted as it passes through concave and convex lenses.	3.03	M	1.00
7.	I get confused about how the position of an object affects the type of image formed in mirrors and lenses.	3.02	M	0.98
8.	I find it hard to understand why light bends when it goes through different materials in lenses.	2.98	M	0.96
9.	I find it hard to understand how tools like microscopes, cameras, and telescopes use mirrors and lenses to change the way light works.	2.90	M	0.98
10.	I have trouble seeing and explaining why some mirrors and lenses make images look bent, bigger, or smaller.	2.90	M	0.99
	Composite	**3.03**	**M**	**0.96**

Note: Extent of Challenges (EoC); 4.21-5.00, Very High (VH); 3.41-4.20, High (H); 2.61-3.40, Moderate (M); 1.81-2.60, Low (L); 1.00-1.80, Very Low (VL); n = 165

Table 2.1. Extent of Learning Gaps Faced by Students when Learning about Mirrors and Lenses in terms of Conceptual Understanding of Light Behavior

These findings align with previous research, which points out that "students' misconceptions in the context of geometrical optics are robust and influenced by their previous knowledge, oversimplified mental models, and the lack of visualization opportunities" (Fliegauf et al., 2022; Nourrit, 2023). For example, students have the mental image of light as a "monotonic beam of light, which flows like a liquid," which prevents them from "properly understanding refraction and image formation" (Putri et al., 2023; Wang et al., 2021).

Research also stresses the importance of "phenomenological teaching sequences and visualization activities in enhancing students' conceptual understanding of complex concepts by addressing misconceptions and relating abstract concepts to the world of experiences" (Fliegauf et al., 2022; MDPI, 2023).

The findings highlight the complexity of students' conceptual difficulties with mirrors and lenses and the need for instructional strategies that incorporate visualization, real-world analogies, and phenomenological approaches.

	Indicators	$\bar{x}$	EoC	SD
1.	I feel like I need more guided practice & examples to confidently solve problems with spherical mirrors and thin lenses.	3.28	M	1.09

2.	I find it hard to understand and use the spherical mirror thin lens formula $[\frac{1}{f} = \frac{1}{do} + \frac{1}{di}]$ when solving problems.	3.14	M	1.01
3.	I struggle with solving word problems that need me to use equations for spherical mirrors and thin lenses.	3.12	M	1.09
4.	I find it challenging to calculate magnification with the formula Magnification (M)= $[\frac{d_o}{d_1} = \frac{h_i}{h_o}]$ and understand the results correctly.	3.10	M	0.96
5.	I find it hard to check if my mathematical answers match on what I see in ray diagrams.	3.10	M	0.99
6.	I struggle to use the mirror and lens formula $[\frac{1}{f} = \frac{1}{do} + \frac{1}{di}]$ to figure out the image formation made by mirrors and thin lenses.	3.02	M	1.01
7.	I find it confusing to understand how focal length, object distance, and image distance are connected mathematically.	2.95	M	0.97
8.	I have trouble rearranging and solving equations when using the mirror and lens formulas.	2.93	M	0.96
9.	I have trouble knowing which signs (positive or negative) to use when solving mirror and lens problems.	2.88	M	0.99
10.	I struggle to tell if an image is real or virtual based on my calculations.	2.87	M	0.98
	Composite	**3.04**	**M**	**1.00**

Note: Extent of Challenges (EoC); 4.21-5.00, Very High (VH); 3.41-4.20, High (H); 2.61-3.40, Moderate (M); 1.81-2.60, Low (L); 1.00-1.80, Very Low (VL); n = 165

Table 2.2 Extent of Learning Gaps Faced by Students when Learning about Mirrors and Lenses in terms of Mathematical Application of Lens and Mirror Formulas

Table 2.2 shows that students experience a moderate level of learning gap ($\bar{x}$ = 3.04, SD = 1.00) in applying mathematical concepts related to mirrors and lenses. This indicates that while students can recall some relevant knowledge, they encounter moderate learning gaps in effectively applying formulas and solving problems, often requiring support. These challenges may result from the abstract nature of mathematical relationships in optics, which demand both conceptual understanding and procedural skills. This finding is consistent with previous studies, which highlight that mathematical concepts in optics are often difficult for students to comprehend and apply (Apsari et al., 2023; Gacovska Barandovska et al., 2023; Wang et al., 2021).

A closer examination of the indicators shows that students experience moderate difficulty in solving problems involving spherical mirrors and thin lenses, particularly in situations requiring guided practice ($\bar{x}$ = 3.28). This suggests limited confidence in independent problem-solving. Students also struggle with applying formulas, interpreting word problems into mathematical expressions, calculating magnification, and verifying whether computed answers are consistent with diagrams ($\bar{x}$ = 3.10 to 3.14). These difficulties indicate learning gaps in both conceptual understanding and procedural application.

These findings are consistent with prior studies, which emphasize that difficulties in applying mathematical concepts in physics often stem from weak conceptual understanding and reliance on procedures (Apsari et al., 2023; Gacovska Barandovska et al., 2023; Putri & Wartono, 2023). Additionally, challenges with sign conventions, identifying real and virtual images, and even math anxiety further contribute to errors in solving numerical problems (Wang et al., 2021; Faridi et al., 2021).

Some indicators show relatively lower difficulty, though still within the Moderate level. Students encounter fewer difficulties in identifying relationships among focal length, object distance, and image distance, as well as in rearranging equations. However, challenges persist in understanding sign conventions and identifying images as real or virtual ($\bar{x}$ = 2.87 to 3.02). This suggests that even in areas perceived as less difficult, students' understanding is not fully consistent.

As a whole, the findings suggest that students' mathematical understanding of mirrors and lenses is more procedural than conceptual. While they can perform calculations, often with guidance, they struggle to interpret results and apply concepts independently. This is consistent with prior studies, which show that difficulties in formula application and weak conceptual understanding hinder effective problem-solving (Winkelmann & Römer, 2023; Wang et al., 2021; Faridi et al., 2021).

A clear pattern further supports this observation: higher difficulty is associated with guided problem-solving and formula use, while lower difficulty relates to independent reasoning and interpretation. This implies that students are more comfortable with procedures than with analytical thinking, a common concern in science education, where learners can apply formulas without fully understanding their meaning.

Table 2.3 on the next page shows that students experience a moderate level of difficulty ($\bar{x}$ = 3.02, SD = 0.97) in constructing ray diagrams. This indicates that while students are familiar with the procedures, they struggle to perform them accurately and often require guidance. These learning gaps likely result from the abstract nature of geometrical optics, which requires a clear understanding of light behavior, particularly reflection and refraction.

	Indicators	$\bar{x}$	EoC	SD
1.	I find it challenging to tell the difference between how light rays behave in concave and convex mirrors or lenses when drawing diagrams.	3.25	M	0.96
2.	I feel like I need more guided practice or hands-on activities to get better at drawing ray diagrams correctly.	3.16	M	1.03
3.	I find it hard to draw ray diagrams correctly for concave and convex mirrors.	3.06	M	0.98
4.	I struggle to understand ray diagrams to check if my mathematical answers are correct when solving problems.	3.04	M	0.93
5.	I have trouble keeping my ray tracing accurate, which leads to wrong image formation.	2.97	M	0.98
6.	I struggle to use two or three rays properly when making ray diagrams for thin lenses.	2.96	M	0.99
7.	I struggle to predict the size, direction, and type of image using ray diagrams.	2.96	M	0.97
8.	I find it hard to position the object correctly with the principal axis and focal point when drawing ray diagrams.	2.94	M	0.94
9.	I get confused about whether an image is real or virtual by looking at where reflected or refracted rays meet.	2.93	M	0.88
10.	I have trouble finding the focal point and putting it in the right place in ray diagrams for mirrors and lenses.	2.88	M	1.01
	Composite	**3.02**	**M**	**0.97**

Note: Extent of Challenges (EoC); 4.21-5.00, Very High (VH); 3.41-4.20, High (H); 2.61-3.40, Moderate (M); 1.81-2.60, Low (L); 1.00-1.80, Very Low (VL); n = 165

Table 2.3 Extent of Learning Gaps Faced by Students when Learning about Mirrors and Lenses in terms of Difficulty in Ray Diagram Construction

A closer analysis reveals that students experience the greatest learning gap in predicting the path of light rays in concave and convex mirrors or lenses ($\bar{x}$ = 3.25), as well as drawing complete and accurate ray diagrams that include image characteristics such as size, orientation, and type. Their expressed need for guided and hands-on practice ($\bar{x}$ = 3.16) further indicates low confidence and limited ability to integrate conceptual understanding with graphical representation.
Some indicators show relatively lower difficulty, though still within the moderate level. Students find it easier to identify focal points, place objects along the principal axis, and determine whether images are real or virtual based on ray intersections. However, occasional errors in interpretation and execution suggest that their understanding remains unstable.

Generally, the findings indicate that students' ability to construct ray diagrams is more procedural than conceptual. While they can follow steps, they struggle to fully understand the underlying principles. This aligns with prior research, which suggests that students often approach ray diagrams mechanically rather than conceptually (Fliegauf et al., 2022).

A consistent pattern supports this observation: tasks requiring higher-order thinking, such as applying rules and integrating concepts, are more difficult than basic procedural tasks. This suggests that students are more comfortable with routine processes than with deeper analysis, highlighting a common issue in science education where procedures are performed without meaningful understanding (Yanti & Thohir, 2024).

Table 3 shows that the extent of instructional delivery is rated High ($\bar{x}$ = 3.57, SD = 1.00). This signifies that students recognize the effectiveness of their teachers in facilitating learning. Notably, students particularly value instructional practices that connect lessons to real-life situations and incorporate hands-on activities ($\bar{x}$ = 3.60 to 3.64; 3.60). This highlights the importance of experiential learning in promoting engagement and understanding (Lucas & Vandergon, 2024). Teacher expertise also contributes to improved student performance ($\bar{x}$ = 3.52), reinforcing the role of strong subject knowledge in learning outcomes.

	Indicators	$\bar{x}$	VD	EoD	SD
1.	I understand and draw ray diagrams more easily when my teacher explains them clearly using strong scientific knowledge.	3.70	A	H	1.01

2.	I gain a better understanding of mirrors and lenses when my teacher has expertise in physics or science.	3.69	A	H	0.95
3.	Teachers with a strong science background explain optical concepts like image formation and magnification more clearly, which helps me understand better	3.68	A	H	1.00
4.	My teacher shows real-life uses of mirrors and lenses, which makes the concepts easier to understand.	3.64	A	H	1.07
5.	My teacher gives hands-on activities and experiments that help me learn how mirrors and lenses work.	3.60	A	H	0.92
6.	I understand spherical mirrors and thin lenses better because my teacher knows a lot about science.	3.54	A	H	0.92
7.	I perform better in tests and hands-on activities with spherical mirrors and thin lenses when guided by a teacher who specializes in science.	3.52	A	H	1.02
8.	My ability to solve problems with mirrors and lenses depends on how well my teacher explains the concepts.	3.47	A	H	1.02
9.	I learn mathematical problem-solving in mirrors and lenses more effectively when my teacher provides focused guidance on solving techniques	3.47	A	H	1.02
10.	I feel more confident using the laws of reflection and refraction when my teacher has strong science knowledge.	3.44	A	H	1.03
	Composite	**3.57**	**A**	**H**	**1.00**

Note: Verbal Description (VD); Extent of Delivery (EoD); 4.21-5.00, Strongly Agree (SA), Very High (VH); 3.41-4.20, Agree (A), High (H); 2.61-3.40, Moderately Agree (MA), Moderate (M); 1.81-2.60, Disagree (D), Low (L); 1.00-1.80, Strongly Disagree (SD), Very Low (VL); n = 165

Table 3. Extent of Instructional Delivery of Science Teachers as Perceived by the Students

However, despite the overall high rating, some areas for improvement remain. Students' ability to solve problems still depends on clear and adequate explanations from teachers ($\bar{x}$ = 3.47). This indicates a need to strengthen instructional clarity and depth. This aligns with studies emphasizing that limitations in teachers' subject knowledge affect students' understanding of scientific concepts (Ekmekci & Serrano, 2022; Gordo, 2021). Teachers with strong content knowledge better address misconceptions and support conceptual understanding (Krumphals & Haagen-Schützenhöfer, 2021).

In essence, the findings emphasize that effective instructional delivery, particularly clear explanations, real-life applications, and hands-on learning, enhances students' comprehension and engagement. Further improvement is recommended in guiding students to integrate conceptual knowledge with mathematical applications and ray diagrams for more independent learning.

Knowledge of the Students on Mirrors and Lenses	**Learning Gaps Faced when Learning about Mirrors and Lenses**			
	Conceptual Understanding of Light Behavior	**Mathematical Application of Lens & Mirror Formulas**	**Difficulty in Ray Diagram Construction**	**Overall Learning Gaps**
Concepts	r_s = .268 p<.001 (significant)	r_s = .255 p<.001 (significant)	r_s = .242 p<.001 (significant)	r_s = .364 p<.001 (significant)
Problem-Solving	r_s = .353 p<.001 (significant)	r_s = .302 p<.001 (significant)	r_s = .301 p<.001 (significant)	r_s = .432 p<.001 (significant)
Practical Applications	r_s = .289 p<.001 (significant)	r_s = .335 p<.001 (significant)	r_s = .276 p<.001 (significant)	r_s = .459 p<.001 (significant)
Overall Knowledge	r_s = .329 p<.001 (significant)	r_s = .323 p<.001 (significant)	r_s = .296 p<.001 (significant)	r_s = .454 p<.001 (significant)

Note: Data are not normally distributed; Spearman's Rank-Order Correlation at α =0.05; n = 165

Table 4. Relationship between the Level of Students' Knowledge and the Learning Gaps Faced when Learning about Mirrors and Lenses

Table 4 shows the relationship between the level of students' knowledge of spherical mirrors and thin lenses and the learning gaps they encounter when learning these topics. The results reveal that all correlation coefficients are positive and statistically significant (p < .001). This finding indicates that students' knowledge levels are significantly related to the challenges they face in optics. The overall correlation between students' knowledge and overall challenges (rs = .454) suggests a moderate relationship. This implies that students who demonstrate higher engagement with concepts, problem-solving, and practical applications are also more aware of and affected by the learning gaps related to conceptual understanding of light behavior, mathematical applications of formulas, and ray diagram construction.

The relationship observed between problem-solving knowledge and overall learning gaps (r_s = .432) signifies that difficulties in optics often become more evident when students attempt to apply their knowledge in solving problems. This finding aligns with studies indicating that students frequently struggle with optics due to weak conceptual foundations and an overreliance on memorized procedures rather than deep understanding (Anggraini et al., 2021; Wang et al., 2021; Sebald et al., 2022). The learning gap with mathematical formulas and ray diagrams is common because optics requires integrating conceptual reasoning with geometric and algebraic representations. Correspondingly, the Constructivist Learning Theory emphasizes that students build understanding through active engagement with concepts and experiences. When learners attempt to construct meaning from complex optical phenomena, difficulties naturally arise as they confront misconceptions and incomplete mental models.

Furthermore, the results align with Cognitive Load Theory, which explains that topics such as spherical mirrors and thin lenses involve multiple interacting elements, such as diagrams, formulas, and spatial reasoning, that may overload students' working memory if instructional scaffolding is insufficient. This is supported by previous research, which reports that students often struggle to visualize image formation and connect mathematical formulas to physical processes, reinforcing the relationship between knowledge development and perceived learning gaps (Tadeo & Yoo, 2022; Sebald et al., 2022; Wörner et al., 2022).

Instructional Delivery of Science Teachers and…	r_s	p	Remark
● Conceptual Understanding of Light Behavior	.190	.014	Significant
● Mathematical Application of Lens & Mirror Formulas	.286	<.001	Significant
● Difficulty in Ray Diagram Construction	.233	.003	Significant

Note: Data are not normally distributed; Spearman's Rank-Order Correlation at α =0.05; n = 165

Table 5. Relationship between the Extent of Instructional Delivery of Science Teachers and the Learning Gaps in Learning Mirrors and Lenses

Table 5 presents the relationship between the extent of science teachers' instructional delivery and the learning gaps students experience in learning mirrors and lenses. The results show statistically significant relationships across all variables: conceptual understanding of light behavior (r_s = 0.190, p = .014), mathematical application of lens and mirror formulas (r_s = .286, p < .001), and difficulty in ray diagram construction (r_s = .233, p = .003). These findings signify that instructional delivery is significantly related to the learning gap students encounter. Since the correlation coefficients are positive, the results further imply that the higher the challenges experienced by students, the higher the extent of instructional delivery provided by the teachers. This suggests that teachers increase or intensify their instructional efforts when students encounter greater learning difficulties in optics topics such as mirrors and lenses.

The significant relationship observed between teachers' instructional delivery and students' learning gap in the mathematical application of formulas implies that teaching strategies play an important role in helping students interpret and apply optical equations. This finding supports previous studies emphasizing the need for clear instructional scaffolding and contextualized problem-solving activities to help students understand the relationships among optical variables (Putri & Wartono, 2023; Winkelmann & Römer, 2023). When students struggle with applying formulas, teachers provide additional explanations, guided practice, and structured learning activities to address these difficulties.

The result is similar to Shulman's Pedagogical Content Knowledge (PCK) framework, which highlights the importance of teachers' ability to transform complex subject matter into understandable forms for learners. Teachers who effectively anticipate misconceptions, use visual representations, and provide guided practice better respond to students' learning needs. Moreover, the findings are consistent with research showing that instructional strategies such as simulations, visualizations, and inquiry-based activities enhance students' comprehension of abstract optical concepts and mathematical relationships (Wu et al., 2024; Haagen-Schützenhöfer et al., 2023).

Conclusion and Recommendations

Students have developed a functional yet still evolving understanding of mirrors and lenses. While they are able to grasp fundamental concepts and apply them in familiar contexts, deeper conceptual mastery and analytical skills remain areas for further enhancement. Their satisfactory level of performance suggests that learning has occurred, although not yet to the extent of full conceptual integration and independent problem-solving.

Moreover, the presence of moderate learning gaps signifies that learning difficulties are not severe but remain persistent enough to influence how students process and apply knowledge, particularly in abstract reasoning and mathematical representations. In this regard, the perceived effectiveness of instructional delivery stresses the meaningful role of teachers in facilitating learning. However, the persistence of these learning gaps despite effective instruction suggests that current teaching approaches may still require refinement to better address diverse learning needs and the inherent complexities of the topic. Consequently, this highlights the importance of adopting more differentiated and interactive teaching strategies.

Furthermore, the significant relationships among knowledge, learning gaps, and instructional delivery reveal that learning is a dynamic and evolving process. As students engage more deeply with the content, they also become more aware of the difficulties they encounter. Rather than signaling a negative outcome, this heightened awareness reflects deeper cognitive engagement, where students who strive for understanding are more likely to recognize and confront complex learning gaps.

Based on the findings and conclusions drawn, it is hereby recommended that:

1 Students engage in guided practice and hands-on activities such as PhET simulation exploration (reflection and refraction), ray diagram drawing workshops, simple refraction experiments (like water and pencil test), and real-life object identification to better understand reflection, refraction, and image formation. They should also explore everyday applications of mirrors and lenses to connect concepts to real-world situations. These activities help make abstract optics concepts more concrete and improve students' understanding.

2 Science Teachers use multiple teaching approaches. They may combine lectures, guided problem solving, simulations, and hands-on experiments to strengthen understanding and application. They must also target misconceptions in identifying common student errors in mirrors and lenses and address them with visual aids or real-life examples.

3 School administrators support teachers through training and resources for evidence-based teaching strategies that include hands-on learning, conceptual learning, and real-world learning. This will help create a balance between the learning strategies used by teachers and the learning needs of their students, which will result in academic success at different levels of performance.

4 Curriculum developers and policy makers reinforce the integration of real-world learning, problem-solving, simulation, and technology-based learning in the study of science, with a focus on teachers' training and guidance regarding the use of digital tools, multimedia learning resources, and interactive demonstrations for effective learning of optics.

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Data sharing is not applicable to this article as no new data were created or analyzed in this study; all data used were obtained from previously published sources as cited in the reference list.

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Appendices

No appendices are attached to this study.