Development and Evaluation of Lumina7E Kit for Learners' Conceptual Understanding of Light and Optics

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ABSTRACT

This study addressed the "grade-level gap" in Grade 8 Science when the DepEd MATATAG Curriculum reallocated the topic Light and Optics concepts, from Grade 10, to a younger audience. The initial needs assessment with students and teachers indicated that traditional pedagogy for these abstract concepts often results in persistent learning challenges. The need assessment identified reflection and refraction as the most challenging for instructional intervention, with Grade 11 students explicitly requesting more hands-on experiments and practical demonstrations, a need that aligned with teachers' reports on the challenge of teaching the topic due to a lack of functional optics kits. Using Modified Research and Development (R&D) by Borg and Gall (1983), this research developed and evaluated the Lumina7E Kit, a fabricated hands-on learning kit. The kit's instructional approach is anchored in Kolb's Experiential Learning Theory (ELT), operationalized through the 7E Instructional Model, to facilitate conceptual change through concrete experience. The kit and accompanying instructional materials underwent rigorous expert validation, achieving a rating of "Excellent" in content (39) and "Very Satisfactory" in technical feasibility, safety, and instructional design (3.78). Pilot testing with Grade 8 learners (n = 73) demonstrated an improvement in conceptual understanding, evidenced by a medium normalized gain ($g \approx 0.40$), indicating the intervention is preliminarily effective. The findings suggest that the Lumina7E Kit is a validated and effective tool for bridging the abstract-concrete gap and successfully addressing the learning challenges posed by the MATATAG curriculum shift.

Keywords: 7E framework, conceptual understanding, experiential learning, learning kit, light and optics

INTRODUCTION

The distinction between concrete and abstract concepts is a fundamental challenge in cognitive science, particularly in the physical sciences, often resulting in diminished conceptual understanding and low learning interest among students (Mkrtychian et al., 2019; Sadera et al., 2020; Wangchuk et al., 2023; Zulkiffli et al., 2024). This global challenge is acutely felt in the Philippines, where global assessments like Programme for International Student Assessment (PISA) consistently place students near the bottom in scientific literacy, signaling a critical deficiency that necessitates instructional intervention (Bernardo et al., 2023). This difficulty is most acute in the domain of Light and Optics, where fundamental phenomena like light rays, reflection, and image formation are invisible and counterintuitive, fostering flawed mental models that traditional didactic instruction fails to correct.

This persistent learning difficulty is now amplified by the recent revision to the K to 12 program under the Department of Education (DepEd) MATATAG Curriculum. This reform significantly reallocated higher-order optics content, such as image-formation competency, from Grade 10 level down to the Grade 8 science curriculum. This curriculum shift has created a significant "grade-level gap," requiring younger learners to master cognitively demanding concepts without adequate instructional tools designed for their developmental readiness (Herrera, 2025; Kilag et al., 2024).

Phenomena like light rays, reflection angles, and image formation are abstract and counterintuitive, leading students to develop deeply ingrained preconceived notions that persist even after formal instruction (Putri et al., 2024). Wahyuni and Taqwa (2022) also showed in their studies that students inaccurately believe there are 'only three possible rays' in image formation or struggle to articulate what they have learned in different contexts, often relying on flawed mental models. The persistence of alternative concepts highlights the limitations of traditional didactic instruction, which often relies on static textbook diagrams and fails to actively engage learners. As Choudhary (2016) demonstrated, inquiry-based approaches that provide concrete, hands-on experiences significantly improve students' attitudes toward physics and enhance their academic achievement, enabling them to reconstruct flawed mental models more effectively.

This study addresses the challenges aligned with Sustainable Development Goal (SDG) 4, which emphasizes inclusive and equitable quality education and the promotion of lifelong learning opportunities for all. Furthermore, strong science education is crucial for fostering the innovation and robust infrastructure needed to achieve SDG 9. Resolving this complex educational challenge requires collaborative efforts among policymakers, educators, and the private sector, directly relating to the spirit of SDG 17: Partnerships for the Goals. Science education plays a pivotal role in equipping learners with critical thinking, inquiry skills, and scientific literacy, which are the competencies essential for sustainable development (Heleta & Bagus, 2020; Odell et al., 2020).

After the study underwent ethical review and obtained approval, the initial needs assessments were conducted on senior high students and science teachers as part of this study. The validated assessment confirmed the severity of this gap, identifying 'Properties of Light' (specifically Reflection and Refraction) as the most challenging topic for instructional intervention. This difficulty was explicitly linked to a significant 'visualization barrier' and a documented lack of functional laboratory equipment. Consistent with educational research confirming the efficacy of active learning tools in teaching complex concepts, students and teachers explicitly requested hands-on experiments and materials to facilitate the "actual tracing of light rays," which was deemed superior to "pure lecture".

To effectively address this critical gap between abstract theory and concrete experience, the study proposed the development and rigorous evaluation of the Lumina7E Kit. While some local efforts have explored active learning through representational means like game-based learning and educational cards (Canino, 2024; Sardinola et al., 2025), a more direct solution is required (UNESCO, 2023). To teach complex optical concepts effectively, researchers suggest experimental kits that use familiar and accessible materials (Anisah et al., 2020; Kit & Ayop, 2022), thereby providing the direct, sensory feedback essential for conceptual change (Dueňas & Montero, 2025; Galarosa et al., 2024; Sotério & Blikstein, 2025).

This integrated, hands-on learning tool is designed to facilitate conceptual change and bridge the grade-level gap by anchoring its instructional approach in Kolb's Experiential Learning Theory (ELT) and operationalizing it through the structured 7E Instructional Model. The findings of this research suggest that the Lumina7E Kit is a validated and effective tool for successfully addressing the learning challenges posed by the MATATAG curriculum shift.

METHODS

The study applied a Research and Development (R&D) design incorporating a quantitative method with qualitative support (via open-ended questions) to systematically develop, validate, and evaluate the initial effectiveness of the Lumina7E Kit. The specific framework employed is a Modified Borg and Gall R&D Model. The original ten-step Borg and Gall model was modified and streamlined into seven core phases: 1) Research & Information, 2) Research Planning and Design, 3) Early Product Development, 4) Expert Validation, 5) Product Revision, 6) Preliminary Field Testing (Pilot Testing), and 7) Pilot-Tested Product Revision to ensure methodological rigor while aligning with the scope and time limitations of this academic study. The research design focuses specifically on the product's initial validity, usability, and preliminary effectiveness, with the investigation concluding at the pilot testing stage. The outputs, therefore, represent preliminary evidence of the kit's potential, serving as a basis for refinement and informing future iterations, ready for immediate large-scale implementation.

Research & Information

Aligned with R&D Step 1, this phase was focused on needs assessment. Evaluation began here through expert feedback on the instruments used to gather baseline data. The need assessments went through a content validation and reliability assessment to ensure that the needs assessment tool can accurately identify the difficulty level and ranking of the six core physics topics, namely: Acceleration, Distance–time and velocity–time graphs, Kinetic and potential energy, Work and energy, Renewable energy, and Properties of light. The needs assessment, consisting of open-ended questionnaires, was administered to Grade 11 students (n = 81) and science teachers (n = 5) to gather qualitative feedback on the specific learning difficulties of students and the instructional challenges of teachers regarding the Grade 8 science topics under the Force, Motion, and Energy learning area of the MATATAG curriculum. Grade 11 learners were chosen because they had already learned the aforementioned topics, aligning with the need assessment's objective to assess how and what made them think the topics among all six under the Grade 8 MATATAG Curriculum difficult, and to identify which is the most difficult to learn and teach.

Research Planning and Design

This phase involved the planning and fabrication of the learning kit and design of the learning manuals (R&D Step 2). The researcher utilized the institutional laboratory to fabricate the necessary physical components, including the lenses, mirrors, and prism, and assemble them with other key structural components of the Lumina7E Kit, such as the 360-degree diagram sheet, two (2) plane mirrors, all secured in a corrugated cardboard box and high-density foam. Meanwhile, the researcher designed the following instructional materials: teacher guide and student activity manuals, both aligned with the learning competencies under the DepEd MATATAG curriculum, with figures or images for visual representations, appropriate wordiness, and guided by the 7E framework.

Early Product Development

Corresponding to R&D Step 3, the learning kit underwent iterations involving nine trials on lens fabrication alone, four trials on the prisms, and three trials on curved mirrors to ensure that components like the multi-beam red laser box, 3D-printed lenses, prisms, and curved mirrors produced sharp, 1mm-thick light rays for accurate tracing. Meanwhile, the instructional materials improved based on suggestions from the face validation with panel members, starting from version 1 to version 3 of the student activity and the teacher's guide manual.

Expert Validation and Product Revision

During these stages (R&D Step 4 and 5), the prototype underwent dual evaluation: instructional and technical validation. At least three subject matter experts (SME) validated the content accuracy of the instructional materials and the technical feasibility and safety of the physical components of the Lumina7E Kit. Each validation step served as a formative evaluation, prompting targeted revisions that ended up in the final version (version 4) of the instructional materials before it was disseminated for pilot testing.

Preliminary Field Testing (Pilot Testing)

This phase corresponds to the active administration of the revised prototype during R&D Step 6. The researcher administered the final prototype to a sample of 73 Grade 8 students from the same school where the needs assessment was conducted. A one-week implementation was observed, during which learners were provided with the Conceptual Understanding Test that served as a pretest to assess their prior knowledge in Light and Optics. Followed by the learning intervention, where students interact with the learning kit, turning concrete experience into conceptual knowledge.

Pilot-Tested Product Revision

This phase (R&D Step 7) encompasses the collection of pre-test and post-test scores. The validated conceptual understanding test was administered to the sample of Grade 8 students (n = 73) before and after the intervention to measure normalized gain (g). The post-test results were collected for item analysis and reliability.

RESULT AND DISCUSSION

Before development, the researcher conducted needs assessments on students and teachers with survey questionnaires (Scale-level Content Validity Index (S-CVI) = 1.00 for both ratings), and identified "Properties of Light" as the most challenging topic in the Grade 8 Physics curriculum (Mean Rank: 1.00).

Topics	Themes	Ranking	Suggested Improvements (Open-ended)
Properties of Light	**Visualization Barrier / Lack of Hands-on Equipment**	**1**	**Hands-on experiments, actual materials, and tracing light rays.**
Graphs (D-T / V-T)	Abstract Interpretation (Slope/Area)	2	Simplified notes, practical demonstrations, and video explanations.
Acceleration	Math Readiness / Formula Application	3	Video explanations and simplified notes.
Kinetic & Potential Energy	Conceptual Confusion (Energy Transfer)	4	Hands-on experiments and practical demonstrations.
Work and Energy	Mathematical Calculation / Variable Differentiation	5	More examples, practical problems, and group study time.
Renewable Energy	Real-world Contextualization (Technology)	6	Video explanations and linking concepts to real-world tech.

Table 1. Students' Feedback and Most Challenging Topic

The data reveal that Properties of Light presents one of the greatest challenges to students, primarily due to a Visualization Barrier caused by a lack of physical resources. Students consistently reported that grasping reflection and refraction is confusing without "hands-on equipment". Multiple respondents emphasized that it is "hard to visualize light rays" and confusing to understand how light behaves without proper visuals.

When asked what would make these topics easier to learn, the overwhelming consensus was a shift toward active learning. Students explicitly requested "more hands-on experiments" and "practical demonstrations". These suggestions highlight that students are looking for a "nice explanation to satisfy their curiosity" through a real-world setup and actual materials.

Teachers identified systemic and instructional barriers that align with student difficulties. These insights help triangulate the root causes of learning gaps, such as:

Topics	Primary Instructional Barrier	Ranking	Requested Professional Support
Properties of Light	**Lack of laboratory equipment and apparatus**	**1**	**New lab equipment, standardized kits, and localized apparatus**
Graphs (D-T / V-T)	Abstract nature and difficulty in data interpretation	2	Visual demonstrations and training on specific teaching strategies
Acceleration	Weak mathematical foundation and formula confusion	3	Curriculum mapping to integrate math skills into physics
Kinetic & Potential Energy	Difficulty with energy transformation and calculations	4	Visual demonstrations of energy transfer and practical activities
Work and Energy	Misinterpretation of terminology and broad definitions	5	Simplified, math-integrated reading materials
Renewable Energy	Lack of localized examples and depth in technology	6	Video explanations and resources on the technology function

Table 2 Teacher-Identified Instructional Barriers and Ranking of Difficulty

The teachers identified a significant "Resource-Pedagogy Gap," particularly in the study of optics. All five teachers labeled Properties of Light as a major challenge, citing that "limited materials to use like lab apparatus" makes the topic "purely theoretical". Educators noted that without specialized equipment like lasers and mirrors, students are forced to rely on "two-dimensional textbook diagrams," which are "insufficient for mastery". Furthermore, teachers emphasized that student "math readiness" and a "weak mathematical foundation" often

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lead to a loss of interest when topics require heavy calculations. This is particularly evident in acceleration and energy transformation, where students struggle to manipulate variables or understand units.

The alignment between student frustration and teacher instructional barriers provides a definitive mandate for this study. The high Inter-Coder Reliability (Kendall's W = 0.937) confirms a robust consensus among independent checkers that Properties of Light is the highest priority for instructional intervention. This statistical agreement, paired with excellent Content Validity (S-CVI = 1.00), ensures that the assessment reliably identified the most critical learning gap.

The Lumina7E Kit underwent a comprehensive evaluation by three (3) Subject Matter Experts (SMEs) in Science, English, and ICT, where the content and accuracy of the instructional manuals (Teacher's Guide and Student Activity Manual) were evaluated using the DepEd LRMDS Evaluation Rating Sheet for General Reference Materials (DepEd LRMDS Guidelines, 2009).

Another instrument used was the Technical Feasibility, Safety, and Acceptability Rubric (Jarantilla, 2008), which included criteria such as physical construction quality, student participation potential, and instructional relevance. The tables below summarize the experts' ratings of the content quality of the manuals and the technical feasibility of the learning kit's physical components.

Criteria	E1 (Science)	E2 (ICT)	E3 (English)	Average Rating
1. Content reinforces, enriches, and or leads to the mastery of certain learning competencies for the level and subject it was intended.	5	5	5	5
2. Facts are accurate.	5	5	5	5
3. Information provided is up-to-date.	5	5	5	5
4. Language is appropriate for the level of the target user.	5	5	5	5
5. Visuals are relevant to the text and suitable to the age level and interests of the target user.	4	5	5	4.67
6. Visuals are clear in content and detail.	4	5	5	4.67
7. Typographic layout / design adequately supports concepts presented.	4	5	5	4.67
8. Size of the letters is appropriate for the target user.	5	5	5	5
Total Points	37	40	40	39

Note. Rating Scale: 1.00–1.79 = Poor; 1.80–2.59 = Fair; 2.60–3.39 = Satisfactory; 3.40–4.19 = Very Satisfactory; 4.20–5.00 = Excellent

Table 3. Average Ratings for Lumina7E Learning Kit's Content Quality and Accuracy

The instructional manuals achieved an "Excellent" quality rating of 39 out of 40 points, which exceeded the passing threshold of 30 points required by the adopted DepEd standards. While the content is scientifically accurate and strictly aligned with Grade 8 competencies, a slight drop to a 4.67 average on criteria 5 through 7 implies that minor refinements are needed for visual clarity, typographic layout, and age-appropriate design. Nonetheless, this high overall rating indicates that the content of the Lumina7E manuals is exceptionally robust, up-to-date, and fully prepared for implementation despite these minor aesthetic recommendations.

Criteria	E1 (Science)	E2 (ICT)	E3 (English)	Average Rating
Technical Feasibility				
Physical Feature	4	4	4	4
Ease of Manipulation	3	4	3	3.33
Conceptual Alignment	4	4	4	4
Safety				
Physical Safety	3	2	4	3
Age Appropriateness	4	4	4	4
Acceptability				
Instructional Utility	4	4	4	4

Support for Inquiry	4	4	4	4
Student Participation	4	4	4	4
Total				3.78

Note. Rating Scale: 1.00–1.74 = Poor (P); 1.75–2.49 = Fair (F); 2.50–3.24 = Satisfactory (S); 3.25–4.00 = Very Satisfactory (VS).

Table 4. Average Ratings for Lumina7E Learning Kit's Technical Feasibility and Safety

The Lumina7E kit's physical components achieved an overall average rating of 3.78, classifying its technical feasibility as "Very Satisfactory". The kit received perfect scores for "Instructional Utility" and "Student Participation," implying that the materials efficiently support hands-on investigations in light and optics. While "Physical Safety" initially received a lower average rating of 3.00 due to the mirror edges, the subsequent refinements were followed. The experts concluded that the kit is age-appropriate for Grade 8 students and provides clear opportunities for observing converging and diverging rays through the included lenses and laser components.

During the implementation, the students were given a 30-item conceptual understanding test (with S-CVI/Ave=0.98), serving as a pre-test to determine their pre-conceived knowledge on light and optics, specifically reflection and refraction. The tests were collected right after, for the answers to remain confidential to avoid students memorizing the key answers that could affect their post-test scores. After the two days of intervention and a delay of a day due to the respondents' unavailability, the post-test was given three days after the pre-test. The papers are collected and analyzed to determine the post-test's item analysis and reliability.

Item Analysis	Value	Interpretation
Easy Items	3	Few items were too simple; good balance.
Average Items	27	The majority of items were appropriately challenging.
Hard Items	0	No items were overly difficult.
Average Difficulty	0.5500	Average
Discriminating Items	11	Effectively distinguish high vs. low performers.
Average Discrimination	19	Moderate discrimination; acceptable for classroom tests.
Not Discriminating	0	All items contributed meaningfully to score variance.
Average Discrimination	0.3600	Average
Reliability Measurements		
KR-20	0.6399	Reliable
Cronbach's Alpha	0.6345	Reliable

Table 5. Summary of Item Difficulty, Discrimination, and Reliability (N=73)

Foster (2021) suggests using KR-20 and Cronbach's Alpha as standard, reliable estimators for test consistency. Sürücü and Maslakçi (2020) argued that while 0.70 is the "gold standard," values between 0.60 and 0.70 are considered acceptable in social science and educational research, especially for newly developed instructional materials.

As seen in the table, the reliability scores ranging from 0.60 to 0.64 imply that the questions are internally consistent, meaning the items are measuring the same general concept (optics or light reflection and refraction) rather than random and unrelated stuff.

Following the validation of the tool, the student scores were analyzed to determine the kit's initial effect on the learners' conceptual understanding.

Group	Pre-Test Mean	Post-Test Mean	Normalized Gain (g)	Net Score Increase	Interpretation
Section A (more active)	10.95	18.65	0.4222	+7.70	Medium gain
Section B (less active)	8.12	16.00	0.3660	+7.88	Medium gain
Overall	9.67	17.44	0.3968	+7.77	Medium gain

Note. Criteria: Low gain: $g < 0.3$, Medium gain: $0.3 \leq g < 0.70$, High gain: $g \geq 0.7$ (Hake, 1998).

Table 6. Central Tendency and Normalized Gain

To further quantify the preliminary effectiveness of the intervention, Hake's normalized gain (g) was calculated. The results yielded an overall gain of 0.3968 or approximately 0.40, which is classified by Hake (1998) as a 'medium gain' ($0.3 \leq g < 0.70$).

While Section A maintained high performance, the intervention was particularly impactful for Section B. Despite the group's low participation in past classroom activities, the use of the Lumina7E Kit resulted in a substantial score increase from 8.12 to 16.0 ($g \approx 0.37$, +7.88 points increase), suggesting that the kit's hands-on engagement effectively engages learners who typically struggle in traditional settings. The consistency of gain between Section A and Section B (0.42 vs. 0.37) underscores the kit's reliability as an instructional tool for diverse learner profiles.

CONCLUSION AND RECOMMENDATION

While the Lumina7E Kit demonstrated preliminary effectiveness with a medium normalized gain, the results indicate that the intervention serves as a strong foundational tool rather than a final solution. The data highlights specific areas for refinement, particularly in physical safety and test instrument reliability. Specifically, the evaluation of the kit's physical components revealed that while functional, the mirror edges require enhanced protective housing to improve user safety ratings. Furthermore, while the conceptual understanding test achieved reliable consistency (Cronbach's alpha (α) = 0.6345), future development should focus on refining item discriminators to further stabilize reliability scores closer to the 0.70 threshold. These findings underscore that the Lumina7E kit is a work-in-progress, providing a viable blueprint for future, more refined iterations.

Local schools may consider the adoption and integration of the finalized Lumina7E Kit as curriculum-aligned instructional material for Grade 8 Science. Utilize the 7E Framework to encourage effective learning and provide students with more "practical demonstration" time and "hands-on experiments" as explicitly requested in the needs assessment.

Moreover, future development iterations should incorporate specialized manufacturing techniques (such as rounded edge-polishing or non-exposed mounting) to improve physical safety metrics and overall kit durability. To address the slight variance in visual appeal ratings, future versions of the student activity manuals should incorporate professional graphic design consultations to ensure visuals are not only accurate but optimally engaging for diverse learner populations. Also, given the 'medium gain' observed in this pilot, future studies should move beyond immediate pre/post-test analysis to investigate long-term retention of optical concepts, determining if the Lumina7E Kit provides sustained understanding throughout the academic year.

Future researchers are recommended to involve larger and more diverse samples across multiple studies to improve the generalizability of findings regarding the Lumina7E Kit, and conduct experimental studies using a comparative experimental design with a control group to quantitatively measure the kit's effect on student academic performance and retention over a longer period.

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