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# Enhancing Secondary Students' Conceptual Understanding through Virtual Reality-Integrated and Guided Inquiry-Based Approach

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## Abstract

This study explored the effectiveness of a virtual reality (VR)-integrated guided inquiry-based learning module in enhancing Grade 7 students' conceptual understanding of heat and temperature—topics often associated with misconceptions. Conducted in a Philippine public school, the quasi-experimental study involved 32 students who completed pretests, posttests, and reflective questionnaires. Results indicated a statistically significant improvement in posttest scores ($p < 0.001$), demonstrating that the VR-enhanced approach effectively addressed conceptual gaps. Qualitative findings revealed increased engagement, improved visualization of scientific phenomena, and greater motivation to learn. Students noted that VR made abstract concepts more tangible compared to traditional methods. However, some reported mild physical discomfort, such as dizziness and eye strain, pointing to the need for ergonomic consideration in VR use. The study highlights the pedagogical value of VR in science education, offering immersive, inquiry-driven learning experiences that foster deeper understanding while emphasizing the need for thoughtful implementation to ensure student well-being.

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## Introduction

The evolving landscape of education continues to shift toward fostering deeper, more meaningful learning experiences, moving beyond the passive absorption of information toward nurturing conceptual understanding. This shift is especially critical in science education, where foundational concepts shape how learners interpret the world and influence their future academic and career trajectories (National Academies of Sciences, Engineering, and Medicine, 2018; Bransford, Brown, & Cocking, 2020). At the heart of this challenge lies the interplay between students' prior knowledge and the new ideas introduced in the classroom. Learners often arrive with intuitive beliefs formed through personal experience, cultural context, or everyday observation. While such preconceptions may initially help students make sense of phenomena, they often conflict with established scientific explanations, creating cognitive dissonance that impedes learning (Aldrich & Duran, 2016).

This tension between intuitive belief and scientific fact can lead to confusion, frustration, and resistance to learning, especially when instruction fails to bridge these conceptual gaps. As Mason (2014) argues, formal explanations that contradict personal experience can stifle curiosity, reduce engagement, and hinder motivation to explore. Over time, this cycle reinforces misconceptions, erodes confidence, and widens the gap between students' mental models and scientific understanding (Gomez-Zwiep & Straits, 2016). When left unaddressed, such misconceptions pose serious threats to students' progression in science learning, particularly in physics, where abstract concepts require high cognitive demand and deep comprehension. Misunderstandings also contribute to broader scientific illiteracy, limiting students' ability to apply knowledge to real-world problems (Santos et al., 2014; Tytler, 2014).

Globally, science education has transitioned toward inquiry-driven, constructivist approaches that cultivate critical thinking and problem-solving rather than rote memorization. This pedagogical shift aligns with calls for a scientifically literate citizenry—an urgent need in the face of complex global challenges such as climate change, public health crises, and technological advancement (National Science Board, 2015). However, persistent misconceptions remain a key barrier to achieving this goal. Students often perceive scientific knowledge as static rather than dynamic and evolving, which limits their engagement and hinders their appreciation of science as a process of inquiry (Smith et al., 2014; Brown & Lemieux, 2017).

In the Philippine educational context, significant reforms have sought to make science learning more hands-on, contextualized, and inquiry-based. Despite these efforts, persistent misconceptions—particularly in physics—continue to obstruct student understanding. Notably, the distinction between heat and temperature is frequently misunderstood, with students often conflating these two distinct but related concepts. This conceptual confusion hampers their grasp of thermal dynamics and energy transfer (Chiu et al., 2017; DepEd Tagbilaran, 2023). Filipino students, like many of their international peers, struggle with mechanisms such as conduction, convection, and radiation—core principles in understanding both everyday phenomena and larger scientific issues such as climate change (Kirkpatrick et al., 2015; Bernardo et al., 2017).

Empirical studies in the Philippine setting underscore the severity of these misconceptions. For example, Bernardo et al. (2017) reported that only 22% of high school students could accurately explain convection, while Singh et al. (2015) found that 40% of university-level students failed to apply heat transfer equations appropriately. These difficulties reflect broader limitations in science learning and pose obstacles to the national agenda for STEM advancement (Department of Education, 2013; National Economic and Development Authority, 2020). Moreover, conceptual misunderstandings in thermal physics hinder students' ability to understand environmental science issues, such as global warming, where accurate knowledge of heat transfer is essential (Kumar & Kaur, 2016).

Recent technological innovations offer promising solutions to these learning challenges. Virtual Reality (VR) has emerged as a powerful tool for enhancing science education by providing immersive, interactive experiences that allow students to visualize and manipulate abstract concepts in safe and engaging environments (Fowler & Rojas, 2015). VR enables students to observe phenomena—such as molecular behavior during heat transfer—that are otherwise invisible or too dangerous to replicate in a typical classroom. Studies show that VR enhances engagement, supports spatial reasoning, and improves conceptual retention (López et al., 2018). Additionally, it fosters collaboration, communication, and deeper inquiry, aligning with essential 21st-century competencies (Bailenson et al., 2018).

When paired with Guided Inquiry-Based Approaches (GIBA), VR becomes even more effective. Guided inquiry scaffolds students' cognitive processes by structuring exploration around critical questions, hands-on experiences, and reflective tasks. This combination promotes self-directed learning while ensuring instructional support, which is essential when addressing entrenched misconceptions (Winn, 2016; López-Muñoz et al., 2017; Dede, 2014; Huang et al., 2019). The integration of VR and GIBA represents a pedagogical synergy that can bridge the conceptual gaps between students' intuitive beliefs and scientific principles.

This study investigates the effectiveness of a Virtual Reality-integrated Guided Inquiry-Based Approach in addressing Filipino Grade 7 students' misconceptions about heat and temperature. Anchored on the localized pedagogical model LIKNAYHUSAY, the intervention aims to uncover, confront, and correct these misconceptions through experiential learning and structured inquiry. In doing so, the research contributes to the broader goal of cultivating scientific literacy and empowering learners to engage critically with real-world issues such as climate change. Findings from this study are expected to inform instructional design, curriculum development, and policy efforts aimed at enhancing the quality and equity of science education in the Philippines.

## Literature Review

### Misconceptions in Heat and Temperature

Students often enter physics classrooms with pre-existing, intuitive ideas about heat and temperature, which can conflict with scientific principles and hinder conceptual understanding. These misconceptions, if unaddressed, become entrenched and resistant to change (None Saparini et al., 2020). Studies reveal that many students struggle to distinguish between heat and temperature, frequently believing that objects with higher temperatures inherently contain more heat (Falcunya et al., 2020; Alwan, 2011). Such misconceptions not only impede comprehension of thermal energy transfer but also limit students' readiness for advanced science learning.

Addressing these misconceptions through modern instructional approaches is crucial. Research shows that strategies focused on conceptual change, such as simulations and targeted scaffolding, positively impact students' understanding and retention of scientific concepts (Turgut & Gurbuz, 2014). Effective teaching must therefore prioritize replacing inaccurate prior knowledge with scientifically accurate explanations, particularly in the area of thermodynamics.

### Conceptual Understanding in Science Education

Misconceptions about heat and temperature are prevalent among students, often rooted in intuitive but inaccurate prior knowledge. Learners commonly equate temperature with the amount of heat or believe that objects at higher temperatures contain more heat—errors that hinder understanding of thermal energy transfer (Falcunya et al., 2020; Alwan, 2011; None Saparini et al., 2020). Without targeted intervention, these misconceptions become deeply ingrained. Instruction focused on conceptual change—particularly through simulations and scaffolding—has shown promise in facilitating accurate understanding (Turgut & Gurbuz, 2014).

Achieving conceptual understanding requires organizing knowledge into coherent mental frameworks and challenging faulty beliefs (Saputra & Mustika, 2022). However, traditional instruction has had only modest success in improving students' scientific understanding (Mekonen, 2014; Noh et al., 2016; Omar, 2017; Putri, 2017; Mengistu et al., 2022). Emerging research calls for active, cognitively engaging approaches that promote meaningful learning and real-world application (Vaiopoulou et al., 2023; Widiyatmoko & Shimizu, 2018).

Virtual Reality (VR) offers an immersive platform to support conceptual change, especially in abstract domains like thermodynamics. VR enables learners to visualize molecular behavior, manipulate variables, and directly interact with heat transfer mechanisms, fostering accurate mental models and sustained engagement (Kim et al., 2019; Durukan et al., 2020; Liu et al., 2020). When integrated with guided inquiry, VR also encourages reflection, exploration, and deeper cognitive processing (Fabris et al., 2019).Simulation-based learning more broadly—including computer and mobile simulations—has also proven effective. Interactive platforms help visualize heat transfer and correct misconceptions when paired with scaffolds and prompts (Liu et al., 2018; Mendez & Kearney, 2020). Mobile apps further enhance engagement through gamified and personalized experiences, promoting positive learner attitudes and deeper cognitive involvement (Karabatzaki et al., 2018; Chuchu & Ndoro, 2019; Rocque, 2022).While international studies support these innovations, localized evidence remains scarce. In the Philippines, few studies have explored VR-integrated inquiry-based instruction targeting thermal misconceptions among junior high school learners. This study addresses that gap by introducing LIKNAYHUSAY, a culturally responsive intervention designed to enhance conceptual understanding and address misconceptions in heat and temperature using VR and guided inquiry.

### Research Questions

This study aims to address misconceptions and enhance conceptual understanding of heat and temperature through a VR-integrated Guided Inquiry-Based Approach. Specifically, it answers the following questions:

1. How may the Virtual Reality Science Simulation-based module be developed and validated in terms of:
    - 1.1. Content: features of VR science simulation, quality of content, and relevance;
    - 1.2. Design: ease of use, visual and auditory elements, and device compatibility?
2. How may students' misconceptions and conceptual understanding of heat and temperature be described prior to and after exposure to the VR science simulation?
3. Is there a significant improvement in students' conceptual understanding of heat and temperature after exposure to the VR science simulation?
4. What are the students' perceptions, insights, and experiences during the VR-based inquiry learning?

## Methodology

### Research Design

This study employed a quasi-experimental, mixed-methods design to examine the effectiveness of a VR-integrated Guided Inquiry-Based Approach in addressing students' misconceptions and enhancing conceptual understanding of heat and temperature. The quantitative component involved pre- and post-tests to measure learning gains, offering objective data on the intervention's impact (De Belen, 2015). The qualitative component consisted of interviews that explored students' misconceptions and perceptions in depth. A quasi-experimental approach was used due to the absence of random assignment, allowing for practical implementation in real classroom settings while ensuring valid evaluation of the instructional intervention (Shadish, Cook, & Campbell, 2002).

### Research Locale and Participants

The study was conducted with 32 Grade 7 students from a public school in Pulilan, Bulacan, Philippines, during the 2024–2025 academic year. Participants were selected through convenience sampling, based on availability, consent, and proximity. These students were chosen because heat and temperature are key topics in the Grade 7 science curriculum under the Department of Education's Matatag Curriculum, ensuring relevance and curricular alignment. This allowed for an accurate assessment of conceptual understanding and common misconceptions related to heat transfer. The research was carried out in person, with informed consent secured from the school, parents, and student participants. The school was selected for its openness to research-based instructional innovations, supporting the study's aim of exploring effective strategies to improve science learning outcomes.

### Research Instruments

*Checklist for Development and Validation of the VR-Integrated Guided Inquiry Based Approach*

To ensure the systematic development and implementation of the instructional intervention, a Checklist for Development and Validation of the VR-Integrated Guided Inquiry-Based Approach (GIBA) was utilized. It served as both a developmental and evaluative tool, guiding the creation of the VR Science Simulation and ensuring its alignment with pedagogical principles and curriculum standards. The checklist assessed four key domains: User Experience & Engagement, Conceptual Understanding & Misconceptions, Instructional Design & Integration, and Reflection & Evaluation. A 4-point Likert scale was used to measure the level of agreement with each item.

The User Experience & Engagement component evaluated the accessibility, intuitiveness, and interactivity of the simulation, focusing on its ability to engage learners through immersive features. The Conceptual Understanding & Misconceptions domain reviewed how effectively the simulation addressed common misconceptions related to heat and temperature, ensuring that scientific explanations were accurate and inquiry-driven. The Instructional Design & Integration section examined the coherence of the content and its alignment with the MATATAG Curriculum competencies, assessing how well the simulation was embedded in the learning experience. Lastly, the Reflection & Evaluation component explored how the simulation supported learners' ability to reflect on their understanding and monitor their progress. The validation process involved expert review by nine (9) science content and curriculum specialists, one (1) language validator, and one (1) software validator. Their feedback guided the refinement of the simulation, ensuring its instructional quality, scientific accuracy, and effectiveness in achieving the intended learning outcomes.

*Adapted and Modified Content Evaluation Rating Sheet (AMCERS)*

To ensure the quality and credibility of the developed instructional module, the study utilized the Adapted and Modified Content Evaluation Rating Sheet (AMCERS). This instrument was based on the standards outlined in DepEd Memorandum No. 167, s.2021 – Enclosure No. 4.1, and was tailored to evaluate the content validity of the VR-integrated guided inquiry learning material. The researcher adapted the criteria and modified the scoring system into a 4-point Likert scale to measure the level of agreement across key content indicators. AMCERS includes six sections that holistically assess instructional quality. The Learning Competencies section examines the module's alignment with DepEd-prescribed learning competencies and evaluates the logical progression of content relative to the cognitive level of Grade 7 learners. The Instructional Design and Organization section reviews the effectiveness of lesson sequencing, content appropriateness, and the integration of strategies that promote engagement, such as overviews, organizers, puzzles, and games. The Readability section ensures that vocabulary, sentence structure, and paragraph organization are suitable for students' comprehension levels and that the module presents ideas clearly and cohesively. The Assessment and Evaluation section focuses on the presence and clarity of tools for gauging learner progress. It examines the alignment between assessments and competencies, the inclusion of varied assessment types, and the clarity of rubrics and instructions. Through AMCERS, the instructional material was rigorously evaluated to confirm its relevance, coherence, and effectiveness in supporting the intended learning outcomes.

*Heat and Temperature Conceptual Understanding Test (HTCUT)*

To assess students' conceptual understanding of heat and temperature, the researchers developed the Heat and Temperature Conceptual Understanding Test (HTCUT), administered as both a pre-simulation and post-simulation assessment. The instrument was designed to measure students' baseline knowledge prior to the intervention and evaluate learning gains following exposure to the VR Science Simulation. It consisted of 20 multiple-choice questions, each with four answer options and one correct response, covering topics such as thermal conductivity, the distinction between heat and temperature, heat absorption by materials, and real-world applications of heat transfer. The test included a mix of lower- and higher-order thinking skills, and the maximum score was 20.To ensure validity, the HTCUT was reviewed by two science education experts and one language expert for content accuracy, clarity, and appropriateness. The test yielded quantitative data used to determine the effectiveness of the VR-integrated Guided Inquiry-Based Approach in improving students' conceptual understanding of heat and temperature.

*Student Reflective Questionnaire (SRQ)*

After the intervention, students completed the Student Reflective Questionnaire (SRQ), which was designed to capture qualitative data related to engagement, motivation, and conceptual understanding based on their experiences with the simulation. This feedback tool allowed students to express their thoughts and reflections on their learning journey during the VR intervention.

The SRQ included open-ended questions that encouraged students to freely share their experiences, challenges, and suggestions for improvement. This enabled the researchers to gather rich, descriptive feedback, helping to identify areas for improvement, such as specific student difficulties or aspects of the VR simulation that could be enhanced. This qualitative data complemented the quantitative data collected from the Heat and Temperature Conceptual Understanding Test (HTCUT), providing a more holistic view of the intervention's impact on students' learning.

*Components of Student Reflective Questionnaire (SRQ)*

To complement the quantitative data gathered from the Heat and Temperature Conceptual Understanding Test (HTCUT), the Student Reflective Questionnaire (SRQ) was administered after the intervention to collect qualitative feedback on students' experiences with the VR Science Simulation. The SRQ was designed to capture student reflections on engagement, motivation, immersion, and technical challenges, providing deeper insights into how the intervention influenced their learning process. The questionnaire consisted of open-ended questions, allowing students to freely articulate their thoughts, challenges, and suggestions for improvement. This qualitative data offered a richer understanding of the VR learning environment and helped identify factors that either enhanced or hindered conceptual understanding. The SRQ was organized into three key components. The Engagement and Motivation section explored how the simulation influenced students' interest and enjoyment in learning about heat and temperature. The Immersion and Presence section assessed students' sense of being part of the virtual environment and how the simulation sustained their attention. The Technical Issues section addressed students' experiences with the functionality and compatibility of the VR tool, identifying any problems that may have affected their learning.

**Teaching Intervention**

The teaching intervention was anchored on the 7E Instructional Model and implemented through a structured integration of the VR Science Simulation into classroom discussions. As shown in Figure 1, the flow began with the "What I Need to Know?" phase (Elicit), which clarified the skills and competencies students were expected to achieve, setting a clear learning focus.

The “Activating Schema” phase (Engage) consisted of two parts: Part A activated prior knowledge about heat and temperature, while Part B encouraged students to recall their previous understanding and identify existing misconceptions. This was followed by the “VR-AGHAM Inquiry Task” (Explore), where students engaged in a guided inquiry using the VR simulation. In this phase, they manipulated different materials and variables to explore heat and temperature concepts within a safe, immersive environment, thereby linking prior knowledge with new learning.

Next, in the “Virtual Reality Temperature Trek” (Explain), students participated in deeper conceptual inquiry, examined the mechanisms of heat transfer, and began addressing the misconceptions identified earlier. The “Digging Deeper!” phase (Explain) further provided structured discussions to solidify understanding by connecting VR experiences with scientific explanations. In the “Extend Your Thermal Knowledge!” phase (Elaborate), students applied their conceptual understanding to real-world contexts through targeted activities, reinforcing key ideas and addressing lingering misconceptions. This was followed by the “Learning Check!” phase (Evaluate), where various formative assessments were conducted to measure mastery of heat and temperature concepts. Finally, the “Debrief the Thermal Experience!” phase (Extend) encouraged students to reflect on their learning, integrate new knowledge, and consider its application in novel situations. This comprehensive approach aimed to foster deep, lasting understanding while leveraging the immersive and interactive strengths of VR to support inquiry-based learning.

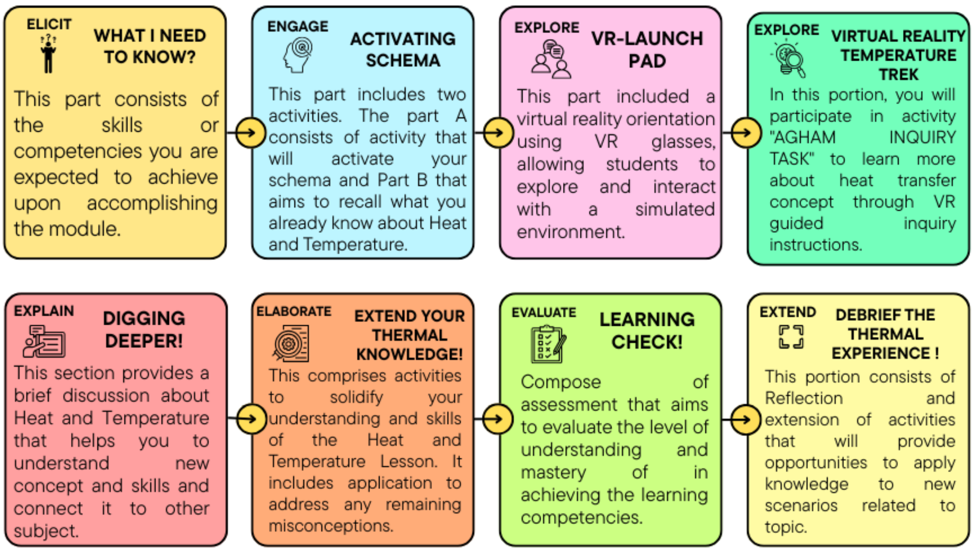


Figure 1. Implementation of VR Science Simulation in Class Discussions using 7E’s Framework

**Research Procedures**

This study followed the ADDIE instructional design model, which consists of five phases: Analysis, Design, Development, Implementation, and Evaluation (Figure 2). The ADDIE model was selected as it provides a systematic and flexible framework for developing educational interventions and has been shown to improve instructional effectiveness by offering a structured, iterative approach (Smith & Johnson, 2019). Each phase guided the planning and execution of the research to ensure that the VR-integrated Guided Inquiry-Based Approach (GIBA) was pedagogically sound and aligned with the intended learning outcomes.During the Analysis phase, the researchers identified the target audience, defined the learning goals, and examined prevalent misconceptions about heat and temperature among Grade 7 students. Through a review of curriculum standards and student difficulties, the need for an interactive, inquiry-based strategy was established. These findings informed the research objectives and set the foundation for instructional planning.

The Design phase involved the formulation of specific learning objectives and the structure of the VR-integrated lessons. The lessons were aligned with the MATATAG Curriculum and carefully sequenced to promote conceptual change. This phase also included the design of assessment tools and validation instruments such as the HTCUT and AMCERS.In the Development phase, the VR Science Simulation module and supporting instructional materials were created and refined. Content experts, curriculum specialists, and validators reviewed the materials to ensure accuracy, clarity, and alignment with scientific and pedagogical standards. This stage also included the programming of the VR module and the integration of guided inquiry tasks.The Implementation phase focused on the delivery of the intervention to a group of Grade 7 students in a public school. The VR-integrated guided inquiry lessons were conducted in-person, and participants engaged with the simulation and accompanying activities over the course of the intervention. Ethical protocols were followed, including informed consent from school authorities, parents, and students.Finally, the Evaluation phase involved the administration of pre- and post-tests (HTCUT) to measure students' conceptual understanding, as well as the Student Reflective Questionnaire (SRQ) to gather qualitative feedback. The results were analyzed to assess the effectiveness of the intervention in improving student learning and addressing misconceptions, and to identify areas for further refinement and improvement.

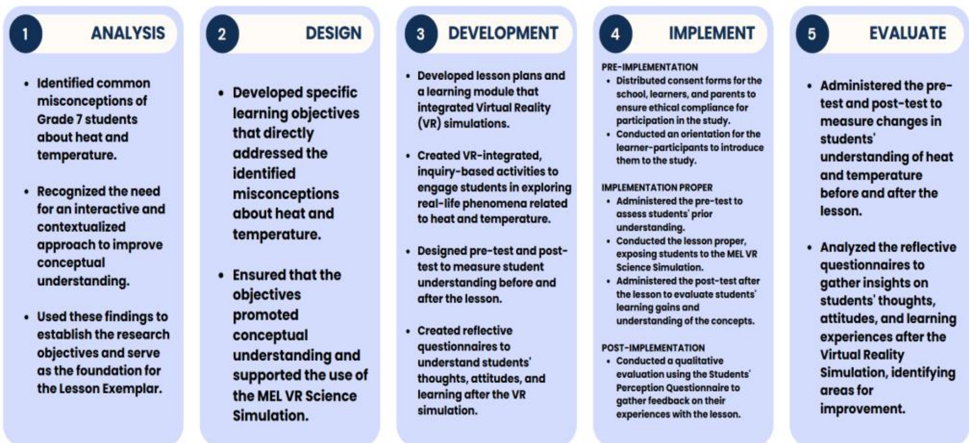


Figure 2. ADDIE Instructional Model

**Data Analysis**

This study employed a mixed-methods approach to evaluate the effectiveness of a VR-integrated Guided Inquiry-

Based module on students' conceptual understanding of heat and temperature. Expert validation of the VR module was conducted, with Cronbach's Alpha confirming high internal consistency ($\alpha \geq 0.80$), and qualitative ratings affirming its pedagogical soundness and curriculum alignment. Students' misconceptions and understanding were assessed using the Heat and Temperature Conceptual Understanding Test (HTCUT). Pre- and post-test scores were analyzed using means, standard deviations, and mean percentage scores (MPS), while the Wilcoxon signed-rank test determined significant learning gains. To complement these findings, qualitative data from the Student Reflective Questionnaire (SRQ) underwent thematic analysis. Emerging themes—such as engagement, conceptual clarity, and technical challenges—highlighted how the VR environment enhanced visualization and motivation while revealing areas for improvement. The integrated findings demonstrate that VR-supported guided inquiry promotes both cognitive and affective learning gains, effectively addressing persistent misconceptions in thermal physics.

## Results and Discussion

### Development of VR Integrated Guided Inquiry Based Approach Pedagogy

To effectively implement the VR-Integrated Guided Inquiry-Based pedagogy, which aims to address student misconceptions and enhance conceptual understanding, a researcher-developed learning module will be utilized as the primary instructional tool. This module is aligned with the Department of Education (DepEd) Grade 7 MATATAG Curriculum and is designed to meet the validation criteria set by subject matter, technology, and language experts. Serving as the foundation of the research, the module contains comprehensive content, structured learning activities, and clear instructional guidelines that align with the lesson objectives, ensuring both pedagogical coherence and content accuracy.


Figure 3. *Development of VR Integrated Guided Inquiry Based Approach Pedagogy*

Figure 3 shows the *Development of the VR-Integrated Guided Inquiry-Based Approach Pedagogy*, illustrating the systematic process followed in designing, implementing, and refining the instructional strategy used in the study.

The process began with the selection of a physics topic based on the least mastered competencies, identified through diagnostic assessments and test data. This ensured the intervention targeted a conceptually challenging area with high potential for meaningful improvement. Once identified, learning objectives were formulated according to the MATATAG curriculum, focusing on promoting scientific reasoning and concept mastery. To support the integration of immersive learning, permission was obtained to use the MEL VR Science Simulation platform through a free trial provided by Vassili Moren, ensuring alignment with ethical and institutional guidelines. With the core content and tools established, a lesson exemplar was created using the 7E's instructional framework (Elicit, Engage, Explore, Explain, Elaborate, Evaluate, Extend), embedding VR tasks into each phase to stimulate curiosity, enable interactive exploration, and deepen conceptual understanding through inquiry.

Following this, a detailed learning module was developed, combining guided inquiry strategies with VR-enhanced simulations. Activities were scaffolded to guide students from virtual experimentation to abstract scientific thinking. Simulations allowed learners to manipulate variables, collect virtual data, and test hypotheses, while embedded inquiry prompts facilitated critical thinking and conceptual development. The guided inquiry process was fully integrated into the module, aligning instructional flow with scientific practices such as questioning, investigating, analyzing, and drawing conclusions. Teachers were provided with facilitation tips, discussion questions, and reflection tools. The module was then validated by subject matter experts, master teachers, and curriculum specialists, who reviewed it for content accuracy, pedagogical soundness, and appropriateness of the VR integration. Based on their feedback, revisions were made to improve clarity, correct scientific inaccuracies, streamline instructions, and include real-world examples. Fair testing principles were emphasized, and guiding questions were refined to enhance student observations, especially in tasks involving temperature changes and molecular behavior. A final quality check was conducted to ensure the module's coherence, functionality, and readiness for classroom use, supported by finalized materials such as teacher guides, rubrics, and reflection sheets. This structured development ensured the module effectively addressed misconceptions, supported conceptual understanding, and enhanced learner engagement through immersive, inquiry-driven instruction.

**Science Experts Validation of VR-Integrated Guided Inquiry Based Approach in Virtual Reality Integration as regards Virtual Reality Integration**

Table 1 presents the consolidated average ratings from expert validators evaluating the Virtual Reality-Integrated Guided Inquiry-Based Approach Module for Heat and Temperature, specifically in terms of its integration of virtual reality. The evaluation focuses on four key domains related to VR integration: User Experience and Engagement, Conceptual Understanding and Misconception, Instructional Design and Integration, and Reflection and Evaluation. These ratings reflect the overall effectiveness and quality of the module in supporting meaningful learning through the integration of virtual reality. Each criterion was assessed in terms of its quality and effectiveness through the use of mean (M), standard deviation (SD), and the corresponding verbal interpretation (VI).

The highest mean scores were recorded in the domains of User Experience and Engagement, and Instructional Design and Integration, both with a mean of 3.878 and a standard deviation of 0.308, receiving a verbal interpretation of "Very Evident." These results indicate that the module is both highly engaging and user-friendly, while also exhibiting strong instructional design and coherence. The next highest domain, Conceptual Understanding and Misconception, received a (M = 3.848, SD= 0.311), also interpreted as *"Very Evident."* This demonstrates the module's effectiveness in promoting accurate conceptual learning and addressing students' misconceptions related to heat and temperature. The domain of Reflection and Evaluation, although slightly lower, still attained a high rating of (M = 3.818, SD = 0.345) and a verbal interpretation of *"Very Evident",* indicating that the module effectively supports learners in evaluating their understanding and recognizing areas that need improvement. The overall average rating across all four domains (M = 3.855, SD = 0.318), which also corresponds to a *"Very Evident"* interpretation. These consistently high ratings across domains confirm strong agreement among expert validators regarding the module's quality and effectiveness. The minimal range of standard deviations (0.308 to 0.345) further underscores the high level of consistency and reliability in their evaluations. These findings are consistent with prior research highlighting the positive educational impact of well-designed virtual reality learning environments on student engagement, conceptual understanding, and metacognitive development (Merchant et al., 2014; Radianti et al., 2020).

Table 1. Summary of Validators' Averaged Ratings for the Virtual Reality Integrated Guided Inquiry Based Approach Module for Heat and Temperature with regards to Virtual Reality Integration

| **Criteria** | **Mean** | **Standard Deviation** | **Verbal Interpretation** |
|---|---|---|---|
| User Experience and Engagement | 3.878 | 0.308 | VE |
| Conceptual Understanding and Misconception | 3.848 | 0.311 | VE |
| Instructional Design and Integration | 3.878 | 0.308 | VE |
| Reflection and Evaluation | 3.818 | 0.345 | VE |
| **AVERAGE** | 3.855 | 0.318 | VE |

*Note: Verbal Interpretation of the Mean 3.26 - 4.00 Very Evident (VE), 2.51 - 3.25 Moderately Evident (ME), 1.76 - 2.50 Slightly Evident (SE), 1.00 - 1.75 Not at All Evident (NE)*

**Science Experts Validation of VR-Integrated Guided Inquiry Based Approach in Virtual Reality Integration as regards to Learning Module**

Table 2 provides a comprehensive summary of the average ratings given by expert validators for the Virtual Reality-Integrated Guided Inquiry-Based Approach Module on Heat and Temperature, focusing specifically on its effectiveness as a learning resource. The evaluation was based on four key criteria: Assessment and Evaluation, Instructional Design and Organization, Content, and Readability. Each was assessed using the mean (M), standard deviation (SD), and corresponding verbal interpretation (VI). Among these, Assessment and Evaluation received the highest mean score (M = 3.927, SD = 0.100), indicating strong and consistent agreement among validators that this component is "*Very Evident*," and affirming the module's strength in measuring student learning and outcomes. Closely following was Instructional Design and Organization with a (M = 3.909, SD = 0.215), also interpreted as "*Very Evident*." This suggests that the module's instructional framework is logically structured and effectively organized, supporting smooth learning progression. The Content criterion obtained a M = 3.886, SD = 0.205), also receiving a "*Very Evident*" interpretation, reflecting that the information presented is accurate, relevant, and well-aligned with the intended learning goals. Although Readability received the lowest mean score (M = 3.836, SD = 0.265), it still met the "*Very Evident"* threshold, indicating that the module is generally clear and understandable, with minor areas that could benefit from enhanced clarity for even greater accessibility. Overall, the module achieved a strong average (M = 3.889, SD = 0.196) across all domains, with a consistent verbal interpretation of *"Very Evident,"* signifying its high level of acceptability and effectiveness in facilitating instruction on heat and temperature through the integration of virtual reality and guided inquiry-based strategies. The narrow range of standard deviations (0.100 to 0.265) further emphasizes the validators' consensus and confidence in the module's quality. These findings are consistent with the study of Radianti et al. (2020), which underscores the positive educational impact of well-structured VR applications across various instructional dimensions, including content delivery, instructional design, and assessment practices. The convergence of high average ratings and low variability supports the conclusion that the module effectively leverages VR technology to deliver a comprehensive, engaging, and pedagogically sound learning experience.

Table 2. Summary of Validators' Averaged Ratings for the Virtual Reality Integrated Guided Inquiry Based Approach Module for Heat and Temperature with regards to Learning Module

| **Criteria** | **Mean** | **Standard Deviation** | **Verbal Interpretation** |
|---|---|---|---|
| Content | 3.886 | 0.205 | VE |
| Instructional Design and Organization | 3.909 | 0.215 | VE |
| Readability | 3.836 | 0.265 | VE |
| Assessment and Evaluation | 3.927 | 0.100 | VE |
| **AVERAGE** | 3.889 | 0.196 | VE |

*Note: Verbal Interpretation of the Mean 3.26 - 4.00 Very Evident (VE), 2.51 - 3.25 Moderately Evident (ME), 1.76 - 2.50 Slightly Evident (SE), 1.00 - 1.75 Not at All Evident (NE)*

Table 3 presents the summarized inter-rater reliability statistics of Virtual Reality Integrated Guided Inquiry-Based Approach Module for Heat and Temperature (VR-GIBA) as regards to Virtual Reality Integration and Learning Module. This evaluation was done to assess the internal consistency of the module's assessment and the Virtual Reality evaluation components.

Table 3. Inter-rater Reliability Statistics of Experts of VR-Integrated Guided Inquiry Based Approach in Virtual Reality Integration as regards to Learning Module

| **N of Items** | **Cronbach's Alpha** | **Internal Consistency** |
|---|---|---|
| 40 | 0.932 | Excellent |

*Note: a≥0.9(Excellent), 0.9≥ a ≥0.8 (Good), 0.8 ≥ a ≥0.7 (Acceptable), 0.7 ≥ a ≥0.6 (Questionable), 0.6 ≥ a ≥ 0.5 (Poor), 0.5 ≥ a (Unacceptable)*

With 40 items assessed, the Cronbach's Alpha was calculated at 0.932, indicating excellent internal consistency among the raters. This suggests a very high level of agreement among the experts in evaluating the quality and effectiveness of the module across various domains. Based on established statistical guidelines, a Cronbach's Alpha value equal to or greater than 0.9 reflects excellent reliability, demonstrating that the evaluation tool is highly consistent and dependable. This strengthens the credibility of the findings related to the module’s overall quality and reinforces its appropriateness for instructional use.

**Quantitative Findings**

Table 4 presents the results of both the pretest and posttest administered to 32 students (N = 32) on the topic of Misconception and Conceptual Understanding of Heat and Temperature. The test consisted of 20 items designed to assess students' conceptual grasp of the topic. In the pretest, the results show a Mean Percentage Score (MPS) of 28.12% (M = 5.625, SD = 1.879), which falls under the "Low" verbal interpretation category. This indicates relatively poor performance and suggests that students held significant misconceptions and demonstrated limited conceptual understanding of heat and temperature. The low scores highlight the shortcomings of traditional teaching methods in addressing and correcting students’ preconceived notions and emphasize the need for instructional strategies that prioritize conceptual clarity over rote memorization. These findings establish a clear baseline, justifying the implementation of targeted, concept-focused educational interventions.

Table 4. Mean and Standard Deviation on Pretest and Posttest Scores on the Misconception and Conceptual Understanding on Heat and Temperature

| | **N** | **N of Items** | **Mean** | **SD** | **MPS** | **VI** |
|---|---|---|---|---|---|---|
| Pre-test | 32 | 20 | 5.625 | 1.879 | 28.125 | Low |
| Post test | 32 | 20 | 17.438 | 1.865 | 87.188 | High |

*Note: MPS interpretation, 0-25 (Very Low), 26-49 (Low), 50-74 (Moderate), 75-89 (High), and 90-100 (Very High).*

In the posttest, the results indicate a Mean Percentage Score (MPS) of 87.18% (M = 17.438, SD = 1.865), which corresponds to a "High" verbal interpretation. The substantial increase reflects a significant improvement in conceptual understanding and a notable reduction in misconceptions. These outcomes validate the effectiveness of the intervention, particularly the VR Integrated Guided Inquiry Based Pedagogy, and underscore the importance of engaging, student-centered approaches. Strategies grounded in constructivist principles, which build on learners' prior knowledge, play a crucial role in promoting accurate scientific understanding. Overall, the data in Table 5 illustrate a marked improvement in students’ understanding of heat and temperature, affirming the critical role of innovative, conceptually driven teaching strategies in developing scientific literacy, which is a foundational goal of science education.

Table 5**.** Wilcoxon Signed-Rank Test for the Difference Between the Students’ Pretest and and Posttest on the Misconception and Conceptual Understanding on Heat and Temperature

| **Skills Developed** | **Pre-test** | **SD** | **Post test** | **SD** | **z** | **Asymp. Sig** | **r** | **Verbal Interpretation** |
|---|---|---|---|---|---|---|---|---|
| Conceptual Understanding | 5.625 | 1.879 | 17.438 | 1.865 | 4.946 | 0.000* | O.618 | Large effect |

*Note: significant at α = 0.05*; at No. of Items =20, effect size (Cohen’s d) is (r=z/√2N), 0.10>r<0.30 (small effect), 0.50<r>0.30 (medium effect), and r>0.50 (large effect).*

Table 6 presents the results of the Wilcoxon Signed-Rank Test, which was conducted to determine whether there was a statistically significant difference in students' conceptual understanding of heat and temperature before and after the instructional intervention. The test was selected as a non-parametric alternative to the paired-samples t-test, given the possibility that the data did not meet the assumption of normality. It is particularly suitable for analyzing repeated measures from the same participants, such as the pretest and posttest scores in this study.

The results revealed a substantial and statistically significant improvement in student performance following the intervention. Specifically, the mean score on the pretest was relatively low (M = 5.625, SD = 1.879), indicating limited prior understanding and the likely presence of misconceptions related to heat and temperature concepts. After the intervention, the posttest scores showed a marked improvement (M = 17.438, SD = 1.865), reflecting significant gains in students' conceptual understanding. The Wilcoxon Signed-Rank Test yielded a z-value of 4.946 with an associated p-value of 0.000. Since the p-value is well below the conventional alpha level of 0.05, the results indicate that the observed increase in scores from pretest to posttest is statistically significant and unlikely to have occurred by chance.

In addition to statistical significance, the magnitude of the effect was assessed through the calculation of the effect size. The effect size, computed as r = 0.618, is interpreted as a large effect based on Cohen's (1988) criteria. This means that the intervention not only led to statistically significant gains but also had a strong practical impact on students' learning outcomes. The large effect size demonstrates that the instructional approach was highly effective in producing meaningful improvements in conceptual understanding.The findings presented in Table 6 have important implications for science education, particularly in areas that are prone to misconceptions, such as heat and temperature. The significant increase in posttest scores, coupled with the large effect size, indicates that the instructional intervention successfully addressed and corrected students' misconceptions. It also supports the use of targeted teaching strategies such as concept-based instruction, inquiry-based learning, and formative assessment to promote deeper understanding of scientific concepts. These results underscore the potential of well-designed instructional approaches to bring about conceptual change and meaningful learning in science classrooms.Overall, the data presented in Table 6 provide strong evidence that the intervention was effective in enhancing students' conceptual understanding of heat and temperature. The statistically significant improvement in scores (M = 5.625, SD = 1.879 to M = 17.438, SD = 1.865), along with the large effect size (r = 0.618), highlights the success of the intervention in achieving its educational objectives and offers valuable insights for future instructional planning and curriculum development.

**Qualitative Findings**

*Thematic Analysis of Responses on Reflective Questionnaire*

To assess their perceptions of using the VR Science Simulation, students reflected on their learning experiences through the questionnaire. From their responses, three underlying themes emerged: *Instructional Impact through Technology, Pedagogical Effectiveness,* and *Learning Difficulties.*

The thematic analysis of student reflections underscores the significant instructional and pedagogical value of the

VR Science Simulation. A prominent theme was enhanced conceptual understanding, with students reporting clearer insights into abstract topics like heat transfer and molecular behavior. This aligns with the findings of Ibáñez and Delgado-Kloos (2018), who assert that virtual reality fosters deeper learning by making abstract concepts more concrete through immersive experiences. Additionally, students noted improvements in visualization of lessons, stating that VR allowed them to "see" how molecules behave at different temperatures. This supports Makransky and Lilleholt's (2018) argument that immersive environments facilitate mental model formation by helping students visualize scientific processes that are otherwise invisible. The simulation's pedagogical effectiveness was also evident in students' descriptions of experiential learning, where the VR environment made them feel as though they were inside a laboratory. This experiential dimension is consistent with Freina and Ott (2015), who found that VR environments provide learners with realistic and engaging simulations, reinforcing understanding through direct interaction.

Table 7. Summary of Thematic Analysis of Student Reflections on VR Science Simulation

| Main Theme | Sub-Themes | Key Ideas / Codes | Frequency |
|---|---|---|---|
| Instructional Impact through Technology | Enhanced Knowledge | Understood concepts better, learned new ideas, grasped molecular motion | 20 |
| | Visualization of Lesson | Imagined real-life scenarios, saw molecular behavior in different temperatures | 7 |
| | Immersive Learning Experience | Explored simulation, found learning fun and engaging | 3 |
| Pedagogical Effectiveness | Engaging Learning | Maintained interest and attention during VR simulations | 2 |
| | Experiential Learning | Felt like being in a laboratory, experienced content through 360° immersive views | 21 |
| | Conceptual Understanding | Differentiated between heat and temperature, improved clarity of concepts | 3 |
| Difficulties Encountered | Physical Discomfort | Eye strain, dizziness, sensitivity from prolonged use of VR | 22 |
| | Technical & Accessibility Issues | Internet lag, device incompatibility, performance issues | 11 |

Moreover, student engagement increased, as indicated by their enjoyment and interest during the simulations—an effect also noted by Parong and Mayer (2021), who documented VR's potential to boost motivation and attention in science learning. Despite these benefits, the study also surfaced important challenges, including physical discomfort (e.g., eye strain, dizziness), which corroborates Sutherland et al. (2018), who warned of VR-induced motion sickness and visual fatigue. Likewise, technical and accessibility issues such as poor internet connectivity and device limitations mirrored those highlighted by Pantelidis (2010), who emphasized the infrastructural demands of implementing VR in classroom settings. Overall, the qualitative data affirm that VR-based instruction can meaningfully improve science learning by enhancing comprehension, engagement, and motivation. However, the findings also highlight the need to address ergonomic design and technical accessibility to ensure equitable and sustainable use in educational contexts.

## Conclusion

This study investigated the effectiveness of a VR-integrated Guided Inquiry-Based Approach (GIBA) in enhancing Grade 7 students' conceptual understanding of heat and temperature. The findings revealed that students held prevalent misconceptions—such as equating heat with temperature or misunderstanding thermal energy transfer—which hindered their comprehension of fundamental physics concepts. Through the implementation of the VR-enhanced module, students demonstrated significant improvements in conceptual understanding, as evidenced by higher post-test scores and decreased misconceptions. The immersive nature of the virtual environment enabled students to visualize abstract processes, manipulate variables, and engage actively in inquiry, all of which contributed to deeper learning. Furthermore, thematic analysis of students' reflections underscored their increased motivation, curiosity, and engagement during the intervention. These results affirm that combining VR with guided inquiry holds considerable promise in making science instruction more effective, meaningful, and responsive to students' learning needs. The study highlights the potential of innovative pedagogies grounded in constructivist learning theories to transform science education and bridge persistent conceptual gaps.

## Recommendations

In light of the study's findings, it is recommended that VR-integrated guided inquiry strategies be more broadly adopted across science curricula, particularly for abstract or challenging concepts such as energy, forces, and electricity. Given the positive impact on conceptual understanding and student engagement, science educators and curriculum developers should consider integrating immersive technologies into instructional design. To facilitate this, professional development programs should be offered to equip teachers with the pedagogical and technical competencies required to implement VR-enhanced inquiry-based learning effectively.

Educational policymakers and school administrators are also encouraged to invest in digital infrastructure that supports VR deployment in classrooms, including compatible devices and stable connectivity. For under-resourced schools, exploring low-cost or offline VR alternatives may help bridge access gaps. Additionally, reflective tools like the Student Reflective Questionnaire (SRQ) should be incorporated regularly to promote metacognitive awareness, allowing students to monitor their own learning progress and confront lingering misconceptions.

Future research is warranted to examine the long-term effects of VR-integrated instruction on knowledge retention and its applicability across diverse science topics and learner demographics. Comparative studies involving control and experimental groups across different grade levels may provide further insights into the scalability and generalizability of the approach. Lastly, co-developing VR learning materials with teachers, students, and subject experts is essential to ensure contextual relevance, curricular alignment, and instructional efficacy tailored to local educational settings.

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