

The Lived Experiences of Students Using Robotics as A Tool in Learning Physics

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Abstract

This qualitative study, under a phenomenological approach, explored the lived experiences of Grade 9 students at Gumaca National High School using robotics to learn physics. The research aimed to understand students' perceptions of how robotics impacted their comprehension of physics concepts, their engagement with the subject, and their overall learning experience. Data was collected through open-ended questionnaires administered to a purposefully selected sample of students participating in a robotics-integrated physics program.

Analysis revealed several key themes. Students consistently reported that hands-on robotics activities significantly enhanced their understanding of abstract physics concepts, making learning more engaging and memorable. The ability to visualize theoretical principles tangibly fostered deeper comprehension and improved retention of key concepts. Students frequently described a heightened sense of accomplishment and satisfaction derived from successfully completing robotics projects, contributing to a positive learning environment. Furthermore, the collaborative nature of many

robotics' projects promoted teamwork and problem-solving skills. Students valued the opportunity to work together, share ideas, and learn from each other's strengths. This collaborative aspect fostered a sense of community and mutual support within the classroom, enhancing the overall learning experience. The projects also stimulated creativity and innovation as students designed, built, and programmed their robots, leading to a more personalized and meaningful learning experience.

The findings suggest that integrating robotics into physics instruction at Gumaca National High School offers significant potential for enhancing student learning and engagement. The identified strengths of robotics integration provide a basis for refining instructional strategies and curriculum design to maximize the benefits of this innovative approach. The positive impact on conceptual understanding, motivation, and collaborative skills highlights the value of experiential learning in physics education. Further research could explore the long-term effects of this approach on student achievement and career aspiration

Keywords: *phenomenological approach, lived experiences, robotics, physics education*

INTRODUCTION

Robotics has become an effective tool for enhancing student engagement and comprehension in subjects like physics, which are often considered abstract. By connecting theoretical concepts with hands-on applications such as robot construction and programming, robotics enables students to visualize motion, forces, and related principles while fostering collaboration and problem-solving skills (Antony et al., 2022). In the Philippine setting, particularly at Gumaca National High School, robotics integration supports the K-12 curriculum's emphasis on inquiry-based and experiential learning (DepEd, 2016).

Physics is frequently perceived as overly theoretical, reducing student motivation and interest (Duit et al., 2014). Robotics addresses this issue by making abstract principles like Newton's laws tangible and relatable, thus improving retention and comprehension (De Souza et al., 2021). Moreover, robotics promotes creativity, innovation, and teamwork - key 21st-century skills (El Mohamad, 2019).

Despite these advantages, limited research exists on the lived experiences of Filipino students in rural settings with robotics in physics learning. Studies have primarily focused on cognitive outcomes, often overlooking motivational and emotional aspects (Buar, 2022; Tajos, 2024). A phenomenological approach is therefore needed to explore how students perceive robotics in terms of accomplishment, group dynamics, and engagement (Petre & Price, 2020). Understanding these experiences can provide valuable insights for inclusive and effective STEM strategies in resource-constrained schools.

Purpose of the Research

This study sought to explore the impact of robotics as a tool for learning physics among selected students at Gumaca National High School. It aimed to investigate how the use of robotics influenced students' understanding of physics concepts, their engagement in the learning process, and their overall academic performance in the subject. Additionally, the research examined the challenges and benefits experienced by students in integrating robotics into their physics education, providing insights into how this technological tool could be effectively implemented within the classroom setting to enhance learning outcomes.

To achieve the purpose of the study, the researcher formulated the following research objectives to explore and investigate the educational impact of using robotics in learning physics based on the lived experiences of students of Gumaca National High School.

1. To explore the lived experiences of selected students of Gumaca National High School in using robotics as a tool in learning Physics.
2. To identify the perceived benefits experienced by students when integrating robotics into Physics learning processes.
3. To explore the challenges encountered by students when using robotics in their Physics learning activities.
4. To examine the influence of robotics projects on students' understanding of complex Physics concepts.
5. To investigate changes in students' attitudes and engagement toward Physics as a result of using robotics projects in the learning process.

Significance of the Research

This study, which investigated the lived experiences of selected Gumaca National High School students who used robotics projects to learn physics, was useful to a wide range of stakeholders, including students, parents, teachers, prospective researchers, and the larger educational community.

For **students**, it highlights how robotics fosters critical thinking, problem-solving, and deeper understanding of physics concepts, transforming abstract topics into concrete experiences.

For **parents**, it provides evidence of how robotics enhances creativity, teamwork, and academic performance, supporting better educational decisions.

For **teachers**, it offers practical insights into integrating robotics to improve teaching strategies and student engagement.

For **future researchers**, it contributes to the literature on robotics and STEM education, providing a basis for comparative or extended studies.

Lastly, for the **educational community and policymakers**, it demonstrates robotics' potential to enrich physics learning and guides curriculum development, resource allocation, and STEM-oriented reforms (Buar, 2022).

Desired Outcomes of the Study

The study aimed to gain a deeper understanding of students' lived experiences with robotics in physics learning. It sought to determine how robotics influences comprehension of fundamental concepts such as motion, energy, and forces, while also exploring its effects on student engagement and motivation. Additionally, the research aimed to identify challenges in robotics integration and strategies for overcoming them. Ultimately, the study intended to provide practical recommendations for educators, administrators, and policymakers on effectively incorporating robotics into physics curricula to foster interactive learning, critical thinking, and STEM interest among students.

Scope and Limitation of the Study

The study focused on selected Gumaca National High School students who actively participated in robotics-based physics classes. It examined their experiences, including perceived benefits, challenges, and learning outcomes. Data were collected using open-ended questionnaire for interviews, and observations. The scope was limited to GNHS students, and the findings may not be generalizable to other schools or contexts. Teachers, parents, and other stakeholders were excluded, and the study concentrated solely on physics learning, not on other subjects or extracurricular robotics activities. These delimitations ensured the research remained focused on student-centered experiences in physics education.

METHODOLOGY

Description of Method or Approach

This study explored the lived experiences of selected Gumaca National High School students who used robotics in learning physics, focusing on their perceptions, problem-solving, and critical thinking

skills. It examined both the benefits and challenges encountered, using questionnaires with 15 open-ended questions, interviews, and observations to capture their experiences. The participants were limited to physics students actively engaged in robotics projects, and the scope was confined to this school, restricting the findings' generalizability. The study concentrated solely on student experiences in physics, excluding other subjects and perspectives of teachers, parents, or stakeholders, ensuring focus on the interaction between robotics and physics learning within this context.

Research Design/Research Instrument/Data Gathering Procedure Research Design

This study employed a phenomenological research design to explore students' lived experiences in using robotics to learn physics, focusing on the meaning they attached to these interactions (Alhazmi & Kaufmann, 2022). Data were gathered through questionnaires, interviews, and observations, which allowed the researcher to capture the complex and nuanced ways students perceived robotics as influencing their understanding of physics. This approach facilitated the identification of common themes and patterns, providing deeper insights into how robotics shaped their learning experiences.

Research Instruments

This study employed a phenomenological research design to explore students' lived experiences in using robotics projects for learning physics. Phenomenology allowed the researcher to understand the meanings students attributed to their experiences, focusing on how robotics influenced their learning of physics concepts (Alhazmi & Kaufmann, 2022). Data were gathered through questionnaires, interviews, and observations to identify common themes and patterns, effectively capturing the complex and nuanced ways students interacted with robotics and perceived its impact on their education.

Data Gathering Procedures

This study used a phenomenological approach with purposive sampling to select diverse participants who could provide meaningful insights into their experiences with robotics in physics education (Stewart, 2025). Rapport was established through informal conversations, and interviews were conducted during students' free time, allowing them to respond in English, Tagalog, or Taglish. With consent, interviews were audio-recorded, transcribed verbatim, and supported by notes, photographs, drawings, and project artifacts to enrich data. Analysis followed Moustakas' (1994) phenomenological method, involving familiarization, thematic analysis, and phenomenological reduction to identify significant statements, meaning units, and essential themes. Reflexive practice was applied throughout to address researcher biases, ensuring rigor and credibility, and leading to a deeper understanding of how robotics shaped students' comprehension and appreciation of physics concepts.

Respondents/Units of Analysis/Subjects of the Study

This research involved 15 Grade 9 students at Gumaca National High School. These students actively engaged in robotics projects as part of their physics subject. The participants were selected to represent a diverse range of high school education levels and to provide a diverse perspective on their experiences using robotics to comprehend physics principles. Those students who did not experience robotics projects were not included in this research.

Selection of Research Participants Procedure

The participants of this study were Grade 9 students from Gumaca National High School who were enrolled in the Special Science Program (SSP) for the School Year 2024-2025. Initially, a survey was conducted to identify students willing to participate in the research.

Since this study employed a phenomenological approach, which typically required a small number of respondents to gather in-depth data, only fifteen (15) participants were needed. To avoid bias in the selection process, the researcher utilized purposive sampling by identifying key characteristics of interest among the student population while also incorporating random selection among those willing to participate. This approach allowed us to ensure diverse representation while respecting participants' willingness to join the study. For example, the student whose surname began with the letter "A" was called Co-Researcher 1, and so on.

For ethical considerations, each participant was assigned a code name and was referred to as "Co-Researcher" to maintain confidentiality, as all were minors. The assigned number of participants was based on their surnames in alphabetical order.

Sampling Design and Procedures

This study used a purposive sampling strategy (Patton, 2015), a non-probability sampling method often employed in qualitative research, to choose participants with specific qualities relevant to the research goals. In this situation, purposive sampling guaranteed that only students who had direct experience with robotics within their physics curriculum were chosen, as their perspectives were crucial to answering the research questions. The sampling procedure involved selecting fifteen (15) students from Grade 9 of the school year 2024-2025 in partnership with physics teachers who assisted in identifying students who had shown the highest interest in robotics.

The purposive sampling strategy was ideal for this study because it allowed the researcher to focus on a group of students who could provide comprehensive, firsthand accounts of how robotics affected their understanding of physics principles. This sample size and design were intended to produce a manageable yet comprehensive data collection, allowing for an in-depth investigation of students' experiences at various academic levels.

Research Locale/Study Site

The secondary educational institution, Gumaca National High School, is situated in the municipality of Gumaca, province of Quezon, where the research was conducted. The school is an optimal environment for this research due to the integration of robotics into its curriculum, particularly in its physics subject. Gumaca National High School offers a natural context in which students are already familiar with using robotics, which enables the study to capture authentic, context-specific insights.

The school's environment also provided an opportunity to investigate the integration of robotics and how the projects were being utilized as tools in learning physics.

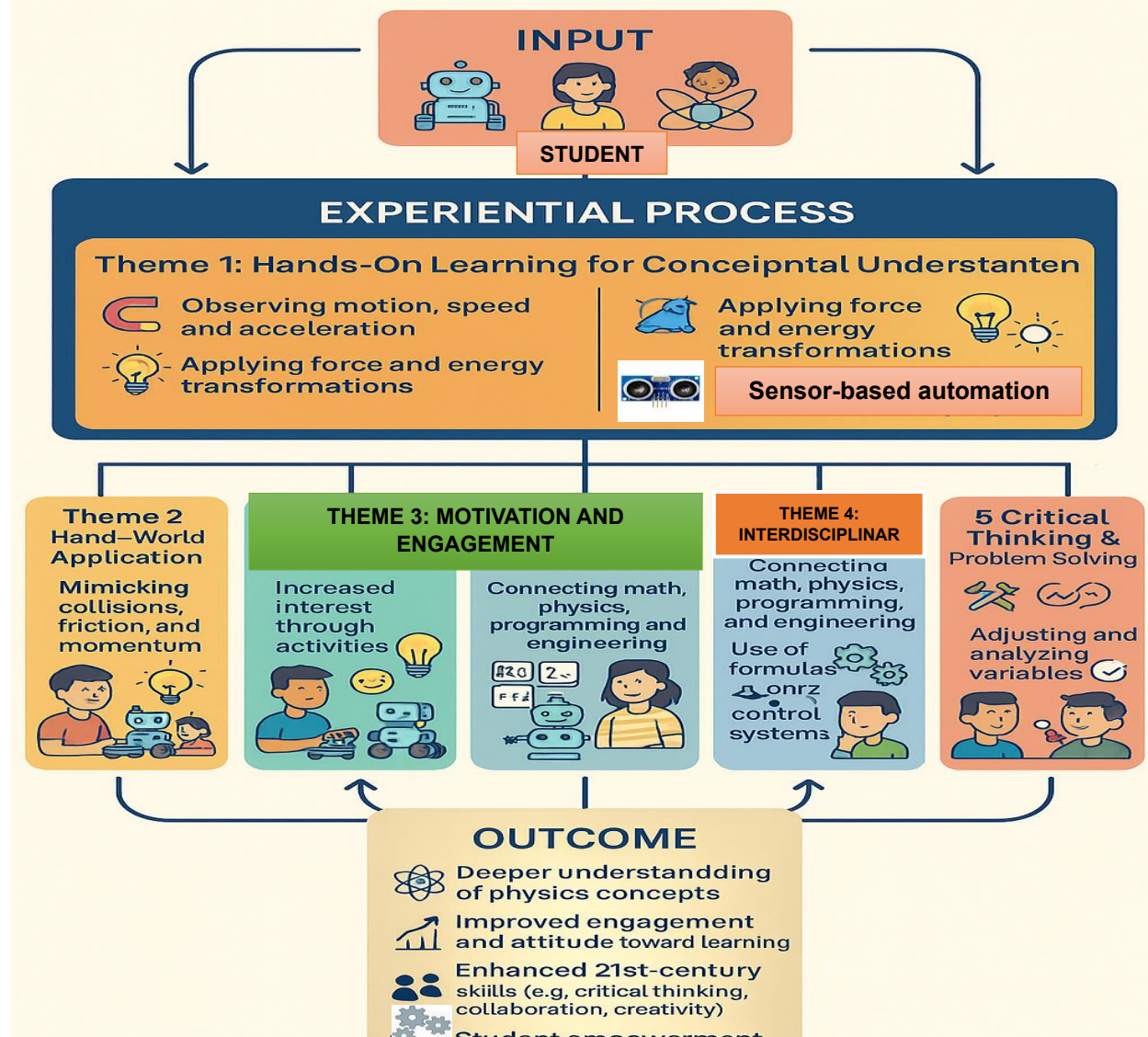
Data Analysis Plan

The data analysis employed Interpretative Phenomenological Analysis (IPA), which enabled an in-depth interpretation of how students made sense of their experiences with robotics in learning physics (Smith & Osborn, 2015). Data from semi-structured interviews and a 15-item open-ended questionnaire (Marshall & Rossman, 2016) were transcribed, read repeatedly, and analyzed to identify themes reflecting shared and unique aspects of students' challenges, motivations, and insights. These themes were validated against reflective notes, observations, and participant feedback to ensure accuracy. Reflexivity was maintained throughout to reduce bias and uphold credibility (Creswell & Poth, 2018), resulting in a systematic and comprehensive understanding of students' lived experiences and the pedagogical value of robotics in physics education.

Research Paradigm/Conceptual Framework

Figure 1

Conceptual Paradigm of the Lived Experiences of Students Using Robotics as a Tool in Learning Physics



RESULTS AND DISCUSSION

Table 1

Theme 1: Enhanced Conceptual Understanding Through Hands-On Learning

Category	Most Significant Insights (Verbatim)	English Equivalent
A. Understanding Motion, Speed, and Velocity	"Ang Robotics po ay nakatulong sa amin na ma-visualize ang lesson para madali naming maintindihan ang konsepto tungkol sa acceleration, deceleration and constant velocity." – Co-Researcher 12	"Robotics helped us visualize the lesson so we could easily understand the concepts of acceleration, deceleration, and constant velocity." – Co-Researcher 12
B. Grasping Momentum and Mass Through Robot Interactions	"Mas malaki ang momentum ng sumobot, mas malakas din ang force. Halimbawa, ang truck na bumangga sa car, mas masisira ng malaki ang truck." – Co-Researcher 15	"The greater the momentum of the sumobot, the stronger its force. For example, when a truck hits a car, the car is more damaged since the truck has more mass." – Co-Researcher 15
C. Visualizing Acceleration and Deceleration	"Na-discover po namin na kapag ang robot ay nasa straight lines, bumibilis... kapag nasa curved paths, ang robot bumabagal." – Co-Researcher 9	"We discovered that when the robot moves on straight lines, it accelerates... but when on curved paths, it decelerates." – Co-Researcher 9
D. Demonstrating Energy Transformation (Potential ↔ Kinetic)	"Kasunod po ay ang Bluetooth controlled robot... nakatulong sa amin na maintindihan ang konsepto ng potential and kinetic energies." – Co-Researcher 12	"The Bluetooth-controlled robot helped us understand the concept of potential and kinetic energies." – Co-Researcher 12
E. Applying Newton's Laws Using Robot Behaviors	"Ang robocar po ay nakatulong sa amin na maintindihan ang Physics by demonstrating motion, forces, and energy transformations." – Co-Researcher 1	"The robocar helped us understand Physics by demonstrating motion, forces, and energy transformations." – Co-Researcher 1

DISCUSSION OF RESPONDENTS INSIGHTS

The respondents emphasized that robotics significantly enhanced their understanding of motion, speed, and velocity by transforming abstract concepts into concrete, observable experiences. As Co-Researcher 12 explained, "*Ang Robotics po ay nakatulong sa amin na ma-visualize ang lesson para madali naming maintindihan ang konsepto tungkol sa acceleration, deceleration and constant velocity*" ["Robotics helped us visualize the lesson so we could easily understand the concepts of acceleration, deceleration, and constant velocity"]. This confirms the findings of Antony et al. (2022), who noted that robotics promotes better comprehension of physics concepts by linking theoretical lessons with practical applications.

Robotics also deepened the students' grasp of momentum and mass through interactive simulations. Co-Researcher 15 remarked, *"Mas malaki ang momentum ng sumobot, mas malakas din ang force. Halimbawa, ang truck na bumangga sa car, mas masisira ng malaki ang car dahil mas mabigat ang truck"* ["The greater the momentum of the sumobot, the stronger its force. For example, when a truck hits a car, the car is more damaged since the truck has more mass"]. This insight resonates with De Souza et al. (2021), who highlighted that robotics makes abstract principles like momentum and collisions more visible and relatable, thereby improving retention.

Furthermore, robotics activities allowed students to visualize the effects of acceleration and deceleration in relation to the path of motion. Co-Researcher 9 shared, *"Na-discover po namin na kapag ang robot ay nasa straight lines, bumibilis... kapag nasa curved paths, ang robot ay bumabagal"* ["We discovered that when the robot moves on straight lines, it accelerates... but when on curved paths, it decelerates"]. Such experiences reflect the principles of inquiry-based and experiential learning encouraged by the K-12 curriculum (Department of Education, 2016), which stresses the importance of observation and discovery in developing conceptual understanding.

The integration of robotics also strengthened the respondents' understanding of energy transformation. Co-Researcher 12 observed, *"Kasunod po ay ang Bluetooth controlled robot... nakatulong sa amin na maintindihan ang konsepto ng potential and kinetic energies"* ["The Bluetooth-controlled robot helped us understand the concept of potential and kinetic energies"]. This aligns with El Mohamad (2019), who argued that robotics provides students with opportunities to witness energy conversion in real time, making the abstract concept of potential and kinetic energies more concrete.

Finally, robotics provided practical demonstrations of Newton's Laws of Motion, which respondents found highly valuable. As Co-Researcher 14 stated, *"Ang robocar po ay nakatulong sa amin na maintindihan ang Physics by demonstrating motion, forces, and energy transformations"* ["The robocar helped us understand Physics by demonstrating motion, forces, and energy transformations"]. This reflects the perspective of Valsamidis et al. (2022), who emphasized that robotics enhances students' scientific reasoning and critical thinking by allowing them to test and visualize core physical laws in action.

Collectively, these insights illustrate that robotics not only facilitated a clearer conceptual understanding of physics but also fostered engagement, discovery, and application-key components of effective 21st-century learning.

Table 2

Theme 2: Real-World Application of Physics Principles

Category	Most Significant Insights (Verbatim)	English Equivalent
A. Relating robot movement to fundamental vehicle dynamics (e.g., turning, speeding, slowing)	<i>"Una ay para sa line tracing robot, natutunan namin kung paano at kailan ito maga-accelerate at magde-decelerate. Kumpara sa totoong car, they are both very similar kung paano sila bibilis o babagal ng takbo."</i> – Co-Researcher 9	<i>"First, with the line tracing robot, we learned how and when it accelerates and decelerates. Compared to a real car, they are very similar in how they speed up or slow down."</i> – Co-Researcher 9

Category	Most Significant Insights (Verbatim)	English Equivalent
B. Observing collisions and momentum in real-life scenarios	“Ang huli ay ang sumobot... sa real life situations po ang lahat ng bagay na gumagalaw ay may momentum... kapag bumangga sa mas malaking object, masisira ka dahil sa momentum.” – Co-Researcher 12	“Lastly, the sumobot is important because in real life, all moving objects have momentum. For example, when crashing into a bigger object, you will be crushed because of its momentum.” – Co-Researcher 12
C. Experiencing how sensors mimic automation in real-world technology	“Opo, ang robotics project tulad ng line tracing ay nakatulong po sa akin na makita how Physics concepts... are used in real-world applications. By learning how the robot follows a path using sensors, mas naintindihan ko kung paano ginagamit ang ganitong technology.” – Co-Researcher 1	“Yes, the robotics project like line tracing helped me see how Physics concepts, such as velocity and motion, are applied in real-world applications. Learning how the robot follows a path using sensors helped me understand its use in technology.” – Co-Researcher 1
D. Recognizing friction and traction on different surfaces	“Ang friction and traction ay pwede pong ma-observe sa gulong ng robocar... Ito po ay kahalintulad ng cars and motorcycles having different types of tires for different terrains.” – Co-Researcher 5	“Friction and traction can be observed in the robocar’s tires... This is similar to cars and motorcycles having different tires for various terrains.” – Co-Researcher 5

DISCUSSION OF RESPONDENTS INSIGHTS

The respondents emphasized that robotics helped them relate the concept of vehicle dynamics to real-life experiences. As one participant shared, “*Una ay para sa line tracing robot, natutunan namin kung paano at kailan ito maga-accelerate at magde-decelerate. Kumpara sa totoong car, they are both very similar kung paano sila bibilis o babagal ng takbo*” [“First, with the line tracing robot, we learned how and when it accelerates and decelerates. Compared to a real car, they are very similar in how they speed up or slow down”] (Co-Researcher 9). This insight demonstrates how robotics can concretize the concept of vehicle dynamics by linking the robot’s programmed movements to the everyday experience of driving. Antony et al. (2022) affirm that robotics activities help learners bridge theoretical physics concepts with practical applications, deepening their understanding of motion.

In terms of collisions and momentum, the students also saw direct applications of physics in everyday life. One respondent explained, “*Ang huli ay ang sumobot... sa real life situations po ang lahat ng bagay na gumagalaw ay may momentum... kapag bumangga sa mas malaking object, masisira ka dahil sa momentum*” [“Lastly, the sumobot is important because in real life, all moving objects have momentum. For example, when crashing into a bigger object, you will be crushed because of its momentum”] (Co-Researcher 12). This reflection indicates that learners not only recognized the abstract law of momentum but also applied it to real-life scenarios involving safety and impact. De Souza et al. (2021) support this by noting that robotics-based experiments allow students to test and observe Newtonian mechanics, reinforcing comprehension through tangible encounters.

The respondents also pointed out how robotics projects allowed them to experience how sensors function similarly to automation in modern technology. As one participant expressed, “*Opo, ang robotics project tulad ng line tracing ay nakatulong po sa akin na makita how Physics concepts... are used in real-*

world applications. By learning how the robot follows a path using sensors, mas naintindihan ko kung paano ginagamit ang ganitong technology” [“Yes, the robotics project like line tracing helped me see how Physics concepts, such as velocity and motion, are applied in real-world applications. Learning how the robot follows a path using sensors helped me understand its use in technology”] (Co-Researcher 1). This finding reflects the link between classroom learning and emerging innovations such as self-driving vehicles and industrial automation. Prior research underscores this potential, showing that robotics enhances both conceptual understanding and technological literacy (Cruz & Isotani, 2014; Antony et al., 2022).

Finally, the role of friction and traction was made clear through robotics experiments. One respondent noted, “*Ang friction and traction ay pwede pong ma-observe sa gulong ng robocar... Ito po ay kahalintulad ng cars and motorcycles having different types of tires for different terrains*” [“Friction and traction can be observed in the robocar’s tires... This is similar to cars and motorcycles having different tires for various terrains”] (Co-Researcher 5). This insight demonstrates how robotics fosters an authentic appreciation of forces at work in mobility and safety. Consistent with Hussain et al. (2019), experiential approaches such as robotics promote better retention and practical application of scientific ideas because they directly relate to learners’ daily encounters.

Table 3

Theme 3: Robotics as a Motivating and Engaging Learning Tool

Category	Most Significant Insight (Verbatim)	English Equivalent
A. Increased interest and enjoyment in Physics	“Sa pag-aaral ng Physics gamit ang Robotics ay nagiging masaya po ang lesson compared to just reading from a textbook. Controlling the robots and apply in real life made me more interested in the subject.” – Co-Researcher 9	“Learning Physics through Robotics made the lessons more entertaining compared to just reading from a textbook. Controlling the robots and apply in real life made me more interested in the subject.” – Co-Researcher 9
B. Motivation through robotics competitions	“Gusto ko ang challenge na gumawa ng sumobot na kayang tumagal sa pwersa ng ibang robots. Kailangan kong mag-isip tungkol sa design at weight distribution ng robot para siguradong ito ay isang malakas at mananalo. Ito ay isang napakagandang learning experience, and it helped me understand nakatulong ito na maintindihan ang mga concepts like force, friction, and concepts like force, friction, and stability.” – Co-Researcher 8	“I loved the challenge of building a sumobot that could withstand the force of other robots. I had to think carefully about the robot's design and weight distribution to make sure it was strong enough to win. It was a great learning experience, and it helped me understand concepts like force, friction, and stability.” – Co-Researcher 8
C. Preference for experiential over theoretical learning	“Using robotics made me realize that Physics isn't just about solving equations or memorizing formulas - it's about applying them in real-life situations. Working on the robocars allowed me to see how Physics works in action, which I found more	“Using robotics made me realize that Physics isn't just about solving equations or memorizing formulas - it's about applying them in real-life situations. Working on the robocars allowed me to see how Physics works in

Category	Most Significant Insight (Verbatim)	English Equivalent
	interesting than just reading textbooks.” – Co-Researcher 7	action, which I found more interesting than just reading textbooks.” – Co-Researcher 7
D. Fun, curiosity, and emotional engagement hands-on activities	“Robotics changed the way I viewed physics. Katulad po ng sinabi ko kanina, I’m not a physics person, pero gamit ang Robotics naging mas masaya ang pag-aaral ng Physics. The use of modern methods made it more interesting, and it hooked me into enjoying and loving physics.” – Co-Researcher 15	“Robotics changed the way I viewed physics. As I’ve said earlier, I’m not a physics person, but using Robotics made it more fun to learn Physics. The use of modern methods made it more interesting, and it hooked me into enjoying and loving physics.” – Co-Researcher 15

DISCUSSION OF RESPONDENTS INSIGHTS

Students reported that robotics made Physics more enjoyable and sparked greater interest: one said, “*Sa pag-aaral ng Physics gamit ang Robotics ay nagiging masaya po ang lesson compared to just reading from a textbook. Controlling the robots and seeing how Physics concepts apply in real life made me more interested in the subject.*” (Co-Researcher 9). This affective shift — from boredom with abstract formulas to curiosity driven by hands-on creation -echoes findings that active, project-based robotics learning increases motivation and situates conceptual understanding in meaningful tasks (Antony et al., 2022). By turning abstract kinematics and dynamics into controllable, observable behavior, robotics transforms passive reception into playful inquiry, which educational researchers link to deeper engagement and longer-term interest in STEM (De Souza et al., 2021).

Competition experiences similarly amplified motivation and promoted applied reasoning. As a student described, “*Gusto ko ang challenge na gumawa ng sumobot... Kailangan kong mag-isip ng maingat tungkol sa design at weight distribution... nakatulong ito na maintindihan ang mga concepts like force, friction, and stability*” (Co-Researcher 8). Robotics contests provide authentic constraints (design, weight, speed) that force learners to iterate and test hypotheses, producing situated problem solving that studies have shown to strengthen conceptual transfer and engineering thinking (Antony et al., 2022; Rusk et al., 2020). The emotional stakes of competition - pride, disappointment, persistence - also motivate reflection and refinement of ideas, turning failure into a productive learning event (De Souza et al., 2021).

Participants expressed a clear preference for experiential over purely theoretical instruction: “*Using robotics made me realize that Physics isn't just about solving equations or memorizing formulas -it's about applying them in real-life situations*” (Co-Researcher 7). This aligns with literature on inquiry-based and constructivist approaches showing that embodied manipulation and design tasks help students form accurate mental models of physical phenomena (Khine et al., 2019; Cruz & Isotani, 2014). When robotics supplies immediate visual feedback and opportunities to test causes and effects, students reconcile formal representations with concrete outcomes, increasing both comprehension and perceived relevance of Physics content.

Finally, respondents highlighted how robotics cultivated fun, curiosity, and emotional engagement, with one remarking that robotics “hooked me into enjoying and loving physics” (Co-Researcher 15). The emotional dimension is important: affective engagement supports persistence, risk-taking, and creativity, all of which amplify learning gains (Hussain et al., 2019). By making abstract concepts tangible (e.g., observing forces on a Bluetooth robocar), robotics lowers cognitive load for novices and creates entry points

for deeper inquiry - a pattern documented in studies that link hands-on robotics to improved conceptual retention and positive attitudes toward science (Antony et al., 2022; De Souza et al., 2021).

Table 4

Theme 4: Integration of Interdisciplinary Knowledge

Categories	Most Significant Insight (Verbatim - Tagalog/Taglish)	English Equivalent
A. Connecting Physics to Engineering and Programming	“Programming the robots to move in specific ways was challenging, lalo na kung iko-consider mo po ang balance and center of mass. Kahit maliit na pagkakamali make the robot move unpredictably, which could meant a lot of trial and error.” – Co-Researcher 10	“Programming the robots to move in specific ways was challenging, especially when considering balance and center of mass. Even small mistakes make the robot move unpredictably, which meant a lot of trial and error.” – Co-Researcher 10
B. Understanding Automation, Control Systems, and AI	“The robotics projects showed me how Physics is applied in real life, especially in understanding how movement, force, and control work. For example, in the line tracing car, I saw how sensors detect lines, which is similar to how automated machines work. The Bluetooth-controlled car also showed how remote control works through signals.” – Co-Researcher 7	“The robotics projects showed me how Physics is applied in real life, especially in understanding how movement, force, and control work. For example, in the line tracing car, I saw how sensors detect lines, which is similar to how automated machines work. The Bluetooth-controlled car also showed how remote control works through signals.” – Co-Researcher 7
C. Application of Mathematical Formulas in Programming Robot Functions	“For me the physics concept that was hard to apply in robotics projects is the calculation of energy. Because for me, calculating is hard, especially when finding out in real life how to measure velocity of the robocar.” – Co-Researcher 3	“For me the physics concept that was hard to apply in robotics projects is the calculation of energy. Because for me, calculating is hard, especially when finding out in real life how to measure velocity of the robocar.” – Co-Researcher 3
D. Integrating STEM (Science, Technology, Engineering, Math) Concepts	“Hindi talaga interested sa science before, pero binago ito ng Robotics. It made learning so much more engaging and exciting. Mas interesado na ako mag-explore sa STEM fields and maybe even pursuing a career in robotics or engineering.” – Co-Researcher 15	“I wasn’t really interested in science before, but Robotics changed that. It made learning so much more engaging and exciting. I am now more interested in exploring STEM fields and maybe even pursuing a career in robotics or engineering.” – Co-Researcher 15

DISCUSSION OF RESPONDENTS INSIGHTS

The insights of the respondents reveal that robotics projects in Physics learning extend beyond disciplinary boundaries by integrating concepts from engineering, mathematics, and technology. These experiences highlight the interdisciplinary nature of STEM education, making the study of Physics more applied and meaningful.

Respondents emphasized the challenges of programming robots, particularly in balancing and maintaining stability. As one participant shared, “Programming the robots to move in specific ways was challenging, lalo na kung iko-consider mo po ang balance and center mass. Kahit maliit na pagkakamali could make the robot move unpredictably, which meant a lot of trial and error” (Co-Researcher 10). This indicates that learning was not only theoretical but also experimental, requiring iterative testing and error correction, which mirrors authentic engineering design processes. Consistent with the findings of Eguchi (2017), robotics-based learning fosters engineering thinking by requiring students to integrate physical laws with design principles.

Robotics projects also allowed students to understand how automation and control systems function in real-world contexts. One student noted, “The robotics projects showed me how Physics is applied in real life, especially in understanding how movement, force, and control work. For example, in the line tracing car, I saw how sensors detect lines, which is similar to how automated machines work” (Co-Researcher 7). This reflects how robotics bridges abstract physical concepts with technologies used in industries such as automation, artificial intelligence, and mechatronics. Previous studies affirm that robotics provides learners with exposure to the foundational principles of automation and control, fostering readiness for future technologies (Alimisis, 2019).

Another category highlighted the difficulty of applying mathematical concepts such as energy calculation and velocity measurement in robotics projects. One respondent stated, “For me the physics concept that was hard to apply in robotics projects is the calculation of energy. Because for me, calculating is hard, especially when finding out in real life how to measure example, the velocity of the robocar” (Co-Researcher 3). This illustrates the challenge of bridging abstract numerical equations with physical experiments. According to Khanlari (2016), robotics activities not only encourage computational thinking but also strengthen the use of mathematical reasoning in solving real-world problems, though learners often face difficulties in transferring formula-based knowledge into experimental applications.

Robotics also motivated students to explore STEM fields more deeply, making science and technology more engaging and inspiring future career interests. As one participant expressed, “Hindi talaga interested sa science before, pero binago ito ng Robotics. It made learning so much more engaging and exciting. Mas interesado na ako mag-explore sa STEM fields and maybe even pursuing a career in robotics or engineering” (Co-Researcher 15). This highlights the transformative effect of robotics on students’ perceptions of science learning, consistent with the findings of Anwar et al. (2019), who reported that robotics fosters long-term interest in STEM by making abstract principles tangible and personally relevant.

Overall, the integration of robotics into Physics learning demonstrates how interdisciplinary knowledge can be cultivated in classrooms. Robotics becomes a platform where physics, engineering, mathematics, and technology converge, promoting not only academic understanding but also curiosity, motivation, and career aspirations.

Table 5

Theme 5: Development of Critical Thinking and Problem-Solving Skills

Categories	Verbatim Insights (Tagalog/Taglish)	English Equivalent
A. Troubleshooting issues in robot behavior and programming	“Mahirap mag-code at mag-adjust ng speed nang sagayon tumakbo ito ng maganda sa parehong tuwid at palikong linya ng maayos... nakak-challenge talaga dahil kailangan mo ng maraming testing para ito ay maging tama.” – Co-Researcher 9	“It was difficult to code and adjust the speed so that it could glide smoothly and travel through both straight and curved lines flawlessly... it was challenging because the line tracing robot project took a lot of testing to get it right.” – Co-Researcher 9
B. Adjusting variables (e.g., mass, speed) and analyzing results	“Kapag nagdagdag po kami ng mabigat na bagay sa aming robocar, nakita po namin paano ito nagbago... kung ang robocar ay mabigat, sigurado na matutumba niya ang bote.” – Co-Researcher 5	“When we added a heavy object to the robocar, we observed how it changed... if the robocar were heavy, it would surely knock the bottle down.” – Co-Researcher 5
C. Observing and reflecting on physical outcomes	“Instead of just reading about concepts like acceleration or center of mass, nagagawa kong obserbahan kung paano naapektuhan ang movement at stability ng robot.” – Co-Researcher 10	“Instead of just reading about concepts like acceleration or center of mass, I could observe how they affected the robot’s movement and stability.” – Co-Researcher 10
D. Drawing cause-and-effect links between robot movement and Physics laws	“Ang epekto ng friction at gravity ay pwede makita kapag ang robocar ay tumatakbo sa iba’t ibang surfaces o umaakyat sa ramp. Inilalarawan din nito ang energy conversion, as electrical energy from the battery turns into mechanical motion, with kinetic and potential energy changing depending on its movement.” – Co-Researcher 14	“The effects of friction and gravity can be observed when a robocar moves on different surfaces or climbs a ramp. It also illustrates energy conversion, as electrical energy from the battery turns into mechanical motion, with kinetic and potential energy changing depending on its movement.” – Co-Researcher 14

DISCUSSION OF RESPONDENTS INSIGHTS

The respondents highlighted that their engagement in robotics activities significantly improved their critical thinking and problem-solving skills as they encountered different challenges that required persistence, analysis, and logical reasoning.

In troubleshooting issues in robot behavior and programming, one student admitted, “*Mahirap mag-code at mag-adjust ng speed nang sagayon tumakbo ito ng maganda sa parehong tuwid at palikong linya ng maayos... nakak-challenge talaga dahil kailangan mo ng maraming testing para ito ay maging tama.*” [“It was difficult to code and adjust the speed so that it could glide smoothly and travel through both

straight and curved lines flawlessly... it was challenging because the line tracing robot project took a lot of testing to get it right.”]. This experience reflects how robotics tasks pushed them to patiently refine their outputs through trial-and-error.

When adjusting variables such as mass and speed, another respondent shared, “*Kapag nagdagdag po kami ng mabigat na bagay sa aming robocar, nakita po namin paano ito nagbago... kung ang robocar ay mabigat, sigurado na matutumba niya ang bote.*” [“When we added a heavy object to the robocar, we observed how it changed... if the robocar were heavy, it would surely knock the bottle down.”]. Such insights reveal that students became more analytical as they experimented with changes and evaluated the corresponding outcomes.

In observing and reflecting on physical outcomes, one participant emphasized, “*Instead of just reading about concepts like acceleration or center of mass, nagagawa kong obserbahan kung paano naaapektuhan ang movement at stability ng robot.*” [“Instead of just reading about concepts like acceleration or center of mass, I could observe how they affected the robot’s movement and stability.”]. This suggests that robotics encouraged them to move beyond memorization and instead engage in reflection by directly linking theory to practice.

Finally, in drawing cause-and-effect links between robot movement and Physics laws, a respondent expressed, “*Ang epekto ng friction at gravity ay pwede makita kapag ang robocar ay tumatakbo sa iba’t ibang surfaces o umaakyat sa ramp. Inilalarawan din nito ang energy conversion, as electrical energy from the battery turns into mechanical motion, with kinetic and potential energy changing depending on its movement.*” [“The effects of friction and gravity can be observed when a robocar moves on different surfaces or climbs a ramp. It also illustrates energy conversion, as electrical energy from the battery turns into mechanical motion, with kinetic and potential energy changing depending on its movement.”]. This insight demonstrates how robotics provided concrete opportunities for learners to logically connect their observations to fundamental scientific laws.

Overall, the real insights of the respondents show that robotics not only exposed them to practical applications of physics concepts but also strengthened their ability to analyze, reflect, and solve problems - skills that are central to the development of critical thinking.

Conclusions

This phenomenological study reveals the transformative potential of robotics in enhancing physics education. Through an analysis of student narratives, five key themes emerged, showcasing the diverse benefits of robotics-based learning, including cognitive gains, increased engagement, and interdisciplinary integration. The findings underscore how robotics not only enriches the learning experience but also fosters a deeper understanding of essential physics concepts.

The first theme, enhanced conceptual understanding through hands-on learning, illustrates how robotics bridges the gap between abstract physics concepts and real-world applications. Students reported a significantly deeper understanding of motion, acceleration, momentum, and energy transformation through interactive, hands-on activities. This experiential approach replaces passive learning with active engagement, resulting in a more intuitive grasp of fundamental physics principles.

Furthermore, the theme of real-world application of physics principles highlights how robotics projects allow students to connect classroom learning with everyday phenomena. By engaging with robot

movement and observing physical interactions, students develop a meaningful appreciation for the practical relevance of physics. This connection between theory and practice enhances their understanding and retention of key concepts.

Robotics also serves as a powerful, motivating, and engaging learning tool. The excitement of competitions and hands-on activities sparks interest in physics, promoting a preference for experiential learning. This dynamic learning environment fosters fun and curiosity, reinforcing how critical hands-on experiences are for long-term comprehension and retention of scientific concepts.

Lastly, the thesis emphasizes the development of critical thinking and problem-solving skills through robotics projects. Students learn to troubleshoot, analyze outcomes, and understand the cause-and-effect relationships inherent in physics laws. These challenges cultivate analytical thinking and reflective learning, preparing students to navigate complex systems effectively.

Overall, robotics holds significant promise for enhancing physics education by providing an engaging, interdisciplinary learning environment that fosters deeper understanding and critical skills. To maximize its effectiveness, it is essential to address the challenges of equitable integration and ensure all students benefit from these innovative educational approaches. Future research should focus on developing solutions to these challenges and exploring the long-term impacts of robotics-based learning on student achievement and career aspirations.

Recommendations

Based on the results and findings of the study, the following recommendations are offered:

Curricular Integration. It is recommended that robotics be formally integrated into the Physics curriculum to promote hands-on, concept-based learning. Robotics projects help students connect abstract physics theories with real-world applications. Embedding robotics in lessons on motion, electricity, energy, and force will deepen students' comprehension and engagement. This integration must align with K-12 competencies and should be phased in gradually to ensure the readiness of both students and teachers.

Student Training. Students should undergo basic robotics training before engaging in complex tasks. Many participants reported difficulties in assembly, coding, and troubleshooting. Orientation sessions focusing on fundamental robotics skills - such as circuit connections, sensor integration, and basic coding - will help build student competence and reduce anxiety in handling robotics tasks.

Teacher Training. The study highlights a clear need for teacher capability building in both the technical and pedagogical aspects of robotics. Teachers must be empowered with hands-on training, not only to support students technically but also to design effective robotics-based learning activities.

Access and Inclusion. Financial barriers were a significant concern for many students. To promote equitable access, it is essential to provide shared or donated robotics kits and source low-cost alternatives. School programs should include all students regardless of economic status by securing grants, donations, or public-private partnerships to make the tools and training widely available.

Support by the School and Stakeholders. Strong support systems are vital for the success and sustainability of robotics-based learning. It is recommended that schools allocate dedicated funding, time, and space for robotics integration. Moreover, involving parents, alumni, local businesses, and community leaders can lead to increased advocacy, sponsorships, and technical support. A multi-stakeholder approach will ensure the long-term implementation and growth of robotics in science education.

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