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A Phenomenological Validation on 5A's Pedagogical Model: An Interdisciplinary STEM Education Framework

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Abstract

This research examines expert opinions about the 5A's Pedagogical Model's clarity, relevance, completeness, and viability in order to validate it as a framework for interdisciplinary STEM education. A qualitative phenomenological design was used to examine the lived experiences of twelve expert validators from K–12 and higher education using Colaizzi's technique. The primary data gathering method was semi-structured interviews, which enabled participants to provide comprehensive insights on the model's advantages and shortcomings. The results showed that the model's organized phases—Association, Action, Abstraction, Assessment, and Assimilation—were very effective in integrating science and mathematics while fostering deeper conceptual comprehension and significant interdisciplinary links. However, in order to improve usability and consistency, experts emphasized the use of classroom exemplars, organized guidelines, clear evaluation rubrics, and the incorporation of digital resources. The primary challenges identified were practical in nature, such as the need for continuous teacher training, adequate preparation, strong institutional backing, and sufficient resources.

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Introduction

Across the world, there is a rising demand to strengthen student achievement in STEM. International assessments such as TIMSS and PISA consistently highlight these concerns, showing that Filipino students perform below many of their peers in essential skills like reasoning, problem-solving, and higher-order thinking (Nguyen et al., 2020; Çavaş et al., 2024). These results underscore the urgent call to improve the quality of STEM education. For the Philippines, this need is even more critical, as the country strives to raise academic performance and remain competitive in a global landscape that increasingly depends on science and technology (Chisom et al., 2024).

Although the importance of linking science and mathematics is widely acknowledged, classrooms often continue to treat them as separate subjects. Science is usually presented as experiments and facts, while mathematics is reduced to abstract rules and formulas. This divide prevents students from seeing how the two disciplines naturally connect and complement each other in solving real-world problems. Many teachers also struggle to show how mathematical concepts apply to scientific inquiry, leaving learners disengaged and unable to appreciate the value of interdisciplinary thinking (Suhirman & Prayogi, 2023; Sulaeman et al., 2022). The situation is made worse by a curriculum that still favors memorization over analysis, application, and connection. Yet, the demands of the 21st century require students to cultivate creativity, critical thinking, and deeper conceptual understanding—skills that are often stifled under traditional approaches (Daniela et al., 2022; Triantafyllou, 2024).

To respond to these challenges, this study introduces and validates the 5A's Pedagogical Model, a teaching framework built around five interconnected phases: Association, Action, Abstraction, Assessment, and Assimilation. The model is designed to bridge science and mathematics, offering teachers a structured yet flexible approach to highlight the natural links between the two disciplines. By grounding abstract ideas in meaningful experiences and guiding students through cycles of inquiry, reflection, and application, the 5A's Model seeks to create classrooms where learners are not only actively engaged but also equipped to think across disciplines (Mahat, 2022; Fante et al., 2024).

A crucial step toward strengthening multidisciplinary STEM education in the Philippines is validating the 5A's Pedagogical Model through expert review and classroom application. When effectively implemented, it has the potential to transform teaching by moving away from fragmented instruction toward more integrated and meaningful learning experiences. More importantly, it helps students develop essential skills—such as problem-solving, critical thinking, and collaboration—that prepare them not only for academic success but also for the demands of a rapidly changing world (Bufasi et al., 2024). In this sense, the 5A's Model is not simply another teaching strategy; it offers a new way of reimagining how science and mathematics education can empower Filipino learners to face future challenges with competence, confidence, and creativity.

Literature Review

Pedagogical Practices

Progressive teaching approaches have long been recognized as essential for improving student outcomes and narrowing the gap between science and mathematics instruction. Among the most effective are contextual learning, inquiry-based learning, and problem-solving. Problem-solving, in particular, encourages learners to apply their knowledge to real-life situations, helping them build creativity and critical thinking skills (Семеніхіна et al., 2022). This aligns with Murat's perspective, cited in Семеніхіна et al. (2022), which stresses that STEM education becomes meaningful when students engage with problems that naturally combine both mathematical and scientific ideas.

Inquiry-based learning strengthens this approach by encouraging students to ask questions, explore possible answers, and draw evidence-based conclusions. Such active engagement promotes deeper understanding and builds transferable analytical skills (Boltsi et al., 2024). Contextual learning further supports this process by connecting lessons to real-world situations, making knowledge more meaningful and relevant to learners (Zhan et al., 2022). Recent innovations, such as the use of tools like SageMath, even allow students to model real-life phenomena and observe how abstract concepts can be applied in practice (Borovský et al., 2025). Together, these strategies create dynamic learning environments where students not only remember content but also develop the ability to think across disciplines and apply their knowledge in meaningful ways.

Didactics and the Theory of Didactical Situations (TDS)

Brousseau's Theory of Didactical Situations (TDS) offers a framework for understanding the interaction between teaching strategies and student learning. At its core is the idea of the "didactical contract," the unspoken agreement that defines the roles and responsibilities of both teachers and learners in the classroom (Tian et al., 2025). TDS views learning as a dynamic process shaped by the classroom environment and the intentions of the teacher, rather than as a simple transfer of knowledge from teacher to student (Семеніхіна et al., 2022).

Recent studies have expanded the application of TDS in STEM education, showing how it helps reveal whether teaching practices support or limit student participation. Su (2025) points out that bringing situational awareness into STEM allows teachers to respond more effectively to learners' needs, while Wang et al. (2020) highlight its role in promoting collaboration among teachers and encouraging cross-disciplinary planning. Viewed through the lens of TDS, educators are guided to adopt more intentional and reflective practices in STEM instruction, which ultimately enhances both student engagement and learning outcomes (Zhan et al., 2022).

Integration of STEM

lobally, research continues to highlight the transformative potential of connecting science and mathematics. Integrated STEM education not only deepens subject knowledge but also strengthens critical thinking, problem-solving, and the ability to transfer learning across disciplines (Muñoz-Losa & Merino, 2024; Suchikova & Kovachov, 2024). Interdisciplinary classrooms, for example, have been shown to increase student engagement by linking lessons to broader social issues (Andreoni & Richard, 2023). Yet, in the Philippine context, studies such as Nguyen et al. (2020) reveal persistent challenges. Teachers often struggle with rigid curricula and limited resources, making it difficult to fully implement integrated STEM in practice.

These challenges reflect global trends as well. Research shows that many teachers feel unprepared to deliver integrated lessons, which affects both their confidence and the quality of instruction (Alm et al., 2021; Chai et al., 2020). Misconceptions also persist, such as the belief that STEM integration is too complex to manage within traditional school structures (Verawati & Sarjan, 2023). Yet, studies like Goos et al. (2023) demonstrate that when integration is implemented effectively, it can transform both teaching practices and student learning. This highlights the importance of deliberate and systematic efforts to overcome these barriers.

Research Gap

While the advantages of integrated STEM education are widely recognized, significant gaps remain in the availability of evidence-based, context-sensitive teaching approaches. Many existing frameworks fall short in practice because they are too rigid and fail to adapt to specific local contexts (Andreoni & Richard, 2023; Yurchenko et al., 2022). To address this, scholars argue for the development of models that balance theory with practical application, offering educators both clear conceptual guidance and workable tools they can apply in the classroom (Aguilera et al., 2024).

Recent research highlights the growing complexity of interdisciplinary education and the need to address key contextual challenges such as curriculum demands, teacher readiness, and institutional support (Ying-qian & Zhu, 2023; Lin et al., 2022; Su, 2025). Many teachers face these obstacles in isolation, often without structured frameworks to guide integration. To move forward, new models must offer clear and practical strategies that help educators meaningfully connect science and mathematics. As emphasized by Bordin et al. (2023) and Joseph and Uzondu (2024), such frameworks should promote interdisciplinary thinking in ways that are not only effective but also sustainable and relevant to local contexts.

Theoretical Foundations of the 5A's Pedagogical Model

The development of the 5A's Pedagogical Model is grounded in two key theories: Lave and Wenger's Situated Learning Theory (SLT) and Brousseau's Theory of Didactical Situations (TDS). TDS highlights that learning occurs through structured interactions among students, teachers, and content, all within purposeful contexts that encourage problem-solving and the validation of ideas (Sousa et al., 2023). The 5A's sequence—Association, Action, Abstraction, Assessment, and Assimilation—embodies this principle. Learners begin with real-world problems, engage in active inquiry, move toward formalizing concepts, test and validate their reasoning, and finally, apply their knowledge to new situations.

Figure 1 illustrates how the stages of the proposed pedagogical model are interconnected. The process begins with the *Association Phase,* where students confront real-world problems that naturally connect science and mathematics. This leads to the *Action Phase***,** in which learners actively explore and engage with tasks situated in meaningful learning contexts. The bidirectional arrows in the diagram highlight the continuous exchange between scientific and mathematical understanding, ensuring that knowledge is integrated and connected rather than treated as separate or fragmented.

The model then progresses to the *Abstraction Phase*, where students move from hands-on exploration to the formalization and generalization of concepts. This is followed by the *Assessment Phase*, which allows learners to test the accuracy of their solutions and evaluate the soundness of their reasoning. The cycle concludes with the *Assimilation Phase*, ensuring that knowledge can be applied to new and varied situations. A feedback loop from Assimilation back to Association emphasizes the cyclical nature of learning, showing that knowledge is continuously refined and strengthened each time it is reapplied in fresh contexts.

The framework is further strengthened by incorporating Situated Learning Theory (SLT), which emphasizes that knowledge is built within social and collaborative contexts. Lave and Wenger argue that learners create meaning as they participate in communities of practice (Feitosa et al., 2023). This idea is most evident in the 5A's Model during the *Association* and *Assimilation* stages, where collaborative inquiry and real-world experiences make learning more relevant and engaging (Prabowo et al., 2022). By embedding science and mathematics into meaningful, socially grounded activities, the model transforms classroom practice into a continuous cycle of inquiry, reflection, and application—an approach that aligns with the essence of authentic STEM learning (Wang et al., 2020; Lin et al., 2022).

In this way, the 5A's Pedagogical Model serves as a bridge that brings together the principles of both TDS and SLT, as illustrated in Figure 1. It promotes a structured yet cyclical approach to teaching that fosters collaboration, critical thinking, and problem-solving. Rather than being a simple sequence of steps, it functions as an integrated cycle of exploration and application, breaking down disciplinary boundaries and preparing students to face STEM challenges with confidence and competence.

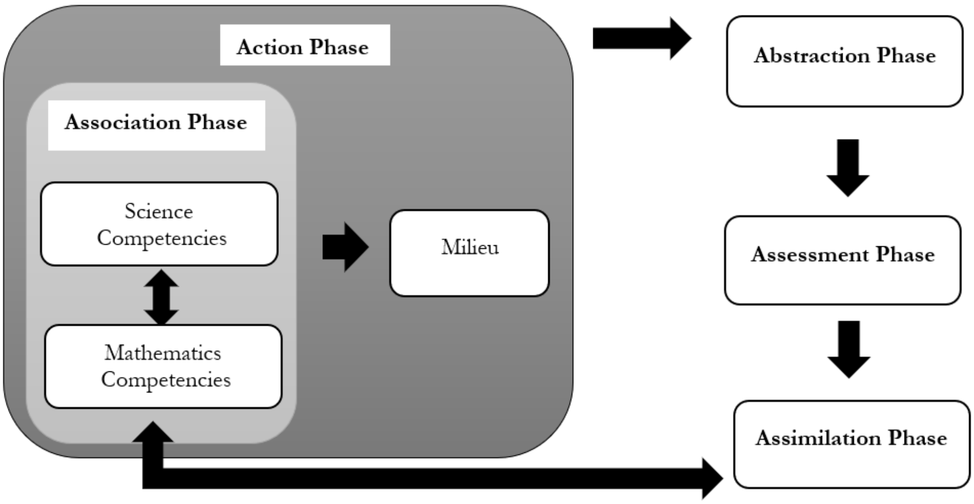

Figure 1. Proposed 5A's Pedagogical Model

The 5A's Pedagogical Model is grounded in constructivist learning and the integration of disciplines, making it a strong framework for effective STEM instruction. While it is built on well-established educational theories, it is equally important to understand how experts in STEM, physics, and mathematics perceive and experience the model in practice. Through a qualitative phenomenological approach, this study captures those authentic perspectives, allowing the model to be validated in terms of its clarity, relevance, and practical application based on the lived experiences and insights of specialists.

Methods

Research Design

This study set out to explore and document the lived experiences and perspectives of experts on the 5A's Pedagogical Model through a qualitative phenomenological approach. Phenomenology was chosen because it focuses on participants' personal insights, making it well-suited for validation studies of this kind. It allows researchers to understand how professionals interpret, evaluate, and assign meaning to the model within the context of integrated STEM education (Neubauer et al., 2019). Unlike purely quantitative validation, which relies heavily on statistical measures, this design emphasizes depth and meaning-making, ensuring that the framework is assessed not only for its theoretical strength but also for its practical value (Sandelowski, 2021).

To achieve this, the study employed Colaizzi's phenomenological analysis method, which follows a systematic process of identifying significant statements, deriving meanings, clustering them into themes, and developing a comprehensive description (Morrow et al., 2020). This approach, widely used in both health and education research, ensures rigor, reliability, and transparency in qualitative analysis. By applying this method, the study was able to validate the 5A's Model through rich, descriptive accounts of expert experiences, making the findings both relevant and grounded in practice.

Participants

The study's participants were expert validators carefully selected for their strong credentials and background in STEM education, science, and mathematics. To ensure the credibility of their contributions, the experts met specific criteria: (a) holding a master's degree in education or a related STEM field, (b) having at least five years of experience in teaching, curriculum development, or research, and (c) being actively engaged in either K–12 or higher education. These qualifications guaranteed that the participants could offer well-informed perspectives on the 5A's Pedagogical Model, balancing theoretical knowledge with practical classroom realities.

In qualitative research, and especially in phenomenological validation studies, the depth and quality of insights often matter more than the number of participants (Creswell & Poth, 2018). Methodological literature suggests that a minimum of three to five expert validators is sufficient to establish content or conceptual validity (Yusoff, 2019). Guided by this standard, the study ensured that the number of participants was both adequate to capture a range of viewpoints and manageable for in-depth phenomenological analysis. Using purposive sampling, which values the richness of perspectives over broad generalization (Palinkas et al., 2015), the research brought together experts from both basic and higher education. This diversity helped ensure that the model's potential relevance could be assessed across different levels of the education system.

Instrument

The primary instrument used in this study was a semi-structured interview guide created to explore expert perspectives on the 5A's Pedagogical Model. Semi-structured interviews were chosen because they strike a balance between structure and flexibility, allowing the researcher to stay aligned with the study's objectives while also giving participants the freedom to elaborate on new or unexpected insights (Adams, 2015). The guide focused on four key areas: the clarity and coherence of the model, its practicality in classroom teaching, its relevance to interdisciplinary STEM education, and recommendations for improvement.

Each section included open-ended questions such as, "How clear and cohesive do you find the progression of the 5A's phases?" and "What opportunities or challenges might arise when applying the model in real classroom contexts?" This format ensured consistency across interviews while still giving participants room to share detailed reflections on their experiences. To strengthen its reliability and appropriateness for data collection, the instrument was peer-reviewed by two qualitative research experts, who suggested minor revisions to improve clarity and ensure alignment with the study framework (Kallio et al., 2016).

Data Analysis

To capture meaning from the experts' lived experiences, the study applied Colaizzi's phenomenological method, a systematic approach well-suited for this type of analysis. The process began with repeated readings of the interview transcripts to achieve familiarity and immersion, following Colaizzi's seven steps. Significant statements directly related to the validation of the 5A's Pedagogical Model were then identified and extracted. These were rephrased into clear, concise meanings and organized into thematic clusters that reflected key areas such as clarity, relevance, application, and suggestions for improvement.

Through this iterative process, the analysis produced a comprehensive account of expert perspectives, highlighting both areas of agreement and points of divergence. To strengthen the credibility of the findings, the essential structure of the phenomenon was summarized and returned to participants for member checking, ensuring their perspectives were accurately represented (Morrow, Rodriguez, & King, 2015; Nowell et al., 2017). By combining thematic interpretation with Colaizzi's structured approach, the study offered a rich understanding of how experts viewed and validated the framework. Member validation further enhanced the trustworthiness of the results, meeting essential standards of qualitative rigor (Creswell & Poth, 2018).

Results

The study applied Colaizzi's (1978) seven-step phenomenological analysis to explore expert validators' views on the 5A's Pedagogical Model. Key statements from the interviews were extracted, reformulated into concise meanings, and then organized into broader thematic categories. These themes highlighted emerging concerns such as teacher preparation, contextualization, and the availability of resources, while also aligning with the four main validation domains: relevance, clarity, completeness, and feasibility.

Table 1 presents these expert insights alongside their thematic clusters, illustrating both the diversity of individual perspectives and the overall validity of the framework.

Table 1. Colaizzi Analysis of Expert Perspectives on the 5A's Pedagogical Model

Participant Code	Significant Statement	Formulated Meaning	Theme Cluster
E1	Implementation is possible if teachers are trained.	Teacher preparation is critical for effective use.	Feasibility (Teacher readiness)
E2	The framework captures essential links between math and science.	Framework aligns with interdisciplinary needs.	Relevance (STEM alignment)
E3	The phases are understandable, but classroom examples are needed.	Clear phases but lacks classroom exemplars.	Clarity (Need for exemplars)
E4	Assessment needs more explicit rubrics.	Assessment design requires more support tools.	Completeness (Assessment support)
E5	Teachers will need structured guides to avoid misinterpretation.	Guidance materials ensure consistent application.	Clarity (Supporting materials)
E6	The model is practical, but resources may be an issue.	Feasible, but limited by available resources.	Feasibility (Resource dependency)
E7	It contextualizes STEM but requires ongoing training.	STEM contextualization requires sustained PD.	Feasibility (Sustainability)
E8	The model encourages learner engagement, but monitoring tools are needed.	Learner engagement needs structured monitoring tools.	Completeness (Monitoring mechanisms)
E9	There is a strong emphasis on theory, but application must be highlighted.	Balance between theory and practical application is needed.	Relevance (Theory-practice balance)
E10	Collaboration between teachers is essential for success.	Collaboration enhances implementation fidelity.	Feasibility (Collaboration)
E11	The phases are logical, but digital tools should be integrated.	Logical flow but integration with technology is required.	Clarity (Integration with digital tools)
E12	It is relevant to STEM goals, but feasibility depends on administrative support.	Framework relevance tied to institutional support.	Feasibility (Administrative support)

As shown in Table 1, experts frequently highlighted the strong alignment of the framework with the goals of STEM integration. Many participants (E2, E9, E12) noted that the model effectively helps students recognize interdisciplinary connections and bridges the gap between science and mathematics. However, while they affirmed its theoretical strength, they also stressed that successful implementation depends heavily on institutional and administrative support. This underscores the importance of embedding the framework within broader educational policies and systems to ensure its sustainability.

While participants agreed that the stages of the 5A's Model were logical and easy to follow, they pointed out the need for clearer classroom examples and additional resources to better guide teachers (E3, E5, E11). Providing exemplars and structured teaching guides was seen as essential to ensure consistent application across different contexts and to minimize misinterpretations. Several experts also recommended integrating digital tools to make the model more relevant, practical, and accessible in today's technology-driven classrooms.

Another key point raised by the experts was the model's treatment of teaching and learning processes. They emphasized that the assessment component needed further development, particularly in providing clear rubrics and monitoring tools (E4, E8). Although the phases of the model are comprehensive in theory, the feedback suggests that incorporating explicit assessment and evaluation strategies would strengthen its practical application in the classroom.

A recurring theme in the feedback was the question of the model's feasibility. Experts agreed that its success largely hinges on teacher readiness, access to resources, and continuous professional development (E1, E6, E7, E10). They noted the uneven distribution of resources across schools, the importance of teacher collaboration, and the critical role of sustained training to ensure long-term implementation.

Overall, the experts affirmed that the 5A's Pedagogical Model is both relevant and promising for advancing multidisciplinary STEM education. However, they also stressed the need to address practical concerns—such as resource support, well-defined assessment tools, concrete classroom examples, and ongoing teacher training—to maximize its impact. These insights not only strengthen the framework's theoretical grounding but also provide actionable guidance for making it more effective in real classroom settings.

Discussion

The findings of this validation study show that the 5A's Pedagogical Model is both relevant and timely for advancing interdisciplinary STEM education. Experts highlighted its strength in clearly illustrating the connections between science and mathematics, enabling students to meaningfully recognize these intersections. The framework's alignment with integrated STEM goals—designed to move beyond compartmentalized, subject-specific teaching toward more holistic learning—was identified as one of its greatest contributions. Similar to Saikat et al. (2022), experts emphasized the importance of pedagogical models grounded in context, which can deepen conceptual understanding and bridge disciplinary gaps. At the same time, they cautioned that successful implementation requires not only strong design but also institutional and administrative support, echoing Clark et al.'s (2025) call for systemic backing to sustain educational innovation.

Clarity and usability emerged as recurring concerns. While the stages of the model were found logical, experts pointed out the need for classroom exemplars, structured guides, and digital tools to prevent misinterpretation and ensure consistency. This aligns with Tondeur et al. (2023), who found that pedagogical models are more effective when supported by digital competencies and instructional scaffolds. Similarly, Praharaj et al. (2024) highlighted the value of real-world examples in teacher training to strengthen implementation.

Another area identified was assessment. Although the framework covers the essential stages of teaching and learning, experts noted that the assessment phase requires clearer rubrics and monitoring tools. This resonates with Kantathanawat et al. (2025), who stressed the importance of structured evaluation instruments in ensuring that learning goals are measurable and meaningful. Incorporating strong assessment practices into the 5A's framework would not only improve accountability but also provide educators with more reliable insights into student progress.

Perhaps the most pressing concern raised was feasibility. The model's success depends heavily on teacher readiness, access to resources, collaboration, and continuous professional development. These challenges mirror broader issues in STEM education, where reforms often falter due to systemic inequities and inadequate training (Caetano et al., 2021; Le et al., 2021). Addressing these barriers will require investments in teacher capacity-building, equitable resource distribution, and the cultivation of collaborative professional learning communities.

In conclusion, the 5A's Pedagogical Model shows strong potential as a framework for integrated STEM instruction. Yet, its promise can only be realized if practical challenges are addressed. These include developing explicit evaluation tools, integrating digital resources, providing clear instructional exemplars, and securing systemic support through policies and training. By resolving these issues, the 5A's Model can serve not only as a theoretically sound framework but also as a practical guide that empowers educators to deliver meaningful interdisciplinary STEM education across diverse contexts.

Conclusion

The study concludes that the 5A's Pedagogical Model offers a well-structured and reliable foundation for advancing multidisciplinary STEM education. Experts affirmed its ability to create meaningful connections between science and mathematics, highlighting its logical sequence and effectiveness in helping students deepen their conceptual understanding. While the model's clarity and applicability were widely recognized, areas for improvement were also identified, such as integrating digital tools, developing clear assessment rubrics, and providing concrete classroom exemplars. For the framework to reach its full potential, practical challenges—including teacher readiness, limited resources, and the need for continuous professional development—must be addressed.

The findings also carry important implications for teachers, curriculum developers, and policymakers. For educators, the 5A's Model can serve as a valuable guide for designing interdisciplinary lessons, provided that proper training and instructional supports are in place. Curriculum designers can enhance its impact by creating detailed evaluation tools and user-friendly teaching guides to ensure consistent application. At the policy level, school leaders and administrators are encouraged to invest in professional development, allocate resources, and strengthen institutional support to sustain the framework's use across diverse settings. Finally, future research should focus on classroom-based studies to generate stronger empirical evidence of the model's effectiveness. With adequate support, the 5A's Pedagogical Model has the potential not only to enrich theory but also to transform teaching practices and improve STEM learning outcomes.

Recommendations

Drawing from the findings, the study recommends that teacher professional development programs should intentionally incorporate the 5A's Pedagogical Model to better prepare educators for interdisciplinary STEM teaching. To promote consistency in classroom practice, curriculum developers are encouraged to design and share clear instructional exemplars, detailed rubrics, and digital toolkits aligned with the framework. At the institutional level, school leaders and policymakers should allocate resources and funding to support materials, training, and collaboration, ensuring that practical challenges are addressed. Finally, future research should focus on piloting the model in actual classrooms to generate stronger evidence of its impact on student learning and to refine the framework for broader application.

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