Design, Development, and Validation of a Self-Learning Module in Relativity

Faith Celeste B. Ole
Carlos Hilado Memorial State University, Talisay City, Negros Occidental, Philippines
faith.celeste.ole@chmsu.edu.ph, faith.celeste29@gmail.com

Abstract

This study aimed to design, develop, and validate a Self-Learning Module in Relativity (SLM-R) for science education majors. Einstein's theory of Relativity, which is an abstract subject in Physics, is a fundamental topic that needs to be comprehended by science education students. This study used the instructional design of the Analysis, Design, Development, Implementation, and Evaluation (ADDIE). Based on the needs *analysis* identified as one of the priorities in the research agenda of the proponent's affiliated institution, developing instructional material (IMs) that could be used for instruction and better-equipped student learning is highly encouraged. Thus, an SLM-R resource was *designed* through Taba's Grassroots Approach and guided by the 4Es of an inquiry-based model. This IM was then *developed* and *implemented* for assessment by science experts and potential users. Based on the data triangulation in the *evaluation phase*, quantitative and qualitative data indicated the SLM-R's compliance with the standard reference set by the institution, suggesting a potential resource for students' and teachers' utilization. Qualitative feedback from potential users supported the quantitative results through their comments on the IM. Accordingly, the IM is helpful, and its well-presented activities challenge them to think critically. Hence, it is recommended that this SLM-R be pilot-tested for students to determine its efficacy on their conceptual understanding of Relativity.

Keywords:

ADDIE, Physics, Relativity, self-learning module, validation

Introduction

Modernity is an undeniable fact of life, as evidenced by the advancements in various frontiers of technology that have dramatically altered our ways of life. These technological achievements, particularly in electronics and communication systems, are only possible through scientific discoveries and innovations. The milestones of 20th-century science are now coming into fruition regarding technological applications that have improved our present quality of life. With this backdrop, 21st-century living is characterized by rapidly changing conditions as a result of fast-paced developments in technology. Consequently, people must have the proper knowledge and skills to adapt to a dynamic modern environment.

To prepare the current and future generations, emphasis must be given to a suitable approach for 21st-century education. Acquiring essential 21st-century skills belonging to three broad clusters of cognitive, interpersonal, and intrapersonal domains has become the primary goal of modern education (Bao & Koenig, 2019). Focusing on the cognitive aspect, various competencies are identified, which include deep learning, non-routine problem solving, systems thinking, critical thinking, computational and information literacy, reasoning and argumentation, and innovation (Bao & Koenig, 2019).

In particular, Physics education in the 21st century promotes high-end reasoning skills, which involve reasoning, creativity, problem-solving skills, and deep conceptual understanding that reflects high-end cognitive abilities (Bao & Koenig, 2019). This contrasts with the traditional Physics education that strongly emphasizes problem-solving drills, which only promotes memorization of formulas with little conceptual understanding. Furthermore, general Physics courses in high school and undergraduate levels, except for Physics majors, are heavily focused on classical physics, with classical mechanics taking the majority of classroom teaching. With this state, Modern Physics (MP) concepts such as relativity and quantum mechanics, foundational in most of the technological achievements of the 21st century, still need to be introduced to the learners.

The Philippine government has established programs that could elevate and ensure the quality of education and meet the global standards set forth by the 2030 Agenda for Sustainable Development Goal (SDG). Accordingly, education should ensure that inclusive, equitable, and quality education and promote lifelong learning opportunities for all must be achieved. For this to be attained, a deeper understanding of MP is inevitable, as this is essential in the innovation of technologies nowadays. Further strengthened by the Science for Change Program (S4CP) of the Department of Science and Technology (DOST) (DOST Science for Change Program, 2020), which aims to accelerate Science, Technology, and Innovation (STI), mastery and deep understanding of the physics concepts must be reinforced. One way to achieve this is through developing contextualized learning materials. Many studies (Abubakar, 2020; Aina, 2013; Fauzana et al., 2019) have shown that Physics is perceived to be difficult and an abstract science subject and requires solid mathematical computations (Erinosho, 2013; Eryılmaz Muştu & Şen, 2019; Russo & Adorno, 2018). However, research on fostering teaching materials in MP, specifically on Einstein's theory of relativity, is a rare teaching material developed by teachers. Thus, according to Suyatna et al. (2018), creating teaching materials on Einstein's relativity is essential for students to use independently, which will foster high-order thinking skills.

Furthermore, teachers who are also expected to have an adequate understanding of the topics find these topics difficult to teach (Eryılmaz Muştu & Şen, 2019). Ironically, most teachers handling physics subjects, especially in basic education, are not graduates of physics programs but of other fields, resulting in students' lack of understanding of the concepts (Gerada, 2021). These teachers who lack professional competencies may have an insufficient knowledge of the basic principles and concepts affecting students' learning and performance in physics. This, in effect, because of the nature of the subject, caused students' low science literacy achievement and reduced interest in pursuing physics-related courses (Abubakar, 2020).

The theory of Relativity by Albert Einstein, taught in the first half of the semester, is one of the essential topics in MP that need to be understood by future Science teachers. Due to the abstract nature of the course, mastery of physics concepts would be more effortless to achieve with the aid of instructional materials (IMs). Furthermore, no studies about teachers in the field of MP education in the Philippines have been found, a gap that should be focused on for students to be oriented with the modern world, which has become a more important concept to understand to enable people to catch up with developing technology.

Hence, the development of IMs, which inculcates high-end reasoning skills and deep conceptual understanding (Bao & Koenig, 2019), could be a vital resource for students and teachers to deepen their learning and aid their instruction, respectively. A module in Relativity is a rare learning material (Suyatna et al., 2018) that must be developed to help students overcome learning difficulties and teachers be given additional aid in facilitating their instructions. Thus, using Taba's Curriculum Development Model, also known as the Grassroots Approach (Bhuttah et al., 2020), this research endeavor designed and developed a Self-Learning Module in Relativity (SLM-R) for all students taking up a Bachelor of Secondary Education in Science for better conceptual understanding as well as for teachers who needed IM in teaching this field.

Research Objectives / Problem Statements

This study aims to design, develop, and validate a Self-Learning Module in Relativity (SLM-R) for science education majors. It specifically seeks to answer the following questions:

1. What is the needs *analysis* for developing the instructional material?

2. What model could be used to *design* the instructional material?

3. What could *be developed* to enhance the conceptual understanding of science education majors?

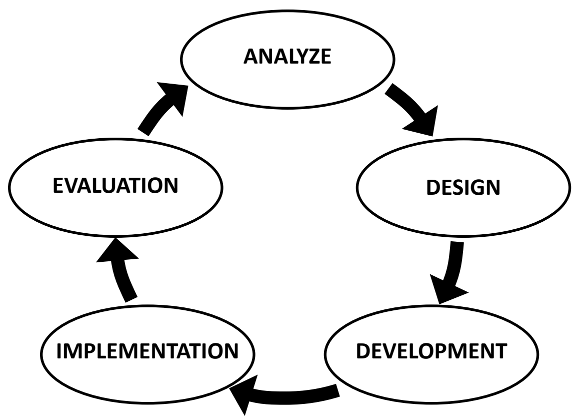
4. What could be *implemented* in the content *to improve the SLM-R?*

5. What are the results of the *evaluation phase* to enhance the conceptual understanding of science education majors in Relativity?

Framework

Figure 1

ADDIE Instructional Design of the Study



As shown in Figure 1, this study employed the ADDIE instructional design. Before developing this instructional material (IM), a needs analysis was conducted to determine students' achievement and motivation and plan programs or materials to increase their high-order thinking skills (Farihah et al. 2021). Based on the needs assessment of the affiliated institution, one of its research agendas is to produce and develop instructional materials that could enhance or uplift the quality of education. Anchoring on the BOR Resolution no. 87, s. 2022, also called the Research Agenda and Community Engagement Priorities, this resolution and the CHED Memorandum Order (CMO) No. 55, s. 2006 is an essential task for all teachers in their respective disciplines.

Similarly, CHED Memorandum 41 s. 2021 also explained that Higher Education Institutions (HEIs) are expected to develop flexible learning and teaching materials for offline and online delivery modes. Thus, designing and developing a self-learning module on relativity under modern physics was formed for a better teaching and learning experience for students and teachers. This learning material was rooted in Taba's Curriculum Development Model or the Grassroots Approach, wherein teachers design the teaching-learning units of students.

The implementation and evaluation stages were subjected to a face and content validation of the experts in the field. Any feedback (quantitative and qualitative) from this pool of experts was used to improve the IM.

Materials and Methods

Research Design and Environment

This study implemented a descriptive-evaluative research design. The quantitative and qualitative data acquired from experts and potential users were used to assess the developed SLM-R. The critical assumption of this approach was that qualitative and quantitative data provide different types of information—often detailed views of evaluators qualitatively and scores on instruments quantitatively—and together, the yielded results should be the same (Creswell, 2014).

Moreover, this study was conducted during the academic year of 2022-2023 in one of the SUCs in the province of Negros Occidental, located near the central part of the Philippine archipelago, which offers secondary education courses, particularly Science as its specialization.

As gleaned from Table 1, various processes were addressed to answer each research objective. To address and identify the need for research question # 1, the developed chart of the institution (see Figure 2) under the category of quality education and good governance served as a pivotal point in conducting the study. The BOR Resolution no. 87, s. 2022, also called the *Research Agenda and Community Engagement Priorities, and* CHED Memorandum 41 s. 2021 served as baseline data to consider developing instructional material that could be used to improve the quality of education in the institution.

Table 1

Summary of the processes undertaken in the study

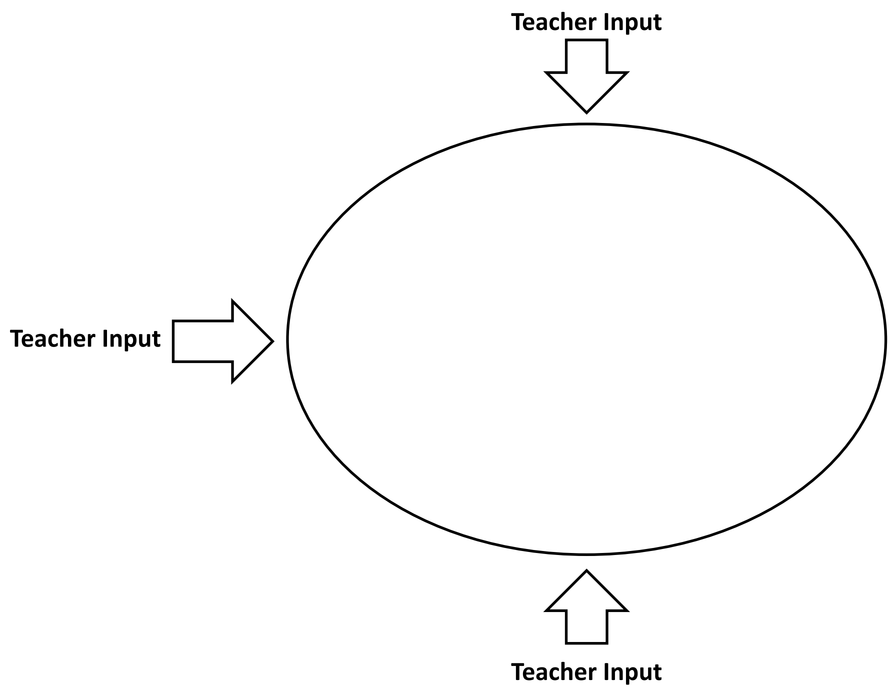
Research Questions	Participant/s	Instrument	Data Collection	Data Analysis
1. What is the needs analysis for developing the instructional material (IM)?	Proponent's affiliated institution	Chart from the Research Agenda Priorities	Institution's Research Agenda, CHED Memoranda	Descriptive Analysis
2. What model could be used to *design* the IM?	The proponent			Taba's Curriculum Development Model or the Grassroots Approach 4E's Instructional Model
3. What could be *developed* to enhance the conceptual understanding of science education majors?				
4. What could be *implemented* in the content *to improve the SLM-R?*	Physics/Science Experts and Potential Users	Instrument for Evaluating Instructional Materials (Board of Regent [BOR] Resolution No. 55, s. 2010) and Student's Feedback Tool	Questionnaires	Descriptive content analysis
5. What are the results of the *evaluation phase* to enhance the conceptual understanding of science education majors in Relativity?				Descriptive statistics and descriptive content analysis

Figure 2

Summary of Research Agenda and Community Engagement Priorities

Figure 3

Taba's Curriculum Development Model



After the proponent justified creating the IM, research question # 2 was addressed using *Taba's Curriculum Development Model or the Grassroots Approach,* as shown in Figure 3. Utilizing the steps of this model, the proponent designed the IM. Meanwhile, the resource learning material used the 4E's instructional model (explore, elaborate, expound, and extract) of an inquiry-based approach to aid students in enhancing their conceptual understanding of Relativity.

Consequently, research questions # 4 and 5 yielded similar methods in acquiring answers, such as the different faculty members known as "experts" in this study from several state universities and colleges (SUCs), Third-year Bachelor of Secondary Education major in science students (BSED-Science) who were called "target respondents or potential users," the questionnaires to be used and its data analysis.

Research Participants

Research participants who served as validators shared valuable suggestions and examined the learning material for a more substantial analysis and feedback that could enhance the module's content. Science or Physics tertiary teachers, called external validators, were sourced outside the province of the researcher's affiliated institution, while some were colleagues from within the institution, known as internal validators.

Overall, three (3) internal validators and two (2) outside-the-organization validators were tapped to assess the SLM-R *(evaluation phase)*. These evaluators provided comments and suggestions on the general aspects of the IM in terms of *content quality,* c*urricular value, appropriateness to user, organization,* and *packaging*. Table 2 shows the profile of the science and Physics experts who examined the IM.

Likewise, the Curriculum of Instructional Materials Development (CIMD) office chose the other three experts from the researcher's affiliated institution to evaluate the material. Their knowledge in the field of science was requested for the improvement of the developed IM.

Table 2

Profile of Evaluators

Experts	Faculty Rank	Area of Specialization	Type of Validator
1	Professor I	Physics	External
2	Associate Professor V	Physics	External
3	Associate Professor V	General Science	Internal
4	Assistant Professor I	Civil Engineering	Internal
5	Assistant Professor II	Civil Engineering	Internal

Aside from experts who validated the SLM-R, several Third-year BSED-Science students were tapped and requested to give feedback on the material using a convenience sampling method. These students were enrolled in a Modern Physics class during the Second Semester of the Academic Year 2022-2023. They voluntarily shared their written feedback using the validated questionnaire and evaluated the contents of IM. Before they were asked to give qualitative feedback, a consent form was provided stating the objective of the evaluation and how their comments could be helpful in the improvement of the IM.

Research Instrument

The five experts used an adopted tool from the affiliated institution called the "Instrument for Evaluating Instructional Materials" to assess the developed IM. This instrument has a 5-point category representing the five criteria in terms of content quality, curricular value, appropriateness to user, organization, and packaging for its objective evaluation.

In the content quality of the module, each evaluator would rate the following components: the *accuracy of contents, the amount and updatedness of material covered, the use of graphical inputs or illustrations,* and *the appropriateness of using references and citations.* With regards to its curricular value, the *congruency of contents to course objectives, promotion of self-learning, the usefulness of materials in aid of instruction, and its curricular relevance* were the areas that should be satisfied by the IM.

Moreover, in the material's *appropriateness to the user* category, such components must be observed (e.g., *user-friendly, promotion of interest in the subject, suitability to target clientele, consideration of the difficulty, and provision of user feedback).* The organization was also assessed based on the quality of the module outline, statement of learning outcomes, grammatical structure *and accuracy, organization of teaching and learning activities,* and *logical/clarity of presentation from beginning to end.*

Lastly, the packaging aspect of IM was also evaluated in terms of its *congruency of title with contents, its readability of texts and figures, the format based on approved standards, and the quality of cover design and binding materials.* Besides each stated standard, the evaluators could use any feedback or recommendations under the "Remarks" column to improve the IM.

Qualitative feedback was gathered using a questionnaire for the potential users or target respondents of the SLM-R. Any comments collected were used to support the quantitative aspects of the evaluation. Their feedback or suggestions were based on the following questions: *Did you find the module helpful? Why or why not? How would you rate the activities from 1 to 10, where 1 denotes poor, and 10 denotes very good? Cite the advantages and disadvantages you have encountered. What can you suggest or recommend for improving the module?*

Data Analysis Procedures

Descriptive statistics such as frequency distributions, means, and standard deviations were used to interpret and analyze the data. This study's quantitative aspect used each criterion's means to interpret and analyze the data. Table 3 shows the number codes, mean score ranges, and their corresponding descriptions in evaluating the instructional material.

Along with its statistical results, qualitative information was also acquired from science major students' comments or written feedback using a validated questionnaire. Using the descriptive content analysis, any remarks that could be gathered from

Table 3

Mean Score Ranges and their Description

Number Codes	Mean Score Ranges	Description
5	4.20 - 5.00	Excellent
4	3.40 - 4.19	Very Good
3	2.60 - 3.39	Good
2	1.80 - 2.59	Fair
1	1.00 - 1.79	Poor

the potential users were validated or reinforced from the quantitative data. Data triangulation from these sources could provide comprehensive information in assessing the IM's quality and increase the validity of this study's findings.

Ethical Consideration

In this study, various ethical considerations were highly considered. Each expert was sent a letter of request asking for ample time to evaluate the IM. No individual identities were reported, and codes were used for their protection. Students' participation was voluntary, assured with anonymity, and did not affect their class performance. They were informed about their participation and could withdraw anytime they wanted. All documentation was kept in locked files at all times.

Results and Discussion

This study employed the ADDIE instructional design, including the analysis, design, development, implementation, and evaluation phases. Each phase will be discussed thoroughly for a detailed research study process.

Analysis Phase

Based on the needs assessment of the identified priorities in the affiliated institution's research agenda, developing instructional materials (IMs) was inevitable. This research endeavor (supported by CHED's Memorandum 41 s. 2021) emphasizes the reinforcement of developing educational resources/ learning and teaching modules to uplift the country's education quality.

Likewise, being perceived as abstract, complicated, and theoretical, Physics remains students' least favored science subject (Erinosho, 2013). With its complexities, such as employing equations/formulas, problem-solving, theoretical/ conceptual understanding, spatial reasoning, and experimentation, the challenges it poses to students are expected.

Modern Physics, usually the last Physics course taken by students taking up a Bachelor of Secondary Education major in science, deals with the basic concepts and principles of special and general Relativity, wave-particle duality of light and electrons, and introduction to quantum mechanics. The theory of Relativity by Albert Einstein, which is taught in the first half of the semester, is one of the essential topics that need to be understood by future Science teachers. Due to the abstract nature of the course, mastery of physics concepts would be difficult to achieve without the aid of instructional materials (IMs). Therefore, creating a learning material in Modern Physics is inevitable.

Design Phase

A self-learning module anchored on Taba's Curriculum Development Model, also known as the Grassroots Approach, was the design of the developed IM. This model, where the teachers design the teaching-learning units of students, would be a primary source of science learning content for both the teachers and the students. It was designed for students by utilizing engaging activities that develop the acquisition of 21st-century skills.

Furthermore, the module's contents were categorized into three main sections: *brain gauge, learning circuit, and brain checkup-*. In the *Brain Gauge* section, the motivation aspect of the topic was presented. It can be a simple and fun activity to prepare the students for the lesson. It would give them an idea of what concepts or terminologies will be discussed in the coming lesson. This part could *diagnose needs* such as misconceptions or unfamiliar terms that would be essential in the topic.

The *Learning Circuit* part, considered the heart and soul of the learning contents, was structured based on the **4Es:** *Elaborate, Expound, Experience,* and *Extract*. Anchoring on the specified objectives *(formulation of objectives)* provided by the course syllabus *(selection of content)*, the *Elaborate* part of the module was the section that provided a comprehensive discussion of the concept (*organization of content*). It also includes several exercises, checkup questions, and trivia, guiding the students' learning process *(selection and organization of learning activities)*. The *Expound* section *(organization of learning activities and evaluation)* discussed the idea further and showed the interconnectedness of the current topic with other subject areas. It presented more in-depth discussions about the concept. The module's experience section or practice session aspect focused on the self-assessment question (SAQ) that needed to be answered or performed by the student to explore further what they have learned in the Expound section. This division of the learning circuit would be the "knowledge in action" aspect of the SLM-R in the form of problem-solving skills or simple inquiry questions. Answers to SAQ can be found at the end of each section via ASAQ. Finally, the *Extract* corner summarized all the essential points of the lesson. These crucial pieces of information have been presented in bullet form for efficient recall.

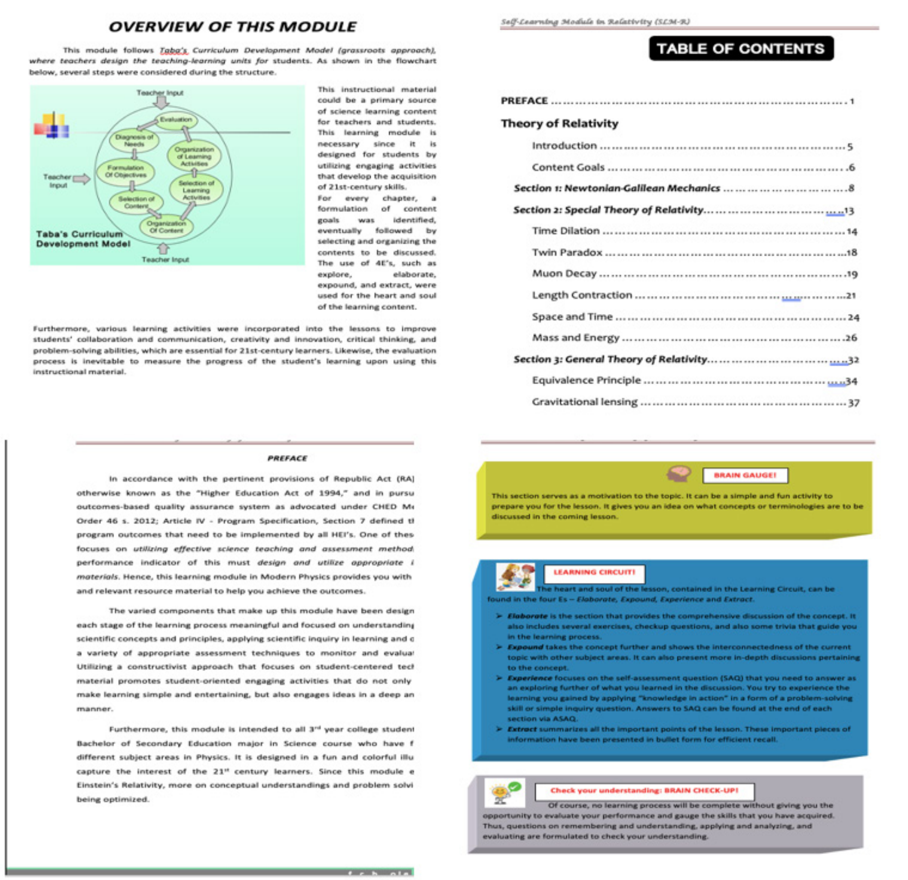
The last main section, called the ***Brain Check-up*** *(Evaluation)*, was an area that examined the learning progress of the students, an inevitable process of the IM. This was to measure the improvement of the student's learning upon using this material. The various learning activities were incorporated into the lessons to improve students' collaboration and communication, creativity and innovation, critical thinking, and problem-solving abilities, essential skills for 21st-century learners.

Development Phase

The development stage began with identifying a topic in Physics that should be developed for instructional

Figure 4

Images of key features of SLM-R



material. With the justification identified in the needs assessment, the next step proceeded into the formulation of the components of the IM based on Taba's Curriculum Development Model.

After selecting the topic, formulating and justifying the appropriate instructional design, and developing the IM called **Self-learning Module in Relativity (SLM-R)**, the subsequent stage concentrated on the revisions and validation processes of the evaluators.

As presented in Figure 4, other key features of SLM-R include the *module overview*, which discusses how it is anchored on Taba's Curriculum Development Model. It explained how a formulation of content goals was identified in every chapter, eventually followed by selecting and organizing the contents to be discussed. The use of 4E's, such as explore, elaborate, expound, and extract, were significantly used for the heart and soul of the learning content. The *table of contents* was divided into three sections: Newtonian-Galilean Mechanics, Special Theory of Relativity, and General Theory of Relativity. The *preface* section featuring the intended user of the SLM-R and its detailed descriptions of the *brain gauge, learning circuit, and brain check-up*, which was explicitly discussed in the design phase, is also included in the developed SLM-R.

Implementation Phase

This section focused on the improvement of the SLM-R. Based on the experts' (phase 1) and target respondents' (phase 2) content validation, the different feedback could be implemented to enhance the module's content. According to their feedback (refer to Table 4), SLM-R has great potential for students' perusal and could be a suitable teaching resource.

For phase 1, a Physics expert revealed the charm of the developed SLM-R, expressing how she loved reading it. Other experts who assessed the IM focused on the numerical rating and commented on adding more references to the materials. One of them also emphasized enlarging the size of the text for improved readability of the resource.

Meanwhile, in phase 2, target respondents or potential users explored the IM and wrote down their feedback. They mentioned that the activities in the SLM-R are presented well and effective in employing critical thinking. This can be seen in the extracts of their written feedback.

Table 4

Experts' and students' remarks or comments

Validators	Remarks or Comments
Experts	*"I loved reading the module."* *"Add more citations, include references"* *"Increase the size of the text to be readable"*
Potential Users/ Students	*"The activities are presented very well and allow learners to **think critically** and to engage their selves effectively."* **(S-A)** *"… various activities **enhance our understanding of the concept and problem-solving skills.** Some of the activities make me **think critically**. It provides more examples for us to understand the lesson better."* **(S-B)**

Note: S-A stands for Student A, and S-B for Student B.

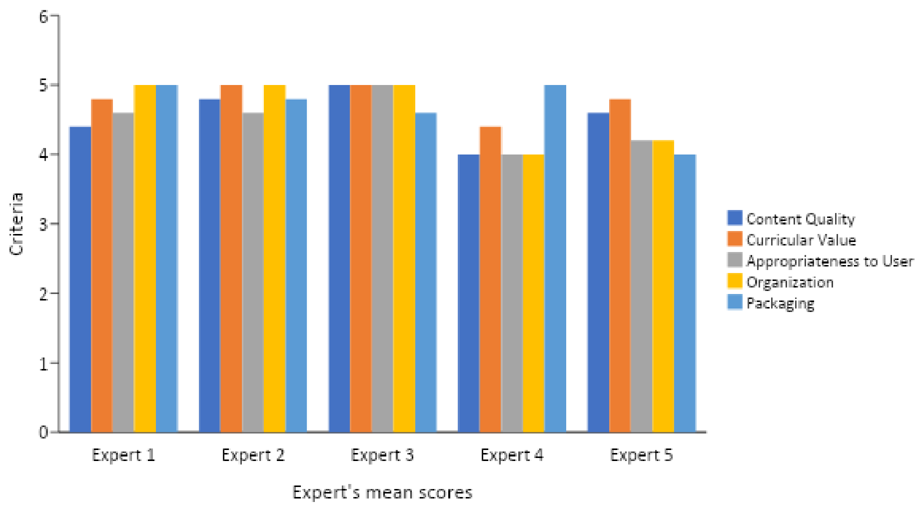
Using higher-order thinking skills (HOTS) instructional materials is fundamental to teaching and learning to elevate students' analytical abilities. If the IM is built on this component, students' metacognitive skills are also developed (Duraippah et al., 2021). Hence, with the feedback gathered from the respondents, it can be noted how their thinking was challenged, raised their cognitive demand, and enabled them to engage more in the process.

Evaluation Phase

In this phase, quantitative data from the adopted tool was analyzed. Based on the experts' ratings per criteria gleaned in Figure 5, an overall mean score of 4.63 was computed, which suggested an *Excellent* descriptive rating of the module. According to the evaluation decision reference of the tool, a mean range

Figure 5

Expert's overall mean scores per criteria



between 3.40 and 5.00 indicated that the developed IM was compliant with the standard reference set by the institution. Therefore, the SLM-R was an excellent resource material for the students' use and a teaching aid for the teachers.

Only a few remarks were suggested, such as additional citations and references to it and improving the readability of letters or text of the module. On the other hand, one of the experts mentioned the charm of the developed SLM-R, expressing how she enjoyed reading it.

Furthermore, to triangulate the quantitative results of the data, qualitative feedback from the potential users was identified for additional support to the gathered information. Based on the students' feedback, they all find the module valuable: *"The module is useful because **it** simplified the complex theories or divided the broad topic into small and easily comprehensible chapters/sections."*

Quality learning could be achieved if the learning material is structured and sequenced, which makes better sense to the students (Butcher et al., 2019). According to the article "Overview of the Understanding of Learning Modules and Main Functions" (2021), a self-instructional learning module can carry out learning activities with or without the guidance of a teacher. With this note, it can be gleaned from the students' narratives how the SLM-R gave better ways to understand the concepts. To wit, *"… the Special Theory of Relativity topic **is structured well**. **The ideas, concepts, and sample problems are presented**. This instructional material gives us a better understanding of our discussion"* **(S-D);** *"… this module helps us to understand Einstein's Theory of Relativity and its importance to our universe understanding… well-structured ideas and organized carefully"* **(S-E).**

According to Butcher et al. (2019), ensuring the learning materials are constructively aligned could aid deep learning. Thus, relating objectives with teaching/learning activities and assessment tasks is an essential module component. Clear and achievable goals (Burge, n. d.) are imperative when designing successful modules.

Moreover, a user-friendly arrangement must be considered when designing a learning medium. This could be achieved if students find it easy to understand, use, and enforce independent learning (Overview of the Understanding of Learning Modules and Main Functions", 2021).

Meanwhile, SLM-R's learner-centered approach could also be manifested, as shown in the feedback by Student F: *"First of all, the tone of the speech; it's in a conversational manner that makes it **more learner-***

***friendly**. The information stated is of **substantial importance and relevant to the learners. Also**, the topics are being applied to technologies and real life."* Accordingly, the tone of the conversation in the material implied a friendlier way of explaining the concepts.

The highlighted phrases that suggested positive feedback on the content, structures, and approaches determined its relevance to gaining students' knowledge and understanding of learning. According to Cramer et al. (2018), learning content is a crucial issue in enhancing students' learning experience in the context of higher education, and thus, activities or ideas included in the module must allow opportunities to better their academic performance.

Meanwhile, potential users have common suggestions for the improvement of IM, and this is centered on the additional provision of problem-solving exercises. According to them, *"I suggest that lots of problem-solving so that we could practice more in terms of our problem-solving skill."* **(S-G);** *"Additional example of problem-solving. Provide sample and pre-made exercises…"* **(S-A);** *"… the disadvantage of this instructional material is that the example problems to practice are very few… add more problems to solve for the next students that will utilize this learning module"* **(S-B).**

Conclusion and Recommendation

This research endeavor, which aimed to design, develop, and validate an instructional material, has been crafted to aid students in understanding the abstract concepts in Relativity. This product is envisioned to promote high-end reasoning skills and deep conceptual understanding in physics education, essential in the interplay between scientific discoveries and innovations. This learning material, the Self-Learning Module in Relativity (SLM-R), has been developed.

Based on the needs assessment indicated by the researcher's institution, developing instructional materials like SLM-R is achievable for all teachers. With the help of the ADDIE instructional design model, SLM-R has acquired an *excellen*t descriptive rating, which signified compliance with the institution's standard evaluation. Using Taba's Grassroots Approach, where teachers design and develop the teaching-learning units of students to inculcate and acquire 21st-century skills and the 4E's instructional model *(Elaborate, Expound, Experience,* and *Extract),* this IM could be a potential learning material for students and teachers to aid their instructions. Based on experts' and potential module users' assessments, SLM-R could foster an understanding of abstract concepts in Relativity to students and teachers, respectively.

It could be suggested that they find the developed material useful and well-presented in its activities that challenge them to think critically. Also, implications for using the ADDIE model suggest its extension and relevance to developing instructional materials. The model is inevitably not limited to designing training programs, a common attribute of this model.

Although one of its weaknesses was the lack of problem-solving exercises, the SLM-R achieved its objective of enhancing its conceptual understanding of Relativity in Modern Physics. These findings could imply that learning Einstein's theory of relativity becomes more interesting if a suitable resource is available. As learning content is crucial in enhancing students' learning experience, activities or ideas included in the module must allow opportunities to improve their academic performance.

Overall, this study was able to design, develop, and evaluate a rare learning material in Physics called the Self-Learning Module in Relativity (SLM-R). Based on the results, the SLM-R's capability as a resource material could enhance one's understanding of Einstien's usually abstract nature concepts. This was strongly supported by the quantitative and qualitative data obtained from experts and potential users, revealing its usefulness and well-presented content structures enabling readers to think critically. With these notions, this instrument could be an initial step in having the teachers, especially the curriculum planners, focus on this aspect of physics, emphasize modern physics, and not heavily dwell on classical physics.

Nevertheless, despite the strong potential of SLM-R to be an effective IM, it is highly recommended that this be used in the actual classroom setting to determine its effectiveness in enhancing students' conceptual understanding of Relativity. Likewise, improving the content, such as adding more problem-solving exercises, may be addressed. Another limitation of this study was that the scope of the topics focused on Einstein's Relativity only, based on the course syllabus approved by the researcher's affiliated institution.

Through the affirmation obtained from this study, future research could be explored by other researchers by developing similar modules, especially the quantum mechanics part of Modern Physics. Furthermore, researchers who intend to develop teaching materials in other areas of physics and sciences could use the ADDIE model to guide and design their instructional materials. Investigating different instructional designs and models could be vital tools in replicating the process of producing IMs.

• • •

References

Abubakar, M.B. (2020). Impact of instructional materials on students' academic performance in Physics, in Sokoto- Nigeria. 2nd International Conference on Civil & Environmental Engineering. *IOP Conference Series: Earth and Environmental Science.* doi:10.1088/1755-1315/476/1/012071

Aina, J. (2013). Instructional materials and improvisation in physics class: implications for teaching and learning. *IOSR Journal of Research & Method in Education (IOSR-JRME), 2,* 38-42.

Alstein, P., & Krijtenburg-Lewerissa, K., & van Joolingen, W. (2021). Teaching and learning special relativity theory in secondary and lower undergraduate education: A literature review. *Physical Review Physics Education Research, 17*. 10.1103/PhysRevPhysEducRes.17.023101.

Bao, L., & Koenig, K. (2019). Physics education research for 21st-century learning. *Disciplinary and Interdisciplinary Science Education Research 1*(2), 1-12. https://doi.org/10.1186/s43031-019-0007-8.

Bhuttah, T. M., Xiaoduan, C., Ullah, H. & Javed, S. (2020). Analysis of curriculum development stages from the perspective of Tyler, Taba and Wheeler. *European Journal of Social Sciences, 58*(1), 14 – 22.

Burge, A. (n.d.). *How to design effective teaching modules.* UACES. https://www.uaces.org/resources/articles/how-design-effective-teaching-modules.

Butcher, C., Davies, C., Highton, M. (2019). *Designing learning from module outline to effective teaching* (2nd Edition). Routledge. https://doi.org/10.4324/9780429463822

Cramer, K. M., Ross, C., Plant, L. & Pschibu, R. (2018). Efficacy of learning modules to enhance study skills. *International Journal of Technology and Inclusive Education (IJTIE), 7*(1), 1251 – 1259.

Creswell, John W. (2014). *Research design: Qualitative, quantitative, and mixed method approaches* (4th Edition). SAGE Publications, Inc.

DOST Science for Change Program. (2020, May 5). https://www.dost.gov.ph/9-programs-and-projects/1811-dost-science-for-change-program.html

Duraippah, K., Zahari Bin Hamidon, Z. B., & Ong, P. (2021). Using instructional materials to develop higher-order thinking skills. *ASEAN Journal of Open and Distance Learning, 13*(2), 83 – 96.

Erinosho, S.Y. (2013). How do students perceive the difficulty of physics in secondary school? An Exploratory Study in Nigeria. *International Journal for Cross-Disciplinary Subjects in Education (IJCDSE), 3*(3), 1510-1515.

Eryılmaz Muştu, **Ö**., & Şen, A.İ. (2019). A comparison of learning high school modern physics topics based on two different curricula. *Science Education International 30*(4), 291-297. https://doi.org/10.33828/sei.v30.i4.6

Farihah, M., Norawi, A., Nur Jahan, A. (2021). Game-based STEM module development for KSSM science teachers. *Journal of Turkish*

Science Education, *18*(2), 249- 262.DOI no: 10.36681/tused.2021.63.

Fauzana, Y., & Ratnawulan, R. & Usmeldi, U. (2019). The effectiveness of physics learning materials using problem-based learning model integrated with local wisdom. *Journal of Physics: Conference Series. 1185*. 012087. 10.1088/1742-6596/1185/1/012087.

Gerada, E. P. (2021). Development and evaluation of modules for senior high school physics teachers. *Multidisciplinary Research Journal (Formerly Patubas*), 53 – 90.

Hartini, S., Thaybah, M., & Mahtari, S. (2018, May 7-8). Developing of physics learning material based on scientific literacy to train scientific process skills. In *Journal of Physics: Conference Series, Yogyakarta, Indonesia.* Doi:10.1088/1742-6596/1097/1/012032.

Russo, A. & Adorno, D. P. (2018). An inquiry-based learning path to introduce modern physics in high school. *Journal of Physics,1076*. https://doi.org/10.1088/1742-6596/1076/1/012007

Suyatna, A., Distrik, I. W., Herlina, K., Suyanto, E. & Haryaningtias, D. (2018, September 21). *Developing an interactive e-book of relativity theory to optimize self-directed learning and critical thinking skills*. AIP Conference Proceedings 2014, 020065, Surakarta, Indonesia. https://doi.org/10.1063/1.5054469

Appendix A

Sample of Expert's Evaluation

INSTRUMENT FOR EVALUATING INSTRUCTIONAL MATERIALS

BOT Resolution No. 55, s.2010

INSTRUCTION

Evaluate the instructional material based on the stated criteria. Place a check mark on the number which represents an objective evaluation of the qualities of the material. You may make comments or recommendations under the column "Remarks" or at the back of the evaluation sheet.

The following are the number codes, mean score ranges and their corresponding descriptions:

Number Codes	Mean Score Ranges	Description
5	4.20 – 5.0	Excellent
4	3.40 - 4.19	Very Good
3	2.60 - 3.39	Good
2	1.80 - 2.59	Fair
1	1.00 - 1.79	Poor

Evaluation Decision Reference:

3.40 – 5.00 - Compliant - Passed
3.39 – 1.00 - Non-compliant - Failed

CRITERIA	1	2	3	4	5	REMARKS
I. Content Quality						
1. Accuracy of contents					✓	
2. Amount of material covered					✓	
3. Updatedness of materials					✓	
4. Use of graphical inputs/illustrations					✓	
5. Appropriateness of the use of references and citations					✓	
II. Curricular Value						
1. Congruency of contents to course objectives					✓	
2. Promotion of self-learning					✓	
3. Usefulness of materials					✓	
4. Aid to instruction					✓	
5. Curricular relevance					✓	
III. Appropriateness to User						
1. User-friendliness					✓	
2. Promotion of interest in the subject					✓	
3. Suitability to target clientele					✓	
4. Consideration of the degree of difficulty					✓	
5. Provision of users' feedback					✓	
IV. Organization						
1. Quality of module outline					✓	
2. Statement of learning outcomes					✓	
3. Grammatical structure and accuracy					✓	
4. Organization of teaching and learning activities					✓	
5. Logical/Clarity of presentation from beginning to end					✓	
V. Packaging						
1. Congruency of title with contents					✓	
2. Readability of texts and figures					✓	
3. Format based on approved standards				✓		
4. Quality of cover design				✓		
5. Quality of binding materials					✓	

Evaluator

4.92

CHMSC-CIMD-FO1
REVISION 02
AUGUST19, 2019

Appendix B

Sample of Expert's Evaluation

INSTRUCTION

Evaluate the instructional material based on the stated criteria. Place a check mark on the number which represents an objective evaluation of the qualities of the material. You may make comments or recommendations under the column "Remarks" or at the back of the evaluation sheet.

The following are the number codes, mean score ranges and their corresponding descriptions:

Number Codes		Mean Score Ranges		Description
5	-	4.20 – 5.0	–	Excellent
4	-	3.40 - 4.19	–	Very Good
3	-	2.60 - 3.39	–	Good
2	-	1.80 - 2.59	–	Fair
1	-	1.00 - 1.79	–	Poor

CRITERIA	1	2	3	4	5	REMARKS
I. Content Quality						
1. Accuracy of contents					✓	
2. Amount of material covered				✓		
3. Updatedness of materials					✓	
4. Use of graphical inputs/illustrations					✓	
5. Appropriateness of the use of references and citations					✓	
II. Curricular Value						
1. Congruency of contents to course objectives					✓	
2. Promotion of self-learning					✓	
3. Usefulness of materials					✓	
4. Aid to instruction					✓	
5. Curricular relevance					✓	
III. Appropriateness to User						
1. User-friendliness					✓	
2. Promotion of interest in the subject				✓		
3. Suitability to target clientele					✓	
4. Consideration of the degree of difficulty				✓		
5. Provision of users' feedback					✓	
IV. Organization						
1. Quality of module outline					✓	
2. Statement of learning outcomes					✓	
3. Grammatical structure and accuracy					✓	
4. Organization of teaching and learning activities					✓	
5. Logical/Clarity of presentation from beginning to end					✓	
V. Packaging						
1. Congruency of title with contents					✓	
2. Readability of texts and figures					✓	
3. Format based on approved standards					✓	
4. Quality of cover design				✓		
5. Quality of binding materials					✓	

Evaluator

Appendix C

Sample of Potential User's Feedback

STUDENT'S FEEDBACK

Name: ______________________ Gender: __________ Date: April 14, 2023

Course/Year & Section: BEED 4A-3A Age: 21 Instructor: __________

Directions: Kindly answer all the questions with honesty. Your feedback is of utmost importance for the improvement of this instructional material. Rest assured that your responses will be kept strictly confidential.

1. Did you find the module useful? Yes [✓] NO [ ]

   Why or Why not?

   Because it has an application of real life situation. The module is useful, because it simplified the complex theories or divided the broad topic into small and easily comprehensible chapters/section. Also it has activities to practice learning.

2. How would you rate the activities presented in the module from 1 to 10, where 1 denotes ***Poor*** and 10 denotes ***Very Good***? Why?

   I will rate 8.5 for the activities since they are simple and easy to comprehend with the use of simple word. However, further activities / problem solving exercise is needed to reinforce the module and give as choices for students.

3. Cite the advantages and disadvantages you have encountered using this module?

   Advantages: Straight forward, concise, simple, easily to comprehend. there are also notes for hints / clues and for the clarification. there are also interesting trivias / facts.

   Disadvantages: Limited Activities / need to supplement with external activities or exercises.

4. What can you suggest or recommend for improving this learning module?

   Additional example of Problem solving. Provide sample and pre-made exercises. Additional Glossary of terms / footnotes for vocabulary.

Thank you for your time!

Appendix D

Sample of Potential User's Feedback

STUDENT'S FEEDBACK

Name: ______________________ Gender: F Date: 4-14-23
Course/Year & Section: BSED SCI 3A Age: 21 Instructor: ____________

Directions: Kindly answer all the questions with honesty. Your feedback is of utmost importance for the improvement of this instructional material. Rest assured that your responses will be kept strictly confidential.

1. Did you find the module useful? Yes [✓] NO [ ]

   Why or Why not?
   Yes, because the topic about Special theory of Relativity is structured well. the ideas, concepts and sample problems are presented. this instructional material gives us the better ~~to~~ understanding of our discussion.

2. How would you rate the activities presented in the module from 1 to 10, where 1 denotes ***Poor*** and 10 denotes ***Very Good***? Why?
   We rate it ~~as~~ 8 because the information is well structured, However the example problems to practice are very few.

3. Cite the advantages and disadvantages you have encountered using this module?

   Advantages: through the help of this instructional material we can properly understand the discussion and to have a concrete reference to special theory of relativity.

   Disadvantages: the disadvantage of this instructional material for us is that the example problems to practice are very few

4. What can you suggest or recommend for improving this learning module?
   the suggestions or recommendation that could say to help improving this learning module is that we hope that this instructional material should add more concepts and examples of problems to solve for the ~~future~~ next students ~~to use~~ that will utilize this learning module

Thank you for your time!