OmniaScience

Journal of Technology and Science Education

JOTSE, 2026 – 16(1): 248-261 – Online ISSN: 2013-6374 – Print ISSN: 2014-5349

https://doi.org/10.3926/jotse.3539

IMPACT OF THE SELF-LEARNING MODULE IN RELATIVITY (SLM-R) ON STUDENTS' CONCEPTUAL UNDERSTANDING OF EINSTEIN'S THEORY

Faith Celeste Ole

Carlos Hilado Memorial State University (Philippines)

faith.celeste.ole@chmsu.edu.ph

Received May 2025
Accepted February 2026

Abstract

The impact of Einstein's theory of relativity has undeniably led to a surmountable advancement in today's technology. Its abstract nature may limit teachers from developing learning materials that could equip students to improve their conceptual understanding. With this rarity of instructional material, a relativity self-learning module (SLM-R) was created, and its efficacy in this study was examined. Using an explanatory sequential research design that employs a quantitative approach, supported by qualitative data, a quasi-experimental method was used for the control and experimental groups of pre-service teachers majoring in science, followed by descriptive content analysis of the feedback form. Based on pre-test and post-test results, the group with the SLM-R significantly improved their conceptual understanding compared to those without the module, as indicated in Cohen's d measure (d = 0.85) and normalized gain (g = 0.30). These findings allow students to use this self-learning module as supplementary instructional material in modern physics.

Keywords – Conceptual understanding, Physics, Relativity, Self-learning module, Mixed method.

To cite this article:

Ole, F. C. (2026). Impact of the Self-Learning Module in Relativity (SLM-R) on students' conceptual understanding of Einstein's theory. *Journal of Technology and Science Education, 16*(1), 248–261. https://doi.org/10.3926/jotse.3539

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1. Introduction

The future of scientific innovations and discoveries depends on today's progress in science education. With the influx of modern technology, physics education plays a fundamental role in advancing it and will continue to be a vital factor in future developments. Thus, students' interest in learning physics should be harnessed by providing a deeper understanding of science and its societal benefits (Cadiz & Orleans, 2023). Accordingly, this is a fundamental concern for all, given the poor scientific literacy and declining interest among students in pursuing scientific studies, especially in physics (De-la-Cruz, 2022; Dwi et al., 2017; Steidtmann et al., 2022).

Studying physics has been known as the least preferred science discipline, especially for those not interested in formulas and derivations (Rashid et al., 2024). It is complicated and challenging topics could lead to further confusion if previous areas still need to be fully understood (Wangchuk et al., 2023). With these connotations, students tend to get negative impressions, which influence their perceptions of the difficulty of this subject (Sadera et al., 2020). Not to mention, qualified physics teachers are scarce in teaching this discipline (Abrantes & Bargamento, 2024; Buabeng et al., 2015; Wangchuk et al., 2023), which may potentially affect teachers' pivotal role in establishing students' interest and understanding of the subject.

Moreover, the recent and dismal result of the Programme for International Student Assessment (PISA) on student creativity, with the Philippines ranking once more amongst the bottom countries, is one more aspect of learning that urgently needs proper attention (Belmi & Mangali, 2020; Diate & Mordeno, 2021; Palines & Ortega-de-la-Cruz, 2021; Saro et al., 2022). Although the Philippine government has initiated several reforms to address these challenges by establishing programs to optimize a science-driven society aligned with the 2030 Sustainable Development Goals (SDG) for transcended and effective learning outcomes (Cadiz & Orleans, 2023), the lack of creativity among students may be a consequence of lesser exposure to learning activities that promote abstract and critical thinking to enhance their imagination (Panergayo & Pelgone, 2023; Zahara et al., 2020). Direct instruction and rote memorization (Alotaibi & Ishak, 2025) of facts, figures, and formulas in general science and, in particular, physics do not promote critical and creative thinking (Arden, 2021). Proper education does not consist merely of teaching subject matter, but must also involve teaching students how to learn and, more importantly, think.

One of the intellectual giants of the 20th century once said, "Imagination is more important than knowledge" (Dwijayanti et al., 2017; Nair, 2017). This idea was vividly illustrated by Dr. Albert Einstein, who arguably single-handedly initiated a revolution in modern physics (Nair, 2017). His imaginative thinking led to a fundamental shift in our understanding of physical reality. Through his creativity and innovative approach, Einstein developed a more accurate understanding of the essential concepts of time, space, energy, and matter, and he reinterpreted and refined Newton's Law of Gravity. Unfortunately, these crucial concepts in modern physics are rarely introduced or effectively taught in basic educational settings, largely due to the lack of learning materials on relativity (Emrahoğlu, & Yalçın, 2025; Suyatna et al., 2018). Therefore, encouraging students to think outside the box and beyond the obvious through innovative, validated learning materials, such as self-learning modules, may increase their interest in and understanding of concepts, foster their imagination, and thereby enhance their creativity (Asrizal et al., 2024).

Although several studies claim (de-Souza et al., 2025; Emrahoğlu & Yalçın, 2025), the better efficacy of simulated and interactive activities in learning physics than the textbook-based approach, it should not be totally undermined how the impact of learning modules has proven to be an effective strategy for teaching physics, too, especially in distance learning contexts, of the asynchronous classes (Suba & Manlapig, 2025). Given the impact of COVID-19, which caused learning loss among students, it is crucial that they have materials to maintain continuity in their learning, especially for those unable to engage in digital platforms.

A self-learning module in relativity (SLM-R) is a learning resource that focuses on Einstein's contributions to modern society, and as attested by de-Souza et al. (2025), there are the limited number of empirical studies on teaching relativity from 2000 to 2024. His theories, particularly the Special and General Theory of Relativity, contributed to an in-depth understanding of a wide range of scientific areas, including electromagnetism, nuclear power, satellite systems, and more. The practical applications of his relativity provided accurate corrections, with implications in agriculture, meteorology, the military, and other fields where navigation precision or the global positioning system (GPS) is inevitable (McNeill et al., 2021). Therefore, a careful understanding of this abstract topic is essential, for the basis of modern applications lies in this core.

Students' understanding of how nature operates should not be limited to classical physics; it should also encompass modern physics, as this knowledge is foundational to many of the technological advancements of the 21st century (Emrahoğlu & Yalçın, 2025; Ole, 2023). By doing so, students will gain a deeper understanding of the crucial roles played by space, time, and subatomic particles in driving technological progress. In this context, this study aims to evaluate the effectiveness and impact of the developed SLM-R in classroom settings.

2. Materials and Methodology

2.1. Research Design and Environment

This study utilized a mixed-method approach, specifically an explanatory sequential research design that involved collecting and analyzing the quantitative data and subsequently supported by qualitative data. The design primarily explains or expands quantitative results for comprehensive findings (Drauker et al., 2020). Under the quantitative method, a quasi-experimental design was used to determine the effect of the developed SLM-R on students' conceptual understanding. Two matched groups, namely, the experimental and the control groups, were randomly assigned and compared in this study. An intact class exposed to the SLM-R and another intact class without the developed material were administered with a pretest-posttest. Table 1 summarizes the research design of this study. On the other hand, the qualitative method utilizes descriptive content analysis to support the findings.

Group	Implementation		
Experimental	O_{1a}	X	O_{2a}
Control	O_{1b}		O_{2b}

Note: O_{1a} and O_{1b} = pre-test; X = intervention; O_{2a} and O_{2b} = post-test

Table 1. Two-group pre-test and post-test design

The conduct of this study transpired in one of the state colleges and universities (SUCs) of Negros Island Region (NIR), which is committed to empowering its learners through academic quality and excellence for global competitiveness. One of its curricular offerings under the College of Education was the Bachelor of Secondary Education major in science.

2.2. Research Participants

The participants in this research endeavor were two intact classes of third-year college students taking up a Bachelor of Secondary Education major in Science (BSED Science) during the second semester of the academic year 2023-2024. The intact classes with heterogeneous intellectual abilities were chosen at random as experimental and control groups. The experimental and control groups have twenty-eight (n = 28) students in each class. Each group consists of 18 females and 10 males, respectively.

Purposive sampling was employed to ensure that respondents in each group were matched based on age, gender, and Optics grades. Students excluded from the data collection included those outside the age range of 20 to 22, individuals who did not complete the pre-test or post-test, and students who repeated the Modern Physics course due to the college's class retention policy.

It is crucial that both groups have a similar level of knowledge before conducting this study to ensure equivalence. A consistent understanding of the participants' entry knowledge enables us to accurately assess the impact of the instructional intervention. As demonstrated in Table 2, preliminary calculations using the Optics grades—a prerequisite for the Modern Physics course—revealed no significant differences in the characteristics of the respondents. Consequently, this confirms that the two groups were effectively matched.

Variable	Mean		SD		n		t	p-value	Interpretation
	CG	EG	CG	EG	CG	EG			
OPTICS GRADES	88.04	89.18	3.10	1.89	28	28	1.88	0.10	NS

Note: CG = Control Group, EG = Experimental Group, NS = Not Significant

Table 2. Computed t-value between control and experimental group on a matching variable

The teacher handling the classes must be the same to reduce bias in the implementation. Hence, the physics teacher who taught the two groups had a Ph.D. in physical science and had taught physics for over a decade.

2.3. Research Instruments

In this study, several instruments were used to assess the impact of the developed learning material on students' conceptual understanding. The Self-Learning Module in Relativity (SLM-R) was the core component utilized by the experimental group. The Relativity Concept Inventory (RCI) provided quantitative data, while the feedback form collected qualitative information to support the measurable results.

Self-learning module in Relativity (SLM-R). The self-learning module in Relativity, developed by the researcher, was designed and anchored in Taba's Curriculum Development Model, also known as the Grassroots Approach. This material has undergone content validation by experts, earning an excellent rating due to its engaging activities that foster the acquisition of 21st-century skills. It adhered to the researcher's institution's standard evaluation and can be appropriately used in a classroom setting (Ole, 2023).

Moreover, some features are included in the structure of the SLM-R's content based on the 7E's (Elicit, Elaborate, Expound, Experience, Extract, Evaluation, Extend) of the inquiry-based learning method (see Appendix A). This module, which uses the 7Es and differs from existing materials in modern physics through its contextualized approach, is grounded in constructivist theory. Accordingly, this instructional design has been shown to effectively elevate students' achievement, critical thinking, and engagement (Alotaibi & Ishak, 2025). The *Elicit* served as motivation for the topic, offering glimpses of the concepts to be revealed. The *Elaborate* section provided a comprehensive discussion of the concept, including several exercises and trivia on real-life applications, guiding students' learning. The *Expound* section delved deeper into the concepts that showed the interconnectedness of the current topic with other subject areas. The *Experience section or practice session* focused on the Self-Assessment Question (SAQ) that the student must answer or perform to explore further what they had learned in the Expound section. This section served as the "knowledge in action" aspect of the SLM-R through problem-solving skills or simple inquiry questions.

Consequently, these answers to the SAQ (ASAQ) are available at the end of each section, so students can check their self-assessments. Meanwhile, the *extract* summarizes the lesson's essential points in bullet form for efficient recall. The Brain Check-up, which served as the *evaluation*, assesses students' learning progress, an inherent part of the module, and lastly, the *extended* section, called "Extra Challenge", that challenges the creativity level of the students.

Relativity Concept Inventory. This standardized test, developed by Aslanides and Savage (2013), was adopted and implemented in this study to measure students' understanding of relativistic concepts. The 24-item questionnaire, composed of a combination of true-or-false and multiple-choice questions, can be answered in 30 minutes and has an unusual feature: confidence testing for each question. After the student had responded to each item, a confidence scaling followed, as shown in Figure 1.

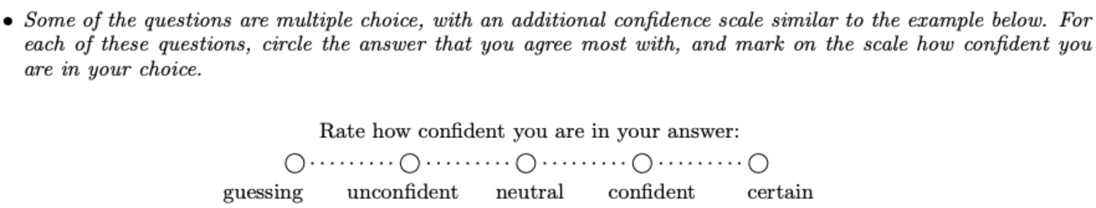

Figure 1. The confidence scale of the RCI test

This test was designed for a paper and pencil approach, but with the trend on digital tests, the RCI was converted into a Google form without changing any of its content. Thus, to establish that the RCI test was reliable for use in the Philippines and its Google form structure, the researcher pilot-tested it on other science major students during the second semester of the academic year 2022-2023. Using Excel to calculate the Kuder-Richardson formula (KR-20), the reliability coefficient obtained a value of 0.996, indicating its high correlation and an acceptable standard for reliability (Yun et al., 2023). Hence, the RCI test is an excellent instrument for classroom tests.

Student's Feedback Form. For the qualitative part, a feedback form found in the last sections of the module was collected from the experimental group after the post-test. Any comments or remarks they have experienced while using the SLM-R served as supporting details to the quantitative data. The participants responded to the following questions: *Did you find the module helpful? Why or why not? How would you rate the activities from 1 to 10, where one denotes poor, and ten denotes very good? Cite the advantages and disadvantages you have encountered. What can you suggest or recommend to improve the module?*

2.4. Data Gathering Procedures

Data acquisition began by securing permission for the classes and explaining the research. A consent form was distributed to the experimental group, following the various ethical procedures. They were also informed about their participation and how their identities would be kept confidential, including the use of codes to protect them. It is worth noting that to reduce potential threats to validity, the schedule of one class was followed consecutively by another. This is to ensure that participants in the control and experimental groups limit communication between themselves due to time constraints and avoid influencing the outcomes of the study.

After the various ethical processes, both classes were administered a pre-test, and the teacher responsible for the classes began instruction. The physics instructor taught both groups using the conventional lecture method. The only difference was that the experimental group had additional learning material; the SLM-R assists them in instruction, whereas the control group had none. The teacher ensured that both classes were provided and exposed to the same activities or tasks. This was carefully employed to reduce potential threats to internal validity.

Einstein's relativity is one of the major topics in a Modern Physics class. As stipulated in the course syllabus, the one-month exposure to this topic was sufficient, and a post-test was eventually administered to both groups. The researcher also asked the students in the experimental group to complete the feedback form at the end of the module for qualitative outcomes analysis. All the information gathered was carefully stored, analyzed, and interpreted, accordingly.

2.5. Data Analysis and Statistical Treatment

Using Excel, this section employed both descriptive statistics (e.g., mean and standard deviation) and inferential statistics (e.g., paired and independent t-tests) to analyze the data. The pre-test and post-test mean scores of the experimental and control groups were compared to evaluate the impact of the developed SLM-R and to determine its effectiveness. The Cohen's d effect size measure was utilized to assess the practical significance of the instructional material, which can be defined as the learning gains resulting from the experimental treatment. Additionally, Hake's normalized gain (g) was examined to characterize students' conceptual improvement (Steward & Stewart, 2010). Qualitative feedback was also gathered using a validated form from the module to further explain and support the statistical analysis.

2.6. Ethical Consideration

All students were presented with a consent letter that explained the study's purpose and how the information would be used for analysis. They were asked to submit the consent form as a binding contract for their voluntary participation in the data acquisition. Should they withdraw their consent and discontinue involvement, this would be accepted without prejudice.

Records obtained from this study were kept confidential, and participants' identities were not disclosed. Codes were provided to all recordings, transcripts, and documentation, and all gathered information was kept in locked files at all times.

3. Results and Discussion

This part presents the findings in light of the study's research objective. It will present the analysis and interpretation of the results to determine the efficacy of the developed material for the student's conceptual understanding of Relativity. Likewise, students' feedback will be exhibited, serving as relevant records to support the findings. Descriptive statistics for the two groups are presented in the following tables to provide an overview of the participants' essential characteristics.

As gleaned in Table 3, both groups' mean scores increased from the pretest to the post-test results, which could suggest a positive effect on their conceptual understanding with and without the SLM-R. It could be observed that the experimental group gained more in their scores (M = 3.32) than the control group (M = 0.89), which may imply the positive implications of the group with a module compared to the other. However, to validate this assumption, further analysis should be conducted to better analyze its impact.

		Pretest		Posttest		Gain	
Group	n	Mean	SD	Mean	SD	Mean	SD
Control	28	7.54	2.35	8.43	1.97	0.89	2.17
Experimental	28	8.18	2.76	11.50	3.32	3.32	3.42

Table 3. Descriptive statistics of the control and experimental groups

Table 4 determines the normality of the pre-and post-test scores between the two groups to investigate the normality of the data. Checking for its normality test is essential to decide on a suitable statistical tool.

Test	Group	KS test (p > 0.05)	Remarks
Pretest	CG	0.090	Normally Distributed
	EG	0.204	
Posttest	CG	0.150	
	EG	0.203	

Table 4. Test of Normality on pre-test and post-test of the two groups

With a Kolmogorov-Smirnov test to determine its normality distribution, the pretest and post-test scores of the two groups were analyzed. Based on the analysis, pretest findings for the control group, where D (28) = 0.090, $p > 0.05$, and the experimental group, where D (28) = 0.204, $p > 0.05$, were found to be normally distributed. Likewise, post-test results revealed normal distribution for the control and experimental groups, with values of D (28) = 0.150, $p > 0.05$, and D (28) = 0.203, $p > 0.05$, respectively. Thus, it can be implied that all data sets satisfied the conditions for applying parametric tests to determine the statistical significance.

With this at hand, paired t-tests and independent t-tests were used to compare the two groups and examine the data. As observed in Table 5, it can be noted that there was no significant difference [t (27) = 1.05; p = 0.302] in the pretest results of the control and experimental groups, signifying a similar entry level of knowledge in the conceptual understanding of the RCI test.

Group	n	Mean	SD	t	p	Interpretation
Control	28	7.54	2.35	1.05	0.302	NS
Experimental	28	8.18	2.76			

Note: NS = Not Significant

Table 5. Computed t-test for the Pretest of the Control and Experimental Groups

Moreover, the RCI test, as shown in Figure 2, supported the results, indicating that most students had gauged their answers at the "Guessing" (47%) and "Unconfident" (29%) levels of confidence for the control. In contrast, the experimental group had a dominant percentage of 30 in the "Guessing" level, followed by 25% in the "Neutral" scale. These results for the two groups indicated low confidence in the pre-test, suggesting little knowledge of the topics in relativity.

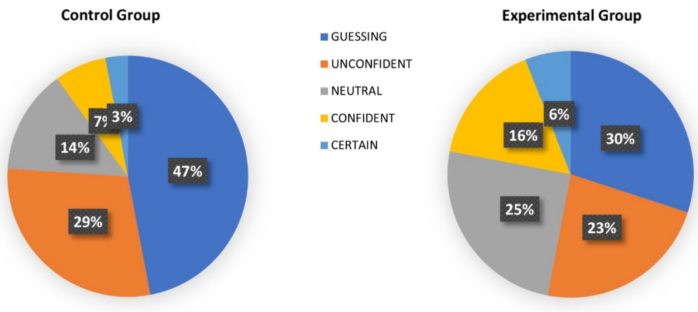

Figure 2. Percentage distribution of the confidence scale in the pretest

The two groups with and without the SLM-R's intervention were analyzed in Table 6 to examine the effect of the SLM-R.

Group	n	Pretest		Posttest		t	df	p-value	Effect (Cohen's d)	Interpretation
		Mean	SD	Mean	SD					
Control	28	7.54	2.18	8.43	1.97	2.18	27	0.038	0.43	Sm
Experimental	28	8.18	2.76	11.5	3.32	5.14	27	0.000	1.09	L

Note: Sm = small effect; L = large effect

Table 6. Computed t-test for Pre- and Post-test of the Control and Experimental Groups

Based on the results, the two groups showed positive effects in enhancing the conceptual understanding of the respondents since the computed p-value in the control group, [t (27) = 2.18; p = 0.038] and experimental group, [t (27) = 5.14; p = 0.000] were lower than the level of significance of 0.05. Both groups improved in the conceptual test, but the experimental group established a high impact on their learning, as indicated in the effect size (d=1.09). It can be inferred that the SLM-R may have significantly affected the experimental group's learning, suggesting they had experienced more learning than the control group.

In contrast, a small effect was observed for the control group (d = 0.43). Nevertheless, the control group, taught without the SLM-R, also increased their test results because the lecture method in science is still a popular and sufficient technique, especially in designing and implementing learning to a large number of students, and thus, could significantly improve student learning outcomes (Alaagib et al., 2019; Zakirman et al., 2019). The teaching method of the physics teacher in this study, regardless of the SLM-R, aided the control group in enhancing their understanding of the concepts. This manifests the teacher's unbiased and equal demonstration of teaching the subject in both classes. Hence, investigating the post-test gains between the two groups could be further analyzed to determine the value of the learning resource.

An independent-sample t-test was run (see Table 7) to determine if the self-learning module in Relativity enhanced students' conceptual understanding more than the class without the module. The results showed that the experimental group (M = 3.32, SD = 3.42) reported increased conceptual understanding, as indicated in their post-test results, than the control group (M = 0.89, SD = 2.17). This difference was significant [t (27) = 3.03, p < .05] and, accordingly, had a substantial effect (d = 0.85) on their scores. Therefore, based on this information, it could be implied that utilizing the SLM-R as an instructional intervention greatly affected the student's conceptual understanding relative to the control group.

Group	n	Gain		Difference	t	df	p-value	Effect
		Mean	SD					
Control	28	0.89	2.17	2.43	3.03	27	0.002 (S)	0.85 (L)
Experimental	28	3.32	3.42					

Note: S = significant, L = large effect

Table 7. Comparison of the level of improvement in the post-test scores between the Control and Experimental Groups

Interestingly, in most of the physics education research (PER) community, Hake's normalized gain (g) is often used to measure the impact of changes in students' learning (Madsen et al., 2016). Unlike Cohen's d effect size, commonly used across disciplines, Hake's g is primarily used in PER. According to Hake in Nissen et al. (2018), the average normalized gain roughly measures the effectiveness of a course in augmenting conceptual understanding. It is typically used to report scores based on research concept inventories, such as the RCI. Thus, this study also used this measure to strengthen the information gathered and to determine the effectiveness of the intervention.

As shown in Table 8, the mean and normalized gain for the pre-test and post-test results of the groups were compared to further support the claim.

Group	n	Pretest		Posttest		Mean Gain	Norm Gain	Interpretation
		Mean	SD	Mean	SD			
Control	28	7.54	2.18	8.43	1.97	0.89	0.07	Lo
Experimental	28	8.18	2.76	11.5	3.32	3.32	0.30	M

Note: Lo = low level; M = medium level

Table 8. Mean and Normalized Gain of Pre-test and Post-test results of the Control and Experimental Group

The experimental group acquired a better measure for promoting conceptual understanding than the control group. The norm gain (g = 0.30), which indicated a medium effect of the SLM-R to enhance students' conceptual understanding, suggests a more effective method than the group without the module (g = 0.07). The experimental group's medium-level result may be affected by their pretest scores, a common issue of utilizing normalized gain in different studies (Mckagan et al., 2022; Nissen et al., 2018; Stewart & Stewart, 2010).

Stewart and Stewart (2010) reveal that guessing in the pretest could significantly affect the results and the impact of intervention on student learning. Thus, Nissen et al. (2018) recommended avoiding using the g for it is biased in favor of high pretest means that may be brought by guessing and instead report using Cohen's d. In this study, it is worth noting that pretest results, as indicated in their confidence level (refer to Figure 2), exhibit high percentages of guessing their responses to the RCI test. Thus, this factor could be a plausible reason for the findings. Despite this case, it could still be observed that the experimental group performed better using the SLM-R than with the other group.

Figure 3 also substantiates the claims by exhibiting the students' confidence level change in the post-test. Unlike in the pre-test, where a high percentage have "guessed" their conceptual test answers, both groups progressively shifted their responses. In the control group, most students had previously "guessed" their responses and now had changed to the "neutral" level, with 64%. Meanwhile, the experimental group shifted their reactions to the "confident" level, with 39% dominating the tally. Hence, it can be implied that the experimental group using the SLM-R improved their conceptual understanding, as manifested in their post-test scores and confidence scale in choosing their responses to the RCI test.

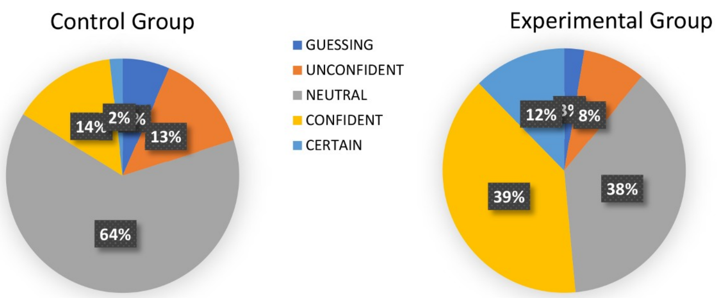

Figure 3. Percentage distribution of the confidence scale in the post-test

Additionally, entries from the SLM-R feedback form validated these quantitative data, as reflected in their comments on the module. According to them, the module helped them understand the abstract nature of Relativity. As emphasized in the following extracts, the resource material helped them learn and made it more accessible to comprehend.

> *"… this module allows us students to understand more concepts of relativity by breaking down the topics and it is well-distributed, information is well provided as well …"* **(Student A)**

> *"… The explanations & concepts in the module are quite detailed, which makes it easier for me to understand…"* **(Student B)**

> *"In complex subjects such as Physics, having an instructional material such as this is really useful. It helps us in becoming independent learners…"* **(Student C)**

> *"Serves as a simple, yet complete in concept type of study material; equations are easy to understand; concepts are well-defined."* **(Student D)**

> *"… it served as our guide by providing or presenting us with the concepts we need to learn…"* **(Student E)**

These students' feedback on their conceptual improvement is parallel to the findings of several studies, signifying that self-learning modules as an independent resource for students could contribute to helping them understand physics learning outcomes (Diansah & Asyhari, 2020; Hamid et al., 2022; Yuliono & Sarwanto, 2018).

The benefits of modular learning allow flexibility in their learning, empowering students to take control of their education and become accountable for their progress (Rahman, 2022). Likewise, the self-learning module enables them to develop confidence and establish their own study habits at their own pace and convenience (Sulaiman et al., 2023). These could be reflected in their feedback, presented in the remarks below.

> *"… It has clarified my ideas about STR and GTR, giving me lots of insights and a better understanding of the topic."* **(Student F)**

> *"… it has given me situations where I can imagine things I didn't use to. It has guided throughout my modphy lessons from STR to GTR."* **(Student G)**

> *"… it helps me understand the problems when I can not understand the topics when discussing inside the classroom."* **(Student H)**

> *"… I find the module useful because it has helped me learned the Theory of Relativity on my own pace."* **(Student I)**

The key terminologies such as *"…clarified my ideas…"*, *"…I can imagine things I didn't use to…"*, *"…it helps me to understand the problems when I can not understand the topics when discussing inside the classroom,"* are implied declarations of their gained confidence upon using the module. It could also entail active participation in one's learning, affecting one's self-efficacy.

Likewise, students expressed that learning at their own pace had a positive impact on their learning, as noted by Cramer et al. (2018), who observed that their academic performance and self-efficacy could be positively influenced when they effectively managed their time. Other remarks from Students J and H, respectively, also described their motivation (Yuliono & Sarwanto, 2018) to study in advance. Sentences emphasizing the phrase "*study in advance*" displayed their anticipation to learn more and inspired them to perform well.

> *"This module is advantage and useful because we can advance study…"* **(Student J)**

> *"… this module gives me a chance to study in advance for the next discussion."* **(Student K)**

Another factor that could have influenced their learning is the simplicity of discussing the complex concepts of relativity. Notably, Einstein's abstract idea of these mechanics is beyond one's imagination, and common sense should be discarded. Within this context, it can be observed from their comments, as shared accordingly by Students D, L, and M that the module made it easier for them to comprehend the abstract nature of this topic.

> *"Serves as a simple, yet complete in concept type of study material; equations are easy to understand; concepts are well-defined."* **(Student D)**

> *"… it presented the concepts in an effective and engaging way that helped me understand the material better."* **(Student L)**

> *"… clear and concise explanations of complex concepts"* **(Student M)**

According to Rico and Mendoza (2021), a significant criterion of a sound self-learning module is its content, which should not be limited to the following characteristics: concise, comprehensive, engaging, presents simplified concepts, and well-organized. A contextualized-based content of the instruction also plays a vital role in achieving effective and productive outcomes. With the 21^{st}-century skills of today's generation, real-life applications should likewise be adhered to in the content, and based on the student's remarks, the SLM-R reflected this criterion (emphasized by Student N).

> *"Studying the module in relativity has been really eye-opening. My understanding of space and time has changed…not only studying about concepts of basic physics, also has real-world application."* **(Student N)**

In summary, common themes were identified through thematic analysis and are summarized in Table 9. These recurrent themes, as reflected in the various feedback, were systematically coded.

Themes	Description
Theme 1: Conceptual Improvement	This theme emphasizes the positive change students acquire from the SLM-R. It reflects the understanding of concepts as they use it.
Theme 2: Self-efficacy Subtheme 1: Enhanced confidence Subtheme 2: Improved study habits	This construct encompasses the positive influence of the module that attributed to the enhanced behavior of the students, such as gained confidence and improved study habits.
Theme 3: User-friendly, easy to understand	This theme entails the quality of the module. The simple yet concise approach of the contents in the SLM-R shows the valuable learning they have acquired.

Table 9. Common Themes and Descriptions

Overall, this study has shown essential insights that could benefit a self-learning module in Relativity. Given the scarcity of contextualized instructional materials in relativistic mechanics, this learning resource could serve as a supplementary resource for students and teachers. As described in both the quantitative and qualitative results, using SLM-R provided a meaningful conceptual improvement and reinforced self-efficacy, affecting one's study habits and motivation.

4. Conclusion

This research study sought to determine the impact of the self-learning module in Relativity (SLM-R) in enhancing the conceptual understanding of third-year students with area of specialization in science. This module, which had undergone face and content validation by experts and was recommended for use, was employed in an actual classroom setting. Using an explanatory sequential research design, the quantitative data acquired in a quasi-experimental method were subsequently supported by qualitative inputs obtained from the student's feedback form of the module.

Based on the findings, using the SLM-R as a potential learning material provided students with an understanding of the concepts of Relativity, indicating improved test performance. The experimental group achieved better outcomes than those without the module, as shown by the significant difference between their pretest and posttest results. Also, as indicated in Cohen's d measure ($d = 0.85$), which suggests an important effect in terms of its practical significance, and the normalized gain of 0.30, indicating a medium level of conceptual improvement by the respondents, the impact of SLM-R achieved a valuable impact on their learning. With these results, students majoring in Science could use this self-learning module as supplementary instructional material in their Modern Physics course.

Further studies are encouraged, especially in developing instructional materials in Modern Physics. A well-structured, contextually relevant module is recommended to grasp the concept quickly. In this way, students could explore and appreciate the relevance of this less-tackled topic in Physics.

5. Limitations of the Study

This research endeavor acknowledges the various limitations that may affect the results. First, the study does not intend to compare the effects of the gender gap in the intervention. Therefore, any discussion of this aspect may not be addressed, as it primarily emphasizes the effect of SLM-R on classroom use. Second, the design, development, and validation of the material are excluded from this study. Hence, articulations of how the SLM-R was compared to existing materials are limited, and a separate study was conducted to address this. Third, the limited number of participants may influence the generalizability of the results. Hence, increasing the sample size could expand the generalizability of the findings. Fourth, the statistical tools employed in this study primarily focused on the effectiveness of the instructional material, which may limit the robustness of the data interpretation. However, potential threats to internal validity were carefully addressed by implementing actions to minimize them. Similarly, qualitative data were collected to support the claims.

Declaration of Conflicting Interests

The author declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author received financial support from Carlos Hilado Memorial State University for the publication fee of this article

Authors' contributions

The author confirms sole responsibility for the following: study conception and design, data collection, analysis and interpretation of results, and manuscript preparation.

Data availability

Data available upon request

Use of Artificial Intelligence

The author declares that she used the artificial intelligence tool "Grammarly" to improve some of the grammatical structure and punctuation.

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Journal of Technology and Science Education, 2026 (www.jotse.org)