American Research Journal of Humanities & Social Science (ARJHSS)
E-ISSN: 2378-702X
Volume-08, Issue-10, pp-51-60
www.arjhss.com

Research Paper **Open Access**

Exploring Physics Teachers' Praxeology in Applying Mathematics to Real-life Contexts

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Abstract: The close relationship between mathematics and physics is often highlighted by the assertion that mathematics serves as the primary language of communication in the field of physics. This study aims to explore that assertion by analysing the instructional methods employed by physics educators, with a specific focus on the activity sheets (ASs) they use. By investigating their pedagogical approaches, this research centres on two critical components: the *Praxis Block*, which involves practical tasks and procedures, and the *Logos Block*, which addresses theoretical and technological domains. These components provide a framework for understanding the mathematical underpinnings of classroom activities, particularly as they relate to real-world applications. The findings reveal a substantial integration of mathematical principles into physics instruction, underscoring the inherent interdisciplinarity of the subjects and highlighting the potential for enhanced educational outcomes through their cohesive implementation.

Keywords: instructional strategies, interdisciplinary teaching, mathematics integration, physics education, real-life contexts

The global concern regarding inadequate performance in mathematics is both significant and well-documented (Chand et al., 2021). Mathematics distinguishes itself among academic disciplines due to its profound influence on overarching educational goals and its relevance to various spheres of human endeavour (Attahiru et al., 2023). It cultivates essential skills such as problem-solving, creativity, critical thinking, logical reasoning, and effective communication (Sami Khan & Salman, 2020). As such, the principal aim of mathematics education is to develop students' capacity for problem-solving (Da, 2023).

However, many students continue to struggle with mathematics, often questioning its practical relevance in everyday life. Consequently, it is imperative for mathematics educators to integrate real-life applications into their teaching practices (Gupta, 2018). A strong commitment to engaging instructional tasks, coupled with the ability to connect mathematical concepts to authentic problems, is essential for fostering student interest and participation (Arthur et al., 2018). Supporting this, Ndiung and Nendi (2018) emphasize the significant role of students' connectivity skills in shaping their academic performance in mathematics.

Perry and Dockett (2008), as cited by Ndiung and Nendi (2018), define the mathematical notion of "connections" as encompassing relationships within and across mathematical domains, as well as their links to a student's life, work, and play. The integration of Science, Technology, Engineering, and Mathematics (STEM) into education equips learners with vital 21st-century skills and strengthens their conceptual understanding of mathematics (Eshaq, 2023). However, Yildirim and Sidekli (2018) argue that while STEM integration enhances self-efficacy in mathematical literacy and pedagogical knowledge, it does not necessarily translate into improved mathematical thinking.

The importance of mathematical representation is also highlighted by Yuanita et al. (2018), who found that it helps bridge the gap between students' beliefs and their problem-solving skills. Moreover, collaborative, real-world teaching approaches have been shown to significantly enhance students' mathematics abilities and overall enjoyment of the subject (Kirby et al., 2023; Abdulrahim et al., 2023). Chavez and Lapinid (2019) further assert that the incorporation of real-life contexts in mathematics instruction expands students' perspectives and enhances their ability to connect mathematical learning with everyday experiences.

Mathematics also plays a critical role in physics, serving as its primary language and reinforcing the deep interconnection between the two disciplines (Pospiech et al., 2015). Physics, in seeking to understand the fundamental laws of nature, benefits greatly from the precision and structure that mathematics provides. Integrating mathematics in physics education not only advances conceptual understanding in both subjects but also prepares learners for scientific inquiry and citizenship (Chassy & Jones, 2019).

Teaching the interrelationship between mathematics and physics at the secondary level is essential for conceptual mastery. However, students often face difficulties linking observable physical phenomena with abstract mathematical concepts (Pospiech, 2015). This disconnect may lead learners to use mathematics solely as a computational tool, rather than as a foundation for logical reasoning, thereby limiting deeper comprehension (Walfridsson & Arvidson, 2023).

In the scientific domain, particularly in physics, blending physical and mathematical knowledge transforms how learners interpret mathematical expressions and attribute meaning to them. Developing mathematical reasoning within physics requires nurturing scientific thinking—a component that is often overlooked in physics instruction (Redish, 2021). Baukan et al. (2010) observed that while teachers acknowledge the importance of mathematical knowledge in various areas of physics, integrating these domains remains challenging due to the lack of structured methodologies. This aligns with the findings of de Winter and Airey (2022), who argue that proficiency in mathematics does not automatically result in success in physics.

The concept of *praxeology*, rooted in the theory of human action introduced by Alfred Victor Espinas in 1890 and expanded by Ludwig von Mises, refers to the logical structuring of intentional actions toward specific goals (Pankowska, 2021). It shares common ground with various disciplines, including psychology, pedagogy, and ethics (Lyashova et al., 2020), and is based on the foundational premise that individuals engage in purposeful behaviour (Rothbard, 2019).

Chevallard (2006), as cited by Pansell and Björklund (2018), adapted praxeology to the educational context to describe how mathematics is organized as a human activity. It comprises two central elements: *praxis* (knowing how) and *logos* (knowing why). This dual structure reflects the practical and theoretical dimensions of teaching, both of which must be addressed in teacher education (Pansell, 2023). One analytical approach is to examine the types of tasks and techniques (praxis block) and the accompanying technologies and theories (logos block) embedded within a teacher's instructional materials (Putra et al., 2021).

In the Philippine context, Alvarez (2020) found that incorporating praxeology into the mathematics curriculum enhanced student engagement and understanding. Similarly, Del Rosario (2018) reported that praxeological strategies in teacher education improved pre-service teachers' instructional methods and significantly elevated students' ability to apply mathematical concepts in practical contexts (Espino, 2019). Other studies support the notion that praxeology enhances critical thinking, motivation, and learning outcomes in mathematics (Lopez, 2017; Martinez, 2019; Nolasco, 2018), and positively impacts classroom dynamics and teacher effectiveness (Santos, 2017; Ramos, 2021).

Given this context, the present study aims to investigate the teaching methodologies of Physics educators in applying mathematics to real-life contexts. It specifically focuses on analyzing activity sheets as instructional tools and identifying the implications of such methodologies for mathematics instruction.

Research Questions

1. What is the praxeology of Physics teachers in applying mathematics in real-life contexts?
2. What is the implication of Physics teachers' praxeology in applying mathematics in real-life contexts for teaching mathematics?

I. Materials and Methods

This study employed a qualitative content analysis approach, which, according to Cohen et al. (2007) as cited by Putra et al. (2021), serves as a theoretical tool for examining broad-spectrum issues wherein the quality of information forms the foundation for inference. Through this method, appropriate analytical categories and units of analysis were meticulously identified.

The data consisted of six (6) activity sheets (ASs) prepared by Physics teachers, each addressing a distinct topic (see Table 1).

Table 1. Topics Discussed by Physics Teachers

Physics Teacher	Topics
1	Finding Earthquake's Epicentre
2	Solving Problems Uniformly Accelerated Motion in One Dimension
3	Determining Resultant Force Graphically and Analytically
4	Distribution of Active Volcanoes, Earthquakes, Epicentres and major Mountain Belts
5	Identifying Different Types of Plate Boundaries
6	Solving Problems on First Condition of Equilibrium

The researcher evaluated the mathematical content of the ASs using praxeology as an analytical lens. The evaluation followed a reference praxeological model constructed in accordance with Pansell's (2023) framework, which aligns the Mathematical Knowledge for Teaching (MKT) with the praxis (task and techniques) and logos (technology and theory) elements of instruction.

Treatment of Data

The analysis of the ASs focused on identifying the mathematical praxeologies present. Table 2 below outlines the analytical framework employed for examining both the Praxis Block (tasks and techniques) and the Logos Block (technology and theory).

Table 2. Analysis Framework of Physics Teachers' Praxeology using Activity Sheets (ASs)

4Ts of Praxeology	Explanation
Type of Tasks	Derived from stated objective of the activity sheet
Techniques	Mathematical methods or process required to complete the task
Technology	Tools and instrument utilised in task execution
Theory	Scientific principles involving mathematical understanding

Ethical Considerations

This study adhered to ethical standards set by the Centro Escolar University-Institutional Ethics Review Board (CEU-IERB) and complied with the Data Privacy Act of 2012 (RA 10173). Measures were taken to protect the anonymity and confidentiality of the participants, including secure data handling, informed consent, and data use strictly for research purposes.

Delimitation of the Study

This study focused exclusively on Physics teachers with at least five years of teaching experience in selected Metro Manila public high schools. The participants' demographic profiles were not used as distinguishing variables. The scope was limited to analysing their prepared ASs,
and implications were drawn concerning the application of mathematics in instructional practices.

II. Results and Discussions

A. Physics Teachers' Praxeology in Applying Mathematics in Real-life Contexts

Table 3 presents a summary of the mathematical praxeologies demonstrated by Physics teachers in applying mathematics to real-life contexts, structured according to the four components of praxeology: task, technique, technology, and theory.

Table 3. Physics Teachers' Mathematics Praxeology

Physics Teachers	Praxis Block		Logos Block	
	Task	**Technique**	**Technology**	**Theory**
1	Locate the earthquake's epicentre using seismograph records from three different stations.	Apply the triangulation method to locate the earthquake's epicentre.	Use of compass, ruler, and pencil.	The triangulation method is used to determine the precise location of an earthquake or its epicentre.
2	Solve Physics problems involving uniformly accelerated motion in one dimension.	Use the Given, Required, Equation, Solution, Answer (GRESA) method to solve problems.	Use of calculator.	Uniformly accelerated motion refers to motion along a straight path with constant acceleration. Kinematic equations relate displacement, initial and final velocity, acceleration, and time.
3	Determine the resultant force by combining multiple forces acting on an object using graphical methods and verify the results analytically.	Use the head-to-tail method graphically and confirm results analytically through the component method.	Use of compass, straight ruler, pencil, and calculator.	The resultant force represents the combined effect of multiple forces. The graphical (head-to-tail) and analytical (component) methods are used to determine this force.
4	Describe the distribution of active volcanoes, earthquake epicentres, and major mountain belts.	Analyse and interpret geological data using map legends.	Use of pencil and calculator.	Volcanoes, earthquakes, and mountain ranges align with the boundaries of tectonic plates. Their distribution is influenced by plate interactions.
5	Identify the type of plate boundary associated with major lithospheric plates.	Analyse plate movement using directional arrows, requiring understanding of vectors.	Use of compass, ruler, and pencil.	Plate boundaries are regions where tectonic plates interact. The theory of plate tectonics categorizes them as convergent, divergent, or transform boundaries.
6	Understand the first condition of equilibrium and analyse balanced forces using mathematics.	Use problem-solving strategies incorporating vector and trigonometric principles.	Use of compass, ruler, pencil, and calculator.	The first condition of equilibrium ensures structural stability by requiring the net force on an object to be zero

According to observations, the mathematical praxeology of Physics teachers involves the application of mathematics in practical contexts, necessitating a solid foundation in prior mathematical knowledge. Studies such as Vinitsky-Pinsky and Galili (2014) highlight the intrinsic connection between mathematics and physics, emphasizing the importance of mathematical proficiency in understanding theoretical frameworks and generating accurate predictions. One of the primary aims of studying Physics is to develop the ability to reason and construct arguments using mathematical principles. This objective aligns with the findings of Pospiech et al. (2015), who stress the utility of mathematics as the language of physics, and how real-world instruction reveals the specific strategies employed by both teachers and students.

Physics elucidates the laws of nature, thereby enhancing our comprehension of the physical world and our interaction with it. Chassy and Jones (2018) assert that integrating mathematics and physics education fosters simultaneous growth in both mathematical understanding and its practical applications in scientific contexts—an essential foundation for cultivating future scientists and informed citizens. However, Brkić et al. (2022) identified a concerning trend: students not adequately trained in applying mathematical knowledge tend to struggle, and their acquired knowledge is often transient. Addressing this issue is crucial for reinforcing a stable foundation in both physics and mathematics education.

To complete assigned tasks, Physics teachers routinely employ problem-solving strategies, underlining the pivotal role of such techniques in Physics instruction (Ince, 2018). A key predictor of students' success in solving Physics problems is their prior mathematical knowledge (Djudin, 2023). Differences in cognitive strategies persist, even though the capacity to use multiple representations effectively is vital for solving Physics problems (Sutriani & Mansyur, 2021). Moreover, students equipped with stronger English and mathematics skills perform better in problem-solving, particularly when explicitly taught problem-solving techniques (Wanya, 2016).

To successfully transfer algebraic competencies from Mathematics to Physics, students must draw upon their pre-existing knowledge through structured problem scenarios and instructional models. These approaches are practical for educators and enhance students' problem-solving capabilities. Tambunan (2019) reported that such strategies surpass traditional science instruction in developing essential mathematical skills, including communication, creativity, reasoning, and problem-solving. This demonstrates how problem-solving strategies can reinforce a broad range of mathematical abilities when learning Physics.

In terms of technology, Physics teachers commonly utilise basic tools such as rulers, compasses, and calculators to execute mathematical techniques within real-life applications. Rulers and compasses are standard tools used to solve geometry-related problems (Graf, 1988), and most of the tasks analysed require foundational skills in geometry. Calculators, meanwhile, support conceptual problem-solving and knowledge exploration (Nguyen & Nguyen, 2023). However, a persistent issue in Philippine classrooms is the limited access to technology for studying and learning Mathematics (Bautista & De Las Peñas, 2006).

Nueva (2019) found that digital inequality in schools, which is linked to students' ability to use technology effectively for academic purposes, correlates with teachers' technological competence and institutional interventions. While educators acknowledge the pedagogical value of technology integration, its effective use remains hampered by multiple factors, including poor internet connectivity, lack of training, limited access to devices, and insufficient time for technology use within the curriculum (Atilano-Tang & Cirilo, 2023).

Fundamental tools such as calculators, compasses, and rulers continue to be heavily relied upon by Physics teachers for executing mathematical procedures in practical contexts. A strong grounding in geometry is essential for these tasks (Graf, 1988). According to Nguyen and Nguyen (2023), calculators facilitate problem-solving, support conceptual thinking, and enhance information discovery.

Nonetheless, challenges persist regarding the accessibility of educational technology in the Philippines. Bautista and De Las Peñas (2006) pointed out that inadequate infrastructure limits technology use in schools. Nueva's (2019) research reinforces this by linking technological access to both teacher capability and institutional initiatives. Despite their awareness of the benefits of educational technology, teachers continue to face barriers, including lack of professional development, inadequate hardware, unreliable internet access, and constrained curricular time (Atilano-Tang & Cirilo, 2023). To fully harness the potential of technology in enhancing Mathematics and Physics education, it is essential to address these systemic challenges comprehensively.

B. Implications of Physics Praxeology in Applying Mathematics in Real-life Context to Mathematics Teaching

In his 2008 study comparing and contrasting the values inherent in scientific and mathematical education, Alan Bishop observed that, from an ideological perspective, science educators place greater emphasis on empiricism, while mathematics educators tend to align with rationalist principles. In terms of the social dimension, both disciplines promote a sense of control; however, with respect to advancement, science seeks to expand understanding through relationships, whereas mathematics aims to generate new knowledge via logical structures. Furthermore, in the emotive dimension, science appears to resonate more strongly with the humanising aspects of knowledge—such as openness and a sense of mystery—than does mathematics.

While the empirical knowledge derived from the sciences is invaluable, it necessarily implies rational thought, as individuals require reason to act purposefully within the world. Achieving personal growth, technological progress, and broader development is made possible through the practical application of learned experiences to everyday and technological contexts. The development of perceptual abilities is central to this application and is facilitated by a philosophical teaching principle. This principle instructs learners in both deductive and inductive reasoning, helping them extract general knowledge from specific examples. The rational element within empiricism is thus highlighted to underscore the role of reason in experience and, consequently, in knowledge.

Scientific and mathematical literacy are vital not only for personal development but also for societal advancement. Mastery of language is essential to excel in science and mathematics (Cruz Neri et al., 2022). According to the OECD Programme for International Student Assessment (PISA), mathematical literacy refers to the ability to recognise how mathematics functions in the world and to apply it effectively for decision-making and meaningful living (Rizki & Priatna, 2019). Science, grounded in the study of patterns in the physical world, and mathematics, the study of abstract patterns, are interdependent—mathematics acts as a language for articulating scientific explanations (Mickens & Patterson, 2017).

Science and mathematics have been linked since at least the 17th century, when mathematically inclined thinkers began exploring natural phenomena with rigorous intensity. However, while mathematics can describe phenomena quantitatively, it cannot explain causes or mechanisms (Gaede, 2014). The concept of mathematics as the language of science is often attributed to Galileo Galilei, who famously noted that the universe cannot be understood unless one learns the language in which it is written—mathematics (Helmenstine, 2020). This underscores why science and mathematics complement each other: science presents intriguing problems, and mathematics provides the analytical tools needed to explore them. According to Osborne (2014), as cited by Wong (2018), mathematics serves both a communicative function—as one of the languages of science—and a structural function that allows for logical reasoning and deduction.

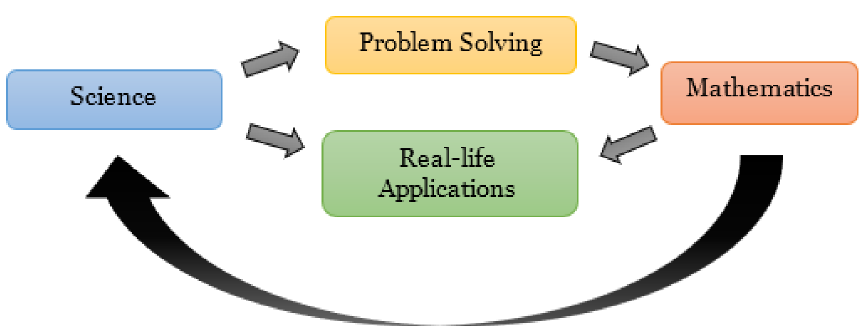
The integration of scientific content with other academic disciplines leads to a more profound understanding of concepts and their real-life applications (DepEd, 2016). With increasing demand for Science, Technology, Engineering, and Mathematics (STEM) competencies, many students pursue advanced mathematics in anticipation of its relevance to their future studies or careers (Kaleva et al., 2019). As scientific communities and educational researchers promote the integration of STEM fields across curricula, it becomes imperative that teachers are well-versed in the nature of science (NOS), a cornerstone of scientific literacy (Wong et al., 2016).

In a study by Nakakoji and Wilson (2018), the transferability of mathematical learning to scientific contexts was examined using university assessment data. Their findings revealed that transfer occurred primarily in Physics and Engineering courses—disciplines where mathematical achievement had a strong, direct, and positive influence on student performance. In contrast, no such effect was observed in Biology or Molecular Biosciences.

The ability to use mathematics to formulate and prove arguments is central to Physics (Redfors et al., 2014). Mathematics establishes precise relationships between symbols, allowing for indefinite repetition within equations—a characteristic that enhances its utility in Physics (Doran, 2017). It seems that the version of mathematics employed in Physics differs from the mathematics typically taught by mathematicians. According to Redish and Kuo (2015), this difference lies in how physicists ascribe physical meaning to mathematical symbols, resulting in distinct interpretations by physicists and mathematicians.

Consequently, based on the results of this study and corroborating literature, the researcher developed the Science and Mathematics Interdisciplinary Learning Environment (SMILE) Framework. This framework encapsulates the synergistic relationship between scientific disciplines—particularly Physics—and the teaching of mathematical concepts. A visual representation of this model is shown in Figure 1 below.

Figure 1. The SMILE Framework



In disciplines such as Physics, the resolution of practical problems is a routine process, given the subject's focus on the fundamental laws that govern the natural world. By applying these principles to everyday scenarios, students develop a deeper understanding of their relevance, thereby enhancing the subject's appeal. In contrast, Mathematics, though often considered a self-contained system, encompasses foundational concepts that are intrinsically linked to real-world contexts, albeit in a more abstract form. As Mitchelmore and White (2007) note, the acquisition of mathematical concepts frequently involves engagement with empirical experiences.

According to research by Asli and Zsoldos-Marchis (2021), Physics is the domain in which the integration of mathematical applications is most pronounced. Despite the evident importance of mathematics in Physics, many students exhibit a negative attitude towards mathematics. This aversion is thought to be influenced by various factors, including instructional strategies and cognitive challenges (Gafoor & Karukkan, 2015).

The ability to relate mathematics to real-world problems depends on several factors, such as teacher motivation, instructional quality, resource availability, and access to appropriate mathematical tools (Arthur et al., 2017). Asli and Zsoldos-Marchis (2021) also identified barriers to teaching interdisciplinary content, including time constraints, rigid curricula, limited scientific and methodological knowledge among teachers, and a lack of adequate materials for demonstrations.

The Science and Mathematics Interdisciplinary Learning Environment (SMILE) Framework is an educational model that blends concepts, strategies, and applications from both scientific and mathematical disciplines. It encourages students to explore the connections between these fields, leading to a more comprehensive understanding of how they mutually reinforce one another.

The SMILE Framework promotes student engagement through activities that apply mathematical principles to scientific problems and vice versa—using scientific inquiry to investigate mathematical concepts in authentic, real-life contexts. Its core objective is to overcome traditional disciplinary silos and foster integrated learning experiences that cultivate critical thinking, creativity, and problem-solving skills.

By taking an interdisciplinary approach, students come to appreciate the practical significance of both science and mathematics. They also acquire the competencies necessary to tackle complex problems in various fields. Furthermore, the SMILE Framework promotes a holistic understanding of the interdependence between natural phenomena and the mathematical tools used to represent and analyse them.

III. Final Considerations

The idea that mathematics is the language of science underscores the importance of ensuring that science educators—especially those teaching Physics—possess a strong command of mathematical concepts appropriate to their instructional level. Conversely, mathematics educators must be able to contextualise mathematical problems and examples within real-life scenarios to ensure their relevance and applicability (Sanchez & Ponce, 2020). A key challenge lies in reconceptualising mathematics instruction so that it serves as a cognitive tool for understanding Physics—an issue that warrants careful reflection.

Given that this study is limited to analysing activity sheets developed by Physics teachers who integrate mathematics into their instruction, further research is required to explore the broader interactions between these two disciplines. Despite their distinct philosophical foundations, recognising the intersections between Mathematics and Physics is critical for advancing education in both fields. Such understanding can inform curriculum development, pedagogical strategies, and educational policy (Vinitsky-Pinsky & Galili, 2014). Progress in both disciplines may be accelerated by deepening our understanding of how mathematical structures underpin physical theories—a process that calls for ongoing research and dynamic collaboration across subject boundaries (Woit, 2015).

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