Journal of Research in Education and Pedagogy
ISSN 3047-7131 (online) & 3047-6410 (print)
August 2026, Vol. 3, No. 3, pp. 396–410

Research Article

Evaluation of Project GTR (Gravitational Teaching Resource) as an Instructional Material for the General Theory of Relativity

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Abstract
Physics is a fundamental science that explores complex and abstract concepts, often presenting significant cognitive challenges for learners. Topics such as Einstein's General Theory of Relativity, specifically spacetime curvature and gravitational lensing, are difficult to grasp through traditional, lecture-based teaching methods. Prior studies have established that integrating tactile physical models, visual analogies, and digital simulations can significantly bridge this gap and enhance conceptual understanding. Building on this theoretical foundation, the present action research evaluates the effectiveness and acceptability of Project GTR (Gravitational Teaching Resource). This innovative instructional material purposefully combines these pedagogical tools, using a multisensory setup to model celestial bodies and light distortion, to improve students' spatial and conceptual comprehension of gravitational lensing. The study involved thirty-seven students and three science teachers from a state university in the Negros Island Region, utilizing convenience sampling. To provide a comprehensive evaluation, a mixed-methods approach was carefully employed. Quantitative data were gathered through an adapted evaluation instrument measuring content and technical quality, while qualitative insights were systematically collected via participant feedback forms, structured interviews, and direct classroom observations. The quantitative results demonstrated a very high level of acceptability for Project GTR in both its content quality (M = 4.91, SD = 0.26) and instructional and technical design (M = 4.91, SD = 0.25). Furthermore, thematic analysis of the qualitative data revealed a marked increase in student engagement, a much deeper conceptual understanding of relativity, and highly positive attitudes toward learning physics. Ultimately, these findings underscore the significant potential of localized, multisensory, and interactive tools to transform abstract physics education and promote highly meaningful learning outcomes.

Keywords: General Theory of Relativity, Gravitational Lensing, Instructional Material, Interactive Learning, Physics Education

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Received
January 19, 2026
Accepted
July 14, 2026
Published
August 3, 2026

Citation: Larra, J. D., Barrera, D. M., Bayadas, L. J., Ellipse, C. A., Lumanas, R. D., Valdez, J. R. R., & Ole, F. C. B. (2026). Evaluation of project GTR (gravitational teaching resource) as an instructional material for the general theory of relativity. *Journal of Research in Education and Pedagogy, 3*(3), 396–410.

DOI: 10.70232/jrep.v3i3.187

1. INTRODUCTION

Physics education is crucial for developing critical thinking, problem-solving skills, and scientific literacy, which are essential for navigating a technology-driven world (Mitrevski, 2019). Physics principles are universal contributors to economic and technological developments, serving as the basis of science and technology used in numerous areas (National Research Council, 2013). Studying physics provides learners with tools to examine and interpret natural phenomena, including logical thinking and decision-making skills (Mitrevski, 2019). Its interdisciplinary nature credits it to many fields, such as engineering, medicine, and environmental science (National Research Council, 2013). Pre-service education in STEM can be improved with the incorporation of historical bases of physics and applied technology to achieve a better understanding and critical participation (Matthews, 2015). The physics subject requires sufficient sources and pedagogical strategies to facilitate its delivery in schools (Docktor & Mestre, 2014). These priorities align with United Nations Sustainable Development Goal 4 (Quality Education), which emphasizes equitable access to quality learning, and resonate with the CHED Memorandum Orders (CMO No. 20, s. 2013) that mandate outcomes-based education in Philippine higher education institutions.

Moreover, the study of physics extends into profound scientific theories such as Einstein's General Theory of Relativity (GTR), which reframed gravity because of spacetime curvature rather than a distant acting force (Will, 2014). This theory has led to groundbreaking astrophysical predictions, including black holes and gravitational waves (Abbott et al., 2016), and continues to inspire questions about entropy, information, and the nature of the universe. One of its most striking applications, gravitational lensing, has become a powerful cosmological tool for investigating dark matter and the structure of galaxies (Cervantes-Cota et al., 2019; Meneghetti, 2021). The historical validation of lensing during the 1919 solar eclipse underscores its enduring relevance in both theoretical and applied physics. These global scientific milestones highlight the interdisciplinary and transformative nature of physics, resonating with SDG 9 (Industry, Innovation, and Infrastructure) by advancing knowledge that drives technological progress and innovation.

However, despite its importance, students often encounter significant challenges in learning relativity and other abstract physics concepts. Difficulties include conceptualizing fundamental ideas, distinguishing between special and general relativity, and grappling with frames of reference and relativistic effects (Bandyopadhyay & Kumar, 2010; Scherr et al., 2001). These challenges stem from cognitive limitations such as misconceptions, working memory constraints, and the abstract nature of the subject (Docktor & Mestre, 2014). To address these barriers, educators have employed strategies such as thought experiments, virtual environments, and analogy-based modules, which have shown promise in enhancing comprehension and engagement (Kapon & diSessa, 2012; Zacharia, 2007). Locally, the Philippine K–12 Science Curriculum and CHED's directives on innovative pedagogy and contextualized instruction (CMO No. 46, s. 2012) emphasize the need for creative, research-based strategies that strengthen student engagement and prepare learners for global competitiveness.

In response to these challenges, innovative instructional projects such as Project GTR (Gravitational Teaching Resource) have emerged to make complex topics like gravitational lensing more accessible to learners. This project integrates hands-on learning, visual simulation, and digital technology to make abstract scientific concepts more concrete and accessible, especially for high school learners. The prototype device is enclosed in a box containing a light source, with three square templates placed on top to represent different visual interpretations of space: a template with grid lines to resemble spacetime curvature, a dotted grid to simulate stars, and a black template with multiple holes mimicking constellations. To model gravitational lensing, the bottoms of three wine glasses of different sizes act as celestial bodies, demonstrating how light bends around massive objects. A camera positioned above the prototype projects the visual distortions onto a laptop, simulating telescope observations. This multi-sensory, interactive format combines model-making, light effects, and real-time visualization, making the training more attractive and powerful for visual and kinesthetic learners.

Ultimately, the integration of such innovative instructional materials reflects both international educational goals and local mandates. Research supports the importance of constructive, situated, and multisensory learning in physics as a means of enhancing student engagement, understanding, and fairness in learning (Rau et al., 2015; Zacharia, 2007). Locally, CHED policies encourage the development of contextualized, learner-centered approaches that foster creativity and critical thinking, while globally, SDG 4 calls for inclusive and equitable quality education. By bridging global scientific advancements with local educational reforms, Project GTR (Gravitational Teaching Resource) demonstrates how physics education can be transformed into a dynamic, accessible, and empowering experience. In this way, physics not only provides a foundation for scientific literacy but also equips learners to contribute meaningfully to both national development and international scientific progress.

1.1. Objectives of the Study

The primary objective of this study is to evaluate the effectiveness of Project GTR as an instructional material for the General Theory of Relativity, and specifically to answer the following questions:

1. What could be designed and developed as instructional material in the general theory of relativity?

2. What is the quality of the developed material in terms of content, instruction, and technicalities as evaluated by students, teachers, and experts?
3. What are the perceptions and experiences of students and teachers regarding the use of Project GTR in teaching complex physics concepts?

1.1.1. Framework of the Study

This action research adopted Kurt Lewin's *Plan–Act–Observe–Reflect* (PAOR) model of continuous improvement. This study employed a cyclical framework to guide the design, implementation, evaluation, and refinement of Project GTR—an instructional prototype for teaching the General Theory of Relativity (GTR). The procedure unfolded across four interlinked phases:

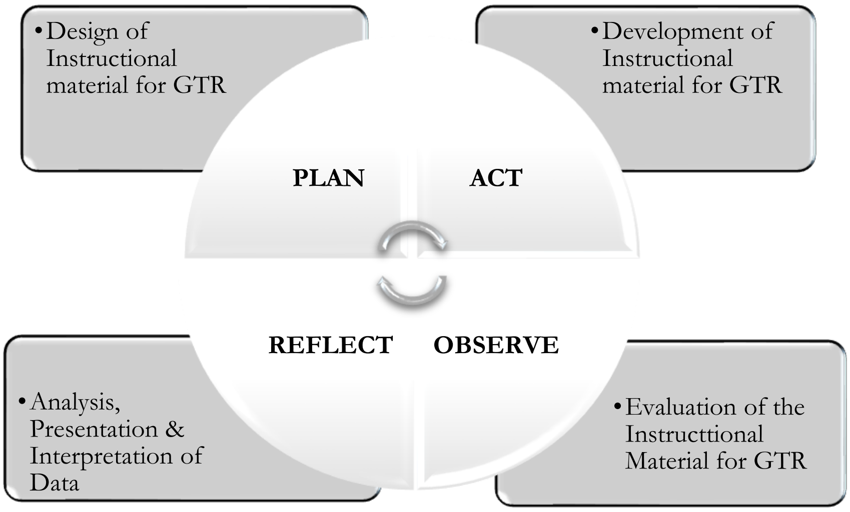


Figure 1. Phases of the Study

Plan: Design of Instructional Material for GTR

The planning phase of the study focused on the conceptualization and finalization of the instructional prototype for teaching the General Theory of Relativity. This phase involved the deliberate design of core components that would serve as the foundation for the learning experience. These included the development of board game mechanics to simulate relativistic phenomena, light-based simulations to visualize gravitational effects, visual analogies to bridge abstract concepts with familiar imagery, and digital projections to enhance engagement and comprehension. In addition to these instructional tools, the research team prepared a structured lesson plan, detailed observation guides, and adapted evaluation instruments to ensure pedagogical coherence and assessment validity.

To establish a shared understanding among all stakeholders, a unified orientation session was conducted for students, classroom teachers, and subject-matter experts. This session clarified the content focus, particularly the concept of gravitational lensing, alongside the intended learning objectives, gameplay procedures, and ethical protocols, including informed consent. By aligning expectations and fostering collaborative engagement, this phase laid the groundwork for coherent instructional delivery and meaningful participation across all groups involved in the study.

Act: Development of Instructional Material for GTR

The implementation phase centered on the delivery of a physics lesson that integrated the interactive components of the instructional prototype. Researchers facilitated the session by presenting content through dynamic simulations and guided gameplay, allowing students to engage directly with the board game designed to illustrate key concepts of the General Theory of Relativity. Throughout the lesson, the team provided instructional oversight, ensuring that the learning experience remained focused, inclusive, and pedagogically sound. As students interacted with the materials, researchers documented detailed field notes capturing levels of learner engagement, the emergence of questions and misconceptions, the nature of instructional facilitation, and any technical challenges encountered. This phase emphasized experiential learning, enabling participants to explore abstract scientific ideas through hands-on activities while allowing the research team to observe and respond to real-time instructional dynamics.

Observe: Evaluation of the Instructional Material for GTR

To evaluate the effectiveness of the instructional prototype, the research team employed a mixed-methods approach that combined quantitative and qualitative data collection. A 15-item adapted Likert-scale questionnaire was administered to all participant groups, including students, classroom teachers, and subject-matter experts. The instrument was structured into three domains: items 1–5 assessed the quality and clarity of the content, items 6–10 examined instructional alignment and pedagogical fit, and items 11–15 evaluated technical usability and overall functionality of the materials. In parallel, semi-structured interviews were conducted using three open-ended prompts designed to elicit participants' reflections on their experiences, perceived strengths and limitations of the prototype, and suggestions for improvement. These interviews were audio-recorded with informed consent and supplemented by researcher observation logs that captured contextual insights during implementation. This phase enabled the collection of diverse perspectives and surfaced nuanced feedback, providing a rich foundation for subsequent analysis and refinement of the instructional design.

Reflect: Analysis, Presentation, and Interpretation of Data

Finally, in the reflection phase, the research team synthesized findings to inform future iterations of the instructional design. Quantitative data were analyzed using descriptive statistics across each domain, while qualitative data underwent thematic analysis to identify recurring patterns and divergent perspectives. Triangulation across students, teachers, and experts ensured the validity and depth of the findings. The resulting insights produced actionable recommendations for content clarifications, gameplay mechanic adjustments, and technical refinements. All data were anonymized, securely archived, and documented alongside orientation materials, lesson plans, instruments, and a revision log to support future PDCA cycles or broader classroom trials.

2. METHODS

2.1. Research Design

This study employed an action research mixed-method design, integrating quantitative and qualitative approaches to evaluate the effectiveness of Project GTR as instructional material for teaching Einstein's General Theory of Relativity. The quantitative component produced numerical measures of acceptability for content and technical/instructional features, while the qualitative component explored participants' perceptions, experiences, and recommendations. Quantitative data were collected first and supplemented by qualitative feedback through open-ended responses, brief interviews, and observations to enrich interpretation and triangulate findings. Data collection occurred during the second semester of the 2024–2025 academic year at a state university in the Negros Island Region. The evaluation took place during a university-wide event in May, providing a naturalistic, walkthrough environment that simulated classroom implementation and allowed participants to interact freely with the game-based material.

2.2. Participants

Table 1 shows the forty (40) participants employed via convenience sampling: thirty-seven (37) students and three (3) science teachers from the affiliated university. Student participants were enrolled in the Bachelor of Secondary Education major in Science (BSED Science) and the Bachelor of Science in Applied Mathematics (BSAM) programs, which include modern physics coursework. The teacher participants also served as subject-matter experts. Of the total participants, nineteen (19) were male, and twenty-eight (21) were female. Among the teachers, two held master's degrees and one held a doctoral degree in science education or a related field. Convenience sampling was used because data collection was event-based and prioritized accessibility and willingness to participate; this choice is acknowledged as a limitation for generalizability.

Table 1. Demographic Characteristics of the Participants

Characteristics	N	Percentage
Gender		
Female Student/s	20	50%
Female Teacher/s	1	2.50%
Male Student/s	17	42.50%
Male Teacher/s	2	5%
Total	40	100%
Age		
18 - 20	25	62.50%
21 - 25	12	30%
26-30	2	5%
26 - Above	1	2.50%
Total	40	100%
Academic Programs		
BSED Science	22	55%
BSAM	15	37.50%
Educators	3	7.50%
Total	40	100%

2.3. Research Instruments

The primary research instrument utilized in this study was a questionnaire adapted from Jeong (2024). Although a separate statistical reliability coefficient was not computed, the instrument's face validity was thoroughly examined by a physics educator with extensive research experience and a doctorate in physics education, ensuring its appropriateness for evaluating the instructional material. The questionnaire was designed to capture both quantitative and qualitative data and was structured into three major components. Criterion A focused on content validity, specifically examining the alignment of the game's content with established learning competencies and curricular expectations. Criterion B assessed instructional and technical quality, addressing aspects such as functionality, ease of use, visual appeal, user engagement, and the extent to which the tool encouraged critical thinking skills. Criterion C consisted of three open-ended questions intended to elicit participants' qualitative feedback, experiences, and recommendations for improving the game prototype. The closed-rating items in Criteria A and B employed a five-point Likert scale, ranging from 5 ("Very Acceptable") to 1 ("Not Acceptable"), and the instrument comprised thirteen (13) closed-ended items alongside three (3) open-ended questions. To provide a systematic framework for analysis, the questionnaire was organized into three parts: Part I gathered respondent background information; Part II contained items on content validity (Items 1–5); and Part III focused on instructional and technical quality (Items 6–10). The instructional material evaluated, Project GTR, is an interactive learning tool designed to represent relativity concepts, particularly gravitational lensing, in teaching the General Theory of Relativity. By integrating multimodal elements such as visual, kinesthetic, and interactive features, the game aimed to accommodate diverse learning styles and enhance student engagement in complex physics topics.

The scale was scored as follows:

Table 1. Interpretation of Raw Scores

Raw Score	Description
1	Not Acceptable
2	Fairly Acceptable
3	Moderately Acceptable
4	Acceptable
5	Very Acceptable

2.4. Procedures

Figure 2 illustrates the sequential stages of the data gathering procedure for Project GTR.

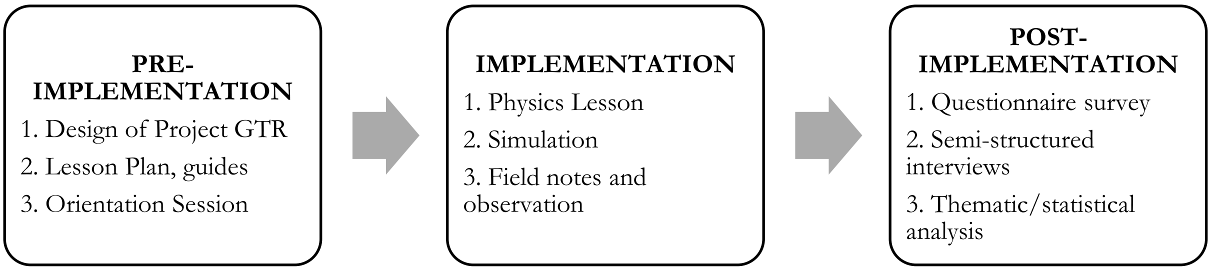


Figure 2. Stages of Implementation

In the pre-implementation stage, the research team focused on the design and development of Project GTR as an instructional prototype for teaching the General Theory of Relativity. This stage involved conceptualizing board game mechanics to simulate relativistic phenomena, light-based simulations to visualize gravitational effects, visual analogies to connect abstract concepts with familiar imagery, and digital projections to enhance comprehension. Supporting materials such as structured lesson plans, observation guides, and adapted evaluation instruments were prepared to ensure pedagogical coherence and assessment validity. To establish a shared understanding, an orientation session was conducted with students, teachers, and subject-matter experts to clarify objectives, gameplay procedures, and ethical protocols, including informed consent.

In the implementation stage, the instructional prototype was integrated into a physics lesson facilitated by the researchers. Content was delivered through dynamic simulations and guided gameplay, allowing students to interact directly with the board game and related instructional tools. Instructional oversight was maintained to ensure inclusivity and pedagogical soundness, while detailed field notes documented learner engagement, emerging misconceptions, instructional facilitation, and technical challenges. This stage emphasized experiential learning, enabling participants to explore abstract scientific ideas through hands-on activities while providing the research team with real-time instructional insights.

In the post-implementation stage, the effectiveness of the instructional material was evaluated using a mixed-methods approach. A 15-item adapted Likert-scale questionnaire was administered to students, teachers, and subject-matter experts, covering three domains: content quality and clarity, instructional alignment and pedagogical fit, and technical usability and functionality. The questionnaire was designed to be concise and accessible, requiring approximately 15 minutes to complete when administered in hardcopy form. To enhance flexibility and convenience, the researcher also prepared a QR code–based version of the instrument, allowing respondents to simply scan the code and be redirected to the online questionnaire. Semi-structured interviews were conducted to elicit reflections on experiences, strengths, limitations, and suggestions for improvement, with responses audio-recorded under informed consent. Researcher observation logs supplemented these data, providing contextual insights. Quantitative data were analyzed using descriptive statistics, while qualitative data underwent thematic analysis. Triangulation across participant groups ensured validity and depth, and findings were synthesized into recommendations for refining content, gameplay mechanics, and technical features.

2.5. Data Analysis

The responses collected using the adapted questionnaire were analyzed quantitatively and qualitatively to produce a well-grounded evaluation of Project GTR as an instructional tool in physics. Although a separate statistical reliability coefficient was not established in this study, the instrument's face validity was confirmed by a physics teacher with significant research experience and a doctorate in physics education. The instrument was structured into two main criteria: Criterion A, which addressed content validity by focusing on the game's alignment with learning competencies and curricular expectations; and Criterion B, which evaluated instructional and technical aspects, including functionality, ease of use, attractiveness, user engagement, and the encouragement of thinking skills.

Quantitative data from experts, teachers, and students were aggregated for the two primary domains—Content Quality and Technical Quality—and analyzed using means and standard deviations computed in Microsoft Excel; the mean provided an overall index of the prototype's perceived effectiveness and acceptability, while the standard deviation indicated the degree of consistency or variability across respondent groups.

Qualitative feedback from the three open-ended interview questions and the researcher's observation notes underwent thematic analysis: the researchers systematically coded responses, identified recurring themes and patterns, and interpreted these findings to surface participants' experiences, perceived strengths, usability issues, and actionable suggestions for improvement. Triangulation of quantitative scores with qualitative themes across students, teachers, and subject-matter experts strengthened the validity of inferences about learning impact, motivation, and classroom suitability, and informed prioritized recommendations for content clarifications, mechanic refinements, and technical fixes to guide subsequent PDCA cycles.

2.6. Ethical Considerations

This study upheld the core ethical principles of respect for persons, beneficence, and justice to ensure the protection and dignity of all participants. Before data collection, participants received a clear orientation on the study's purpose, procedures, and their rights; informed consent was obtained from every participant, and participation was entirely voluntary. Participants were informed of their right to decline to answer any question or to withdraw from the study at any time without penalty, and interviewers allowed participants to share only what they felt emotionally and psychologically comfortable disclosing.

To protect privacy and confidentiality, identifying information was removed, and participants were assigned pseudonyms in accordance with the Data Privacy Act of 2012; audio recordings and transcripts were stored securely and accessed only by the research team. The researchers also disclosed that there were no monetary incentives for participation and stated that there were no conflicts of interest. Overall, the study procedures were designed to maximize potential benefits, minimize risks, and treat all participants fairly and respectfully.

3. RESULTS

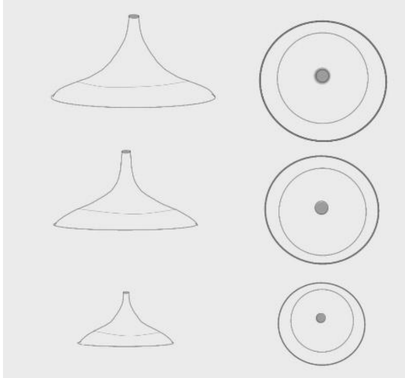
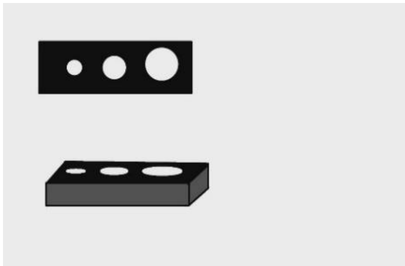
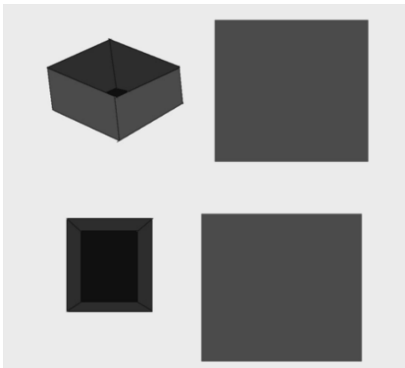
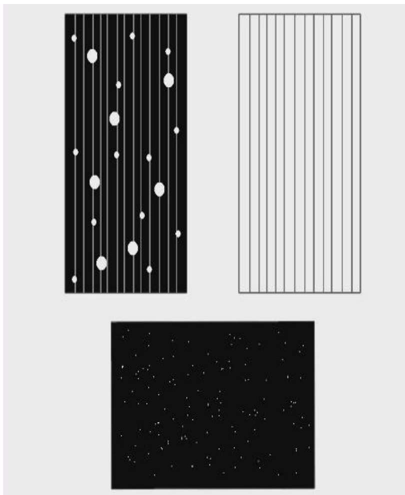
This section reports the quantitative and qualitative findings within the P- framework, showing how Project GTR functions as an instructional tool for the General Theory of Relativity and how each PDCA phase contributed to answering the research problems. In the Plan phase, the prototype's content and design were validated: materials, visual analogies, light simulations, and game mechanics were confirmed as aligned with the study's learning goals (especially gravitational lensing) and judged appropriate for classroom use. Participants noted that the prototype successfully translated abstract GTR ideas into concrete, teachable elements, supporting the prototype's face and content relevance for intended learners.

3.1. Plan Phase

During the planning phase, Project GTR was conceptualized as a multimodal instructional prototype to help high school students visualize and understand gravitational lensing by combining hands-on models, light effects, and digital visualization. The design specified a boxed prototype housing an internal light source and three-square templates—one with grid lines to represent spacetime curvature, one with dotted grids to simulate spacetime populated with stars, and a black template perforated to mimic constellations—placed over the light to vary visual input. To model massive bodies and demonstrate light bending, the bottoms of three wine glasses of different sizes were selected as physical lenses whose placement and movement illustrate how light curves around objects. The prototype's workflow included mounting a camera above the box to stream real-time projections to a laptop, enabling students to observe simulated telescope views and the dynamic effects of lensing.

Learning objectives were defined to emphasize conceptual clarity on spacetime curvature and gravitational lensing, foster multisensory engagement for visual and kinesthetic learners, and provide flexible classroom uses (pretest, posttest, demonstration, or lab activity). Draft facilitation notes, observation guides, the adapted 15-item Likert instrument, and consent and data-management procedures were prepared to ensure alignment between instructional goals, classroom enactment, and subsequent PDCA-cycle data collection.

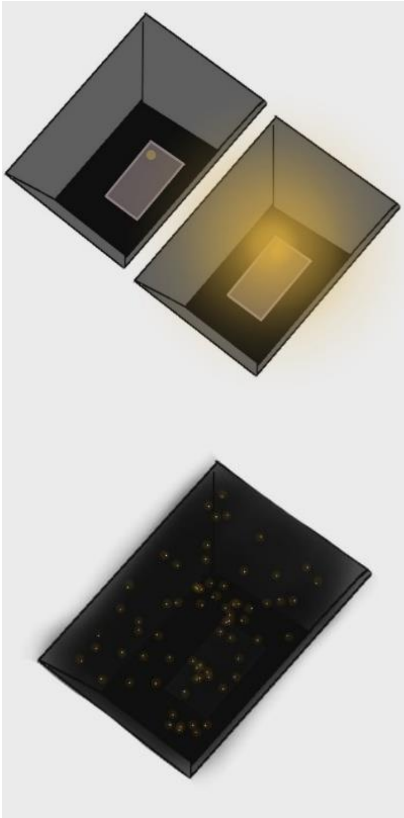
Table 2. Components of Project GTR (Gravitational Teaching Resource)

Components	**Actual Images**
1. Spacetime Curvature Model (Wine Glass Set) Description: A set of cut wine glass models of varying sizes designed to represent different curvatures of spacetime caused by varying masses. Each cut glass mimics the shape of a gravitational well, allowing students to visualize how mass distorts spacetime.	
2. Model Base or Holder Description: A rectangular platform with circular slots that securely hold the cut wine glass models in place. The holder stabilizes the demonstration setup, ensuring that each curvature model remains upright during classroom discussion or experiment.	
3. Light Source Box Description: A small, dark enclosure designed to hold a mobile phone's flashlight, serving as the controlled light source in the experiment. The box directs and limits the light to simulate how light travels through space, minimizing unwanted reflections or dispersion.	
4. Lensing Platforms Description: A series of three interchangeable flat panels used to demonstrate gravitational lensing effects caused by massive celestial objects. • Platform 1 – Linear Grid: A plain grid pattern representing undistorted spacetime where light travels in straight lines. • Platform 2 – Grid with Dots: A grid marked with circular masses symbolizing celestial bodies (e.g., stars, galaxies) that distort spacetime. The pattern helps visualize how light paths bend near massive objects. • Platform 3 – Star Field Screen:	

A dark panel with small openings to simulate distant stars. When the light from the box passes through, it demonstrates how gravitational lensing magnifies or distorts the apparent position of these stars.

5&6. Gravitational Lensing Demonstration Setup

Description: This setup combines the light source box and lensing platforms to simulate gravitational lensing. The mobile phone's flashlight acts as a distant light source, projecting through the platforms that represent different spacetime distortions. The resulting light patterns help learners visualize how massive objects like galaxies bend light, magnify distant stars, and distort their apparent positions—mirroring Einstein's predictions in the General Theory of Relativity.



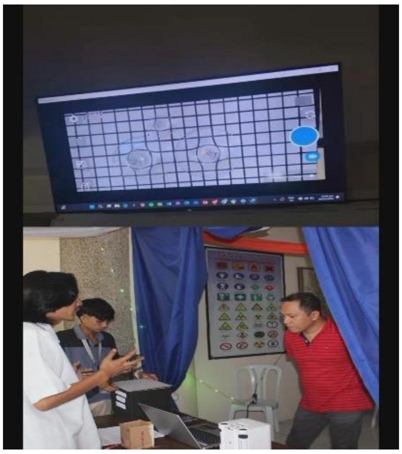


Figure 3. The Researchers with the Actual Sizes of Components and Some of the Participants during the Demonstration

3.2. Act Phase

Project GTR was conceptualized, developed, and implemented using the boxed prototype, three templates, wine-glass bottoms, and a live camera feed to a laptop; students worked in small groups while researchers and teachers facilitated inquiry and recorded observations. Engagement was high: students adjusted glass positions, predicted light paths, and compared template views to link visible distortions with spacetime curvature. Researchers logged timestamped notes on interaction patterns, recorded misconceptions (e.g., confusing magnification with lensing), and captured moments of conceptual breakthrough. Teachers confirmed the lesson's fit within class routines and prompted productive discussion; experts validated demonstration fidelity and suggested minor clarifications. Minor technical issues (camera alignment, projection brightness) and interpretive scaffolding needs were addressed in real time and documented for refinement in the subsequent Check and Act phases.

3.3. Observe Phase

The Observe Phase presents the evaluation of Project GTR, focusing on its effectiveness as instructional material for teaching the General Theory of Relativity. This phase directly responds to the research objectives by assessing the quality of the developed material in terms of content relevance, instructional design, and technical execution. It also aims to determine the content validity and instructional-technical quality of the project, as evaluated by key stakeholders, including students, teachers, and subject-matter experts.

Table 3. Mean Scores of the Content Accessibility of the Developed Instructional Material for Physics

Content	Mean	SD	Interpretation
1. Objectives of the laboratory experiment/ learning materials are clear.	4.90	0.30	Very Acceptable
2. The level of K (Knowledge) is appropriate under the (MATATAG Education Curriculum).	4.92	0.26	Very Acceptable
3. The designed laboratory experiments/learning materials are suitable for science learning.	4.92	0.26	Very Acceptable
4. The higher-order thinking skills (HOTS) such as critical thinking, creativity, inquiry, problem solving, and reasoning are promoted through this activity.	4.85	0.36	Very Acceptable
5. The activity motivates students through engaging laboratory activities/learning materials inside the classroom.	4.97	0.15	Very Acceptable
Total	4.91	0.26	Very Acceptable

Table 3 presents the evaluation results on the acceptability of the physics instructional material developed under Project GTR. The overall mean rating was 4.91 with a standard deviation of 0.26, indicating a "Very Acceptable" level of quality across all five indicators. These indicators include clarity of instructional objectives, alignment with grade-level knowledge under the MATATAG Curriculum, suitability for science learning, promotion of higher-order thinking skills (HOTS), and student engagement through interesting activities. Each criterion received high scores, with the highest mean of 4.97 for student engagement, and the lowest—still very acceptable—mean of 4.85 for HOTS. These results affirm the material's strong fidelity to instructional standards and its capacity to foster motivation, critical thinking, and conceptual understanding.

Table 4. Mean Score and Interpretation of Instructional and Technical Quality of the Developed Instructional Material for Physics

Criteria	Mean	SD	Interpretation
6. The instructional reasons behind the laboratory activity/learning activity are clear and well explained.	4.92	0.26	Very Acceptable
7. The activity provides real-time, accurate results and outcomes.	4.95	0.22	Very Acceptable
8. The device/instructional material functions efficiently.	4.97	0.15	Very Acceptable
9. It is easy to navigate and operate.	4.92	0.26	Very Acceptable
10. It stimulates the learner's creativity.	4.92	0.26	Very Acceptable
11. It is better and more innovative than existing laboratory apparatus or devices.	4.80	0.40	Very Acceptable
12. It is appealing and interesting.	4.97	0.15	Very Acceptable
13. It is used effectively in laboratory experiments/classroom settings.	4.92	0.26	Very Acceptable
14. It possesses a consistent interface, including visual cues such as buttons, menu icons, labels, messages, etc.	4.87	0.33	Very Acceptable
15. It is safe to use.	4.90	0.30	Very Acceptable
Total	4.91	0.25	Very Acceptable

Table 4 presents the evaluation results of the instructional and technical quality of the developed physics material. The general mean score was 4.91, with a standard deviation of 0.25, interpreted as "Very Acceptable." This indicates that the material meets high standards in design, usability, and learning effectiveness. Supporting literature affirms that well-designed instructional tools—especially those that are inquiry-based, visually engaging, and contextually relevant—can enhance student motivation, retention, and creative thinking. The findings highlight the importance of developing materials that are not only technically sound but also emotionally engaging and tailored to learners' contexts to optimize educational outcomes.

Table 5. Emerging Themes and Subthemes from Evaluation of Project GTR

Main Theme	Subtheme	Description	Sample Comments	Frequency
Functionality and Conceptual Clarity	Conceptual Understanding of GTR	The material effectively supports comprehension of gravitational lensing and Einstein's General Theory of Relativity.	"Helped us visualize how celestial bodies behave" (Student 9)	12
	Simplification of Complex Ideas	Visual models and analogies made abstract physics concepts more accessible.	"Simplified and showed how stars behave" (Student 11)	10
	Classroom Accessibility	The prototype worked well under typical classroom conditions.	"Worked as expected" (Teacher 2)	8
Engagement and Ease of Use	Interactive and Appealing Design	Students and teachers found the tool visually engaging and immersive.	"I felt like I was in space" (Student 14); "Surreal" (Teacher 2)	14
	User-Friendliness	The activity was easy to understand and navigate.	"Fun and easy to understand" (Student 17); "Simple and practical" (Teacher 3)	13
	Motivation and Enjoyment	The tool stimulated interest and made learning enjoyable.	"Very extraordinary!" (Student 11); "Amazing" (Teacher 1)	15
Perceived Value and Suitability	Practicality and Accessibility	The material was seen as affordable, safe, and suitable for classroom use.	"Very affordable and used materials that are not costly" (Student 27)	9
	Support for Visual Learners	The tool was especially helpful for students who learn best through visual aids.	"Especially to visual learners" (Teacher 2)	7
	Knowledge Retention and Recall	Students felt the model helped them remember and deepen their understanding of physics concepts.	"They can recall the theory" (Student 13); "Enhance the knowledge" (Student 33)	11

Overall, the evaluation of Project GTR revealed three core themes: conceptual clarity, engagement and usability, and instructional value. Students and teachers affirmed that the material effectively simplified complex physics concepts like gravitational lensing through visual models and analogies. Its interactive and immersive design made learning enjoyable and easy to navigate, fostering strong motivation and interest. Additionally, the tool was praised for being practical, affordable, and suitable for diverse learners—especially visual learners—while supporting retention and deeper understanding. These findings confirm the material's effectiveness as a student-centered, contextually relevant instructional resource in science education.

3.4. Reflect Phase

The evaluation of Project GTR yielded consistently high ratings across both content and instructional-technical dimensions, affirming its effectiveness as a student-centered instructional material in physics. The overall mean rating of 4.91 (SD = 0.26) for content quality and 4.91 (SD = 0.25) for instructional and technical quality fall within the "Very Acceptable" category, indicating strong alignment with the research objectives, particularly in assessing relevance, usability, and pedagogical impact.

These findings are consistent with recent studies emphasizing the value of interactive and localized instructional tools. Agbunag (2022) demonstrated that localized and contextualized supplementary materials in physics significantly improved student performance and engagement, highlighting the importance of situating academic activities within the learners' immediate environment. Similarly, Quimoyog, Torres, and Galay-Limos (2025) reported that PhET simulations enhanced science achievement and critical thinking among Filipino learners, particularly in abstract topics such as magnetism and optics. Villaruel (2025) further reinforced this trend, showing that interactive simulations improved conceptual understanding of projectile motion and vector addition among college students. Collectively, these studies affirm that interactive, context-sensitive tools foster deeper learning, engagement, and accessibility in physics education.

The consistently high acceptability ratings for Project GTR can be attributed to several interrelated factors. First, the material's localized relevance ensured alignment with the MATATAG Curriculum and directly addressed competencies, making it meaningful for Filipino learners. Second, its multimodal design—integrating visual, kinesthetic, and interactive elements—accommodated diverse learning styles and enhanced comprehension of complex concepts such as gravitational lensing. Third, the tool's ease of use and accessibility, including both hardcopy and QR code–based formats, reduced barriers to participation and provided flexibility for respondents. Fourth, curriculum alignment and expert validation reassured teachers and subject-matter experts of the material's academic soundness. Finally, the engagement factor was particularly notable, with the highest score of 4.97 for student engagement, underscoring the material's capacity to captivate learners through immersive experiences.

The lowest score of 4.85 for higher-order thinking skills (HOTS), while still within the "Very Acceptable" range, suggests a potential area for improvement. This finding aligns with broader literature noting that while interactive tools boost engagement, explicit scaffolding strategies are needed to deepen analytical and problem-solving skills (Quimoyog et al., 2025). Future iterations of Project GTR should therefore incorporate structured prompts and guided inquiry tasks to further strengthen learners' critical and analytical capacities.

Qualitative feedback reinforced these quantitative results. Students described the material as engaging, easy to understand, and effective in simplifying complex concepts such as gravitational lensing—a topic central to Einstein's General Theory of Relativity. Comments like "It helped us visualize how celestial bodies behave" and "It simplified and showed how stars behave" reflect the material's success in translating abstract scientific ideas into accessible learning experiences. Teachers echoed this sentiment, noting its practicality and suitability for typical classroom conditions, which supports Agbunag's (2022) findings on the importance of contextualized instructional design.

4. CONCLUSION

The development and evaluation of Project GTR demonstrated its effectiveness as a student-centered, contextually relevant instructional material for teaching complex physics concepts such as gravitational lensing. Quantitative results revealed a consistently high level of acceptability across all indicators, with an overall mean rating of 4.91, affirming the material's strong alignment with instructional standards in terms of content, design, and technical quality. Qualitative feedback from students and teachers further validated its clarity, usability, and capacity to foster engagement, motivation, and conceptual understanding. The integration of visual models, interactive elements, and contextualized content proved instrumental in simplifying abstract scientific ideas and enhancing learner experience. The material's affordability and adaptability also make it a practical tool for diverse educational settings, particularly in resource-constrained environments.

Beyond these findings, the study carries several practical implications for key stakeholders. For educators, Project GTR offers a ready-to-use, interactive resource that can be seamlessly integrated into classroom instruction to enhance engagement and conceptual mastery, particularly in topics traditionally perceived as abstract or difficult. For curriculum developers, the results highlight the importance of embedding multimodal and localized instructional tools into the MATATAG Curriculum to ensure relevance and accessibility for Filipino learners. For researchers, the study underscores the value of mixed-methods evaluation in validating instructional innovations and provides a model for adapting and testing educational technologies in physics education. For policymakers, the demonstrated effectiveness and affordability of Project GTR suggest that similar innovations could be scaled across schools to promote inquiry-based, student-centered learning, thereby supporting national goals for science and technology education.

Taken together, these implications position Project GTR not only as a prototype instructional material but also as a model for sustainable, innovative, and curriculum-aligned approaches to teaching complex scientific concepts in the Philippine context. Future work should focus on expanding its scope to other physics topics, strengthening scaffolding for higher-order thinking skills, and exploring its integration into broader digital learning ecosystems.

5. RECOMMENDATIONS

While the findings of this study affirm the effectiveness of Project GTR as a student-centered and contextually relevant instructional material, several methodological limitations must be acknowledged. The study relied on convenience sampling, which limited the sample size and may affect the generalizability of results to broader populations. Additionally, although the adapted questionnaire underwent expert face validity review, no separate statistical reliability coefficient was established, which constrains the strength of claims regarding instrument consistency. These limitations highlight the need for cautious interpretation of the findings and point to areas where future research can build upon this work.

For educators, Project GTR can be integrated into classroom instruction as a supplementary tool to enhance engagement and conceptual mastery of abstract topics such as gravitational lensing. Teachers are encouraged to pair the material with scaffolding strategies and inquiry-based activities to strengthen higher-order thinking skills and address the slight gap noted in HOTS ratings.

For curriculum developers, the results emphasize the importance of embedding multimodal, localized, and interactive instructional materials into the MATATAG Curriculum. Developing similar tools for other physics topics, such as electromagnetism, quantum mechanics, or thermodynamics, can broaden the reach of innovative, accessible learning resources.

For researchers, future studies should expand the evaluation of Project GTR to larger, more diverse samples, employ randomized or stratified sampling to strengthen generalizability, and conduct reliability and validity testing of adapted instruments. Longitudinal studies are also recommended to examine the sustained impact of interactive materials on student achievement, motivation, and critical thinking. Comparative research with other digital tools, such as PhET simulations, may further clarify the unique contributions of Project GTR.

For policymakers, the demonstrated effectiveness and affordability of Project GTR suggest that similar innovations could be scaled across schools to promote inquiry-based, student-centered learning. Investment in localized educational technologies can help bridge resource gaps in public schools and support national goals for science and technology education.

Acknowledgments. The author would like to thank Carlos Hilado Memorial State University for providing the facilities, resources, and support necessary to complete this research. Appreciation is also extended to the participating students and teachers for their cooperation and valuable feedback.

Research Ethics. This study was conducted in accordance with established ethical standards for educational research involving human participants. Ethical approval was obtained prior to data collection. Permission to conduct the study was secured from the school administration and the concerned authorities. All participants were fully informed of the purpose, procedures, and voluntary nature of the study, and informed consent was obtained prior to participation. Participants were assured of confidentiality, anonymity, and the right to withdraw at any stage without penalty. Data collected were used solely for research purposes and handled with strict confidentiality.

Data Availability Statement. All data supporting the findings of this study are available from the corresponding author upon reasonable request.

Conflicts of Interest. The author reports that there are no competing interests to declare.

Funding. This research received no external funding.

Declaration of Generative AI in Scientific Writing. During the preparation of this work, the author used Microsoft Copilot to refine grammar, improve clarity, and enhance the organization of ideas. The author reviewed and edited all AI-assisted outputs and takes full responsibility for the accuracy and integrity of the content. Generative AI tools were not used for data analysis, interpretation, or authorship.

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