Challenges in Modern Mathematics Education for Non-STEM Graduates in Aviation: A Systematic Review

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Abstract: This literature review systematically explored the challenges faced by non-STEM graduates in acquiring essential mathematical competencies for aviation-related careers. Although mathematics education has been widely studied, limited research has focused on the unique needs of non-STEM learners in the aviation sector, a field that requires applied skills such as spatial reasoning, data interpretation, and problem-solving. The key challenges identified were foundational skill deficiencies, curriculum misalignment, low motivation, and insufficient pedagogical support. A systematic literature review methodology was employed, drawing on peer-reviewed studies from reputable academic databases, such as Google Scholar, IEEE Xplore, ResearchGate, ScienceDirect, Scopus, and Springer. This review highlights effective strategies, such as blended learning, flipped classrooms, gamification, and computer-aided instruction, while emphasizing the need for contextualized aviation-specific content. The findings revealed significant research gaps in instructional design and assessment practices for this demographic. Addressing these gaps through targeted interventions and evidence-based pedagogies is essential for improving mathematics education and operational readiness among non-STEM graduates in aviation.

Keywords: Applied Mathematics, Aviation Education, Non-STEM graduates, Modern Mathematics Education, Pedagogical Strategies

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1 Introduction

The aviation industry, often associated with high-level technical professions, encompasses a wide range of roles that demand mathematical proficiency. These roles are not exclusive to STEM graduates; in fact, many aviation professionals, such as air traffic controllers, flight operations personnel, maintenance technicians, and administrative staff, come from non-STEM backgrounds as well. For these individuals, the application of mathematical knowledge is integral to safety, operational efficiency and decision-making. However, the mathematical preparation of non-STEM graduates is often misaligned with the demands of aviation-related tasks, presenting unique challenges in their education and professional development fields.

This literature review systematically examines the challenges encountered in modern mathematics education, specifically for non-STEM graduates pursuing careers in aviation. While the broader field of mathematics education has been extensively studied [1], [2], [3], [4], [5], the unique needs and difficulties faced by non-STEM graduates require a focused analysis.

In particular, the mathematical competencies required in aviation are practical and applied in nature, emphasizing estimation, spatial reasoning, proportional thinking, and data interpretation. However, traditional mathematics curricula often prioritize abstract, theory-driven approaches that are more suitable for STEM pathways than for the humanities. This mismatch creates barriers for non-STEM learners, many of whom may lack prior exposure to advanced mathematics or struggle with motivation owing to perceived irrelevance.

In this study, the term “non-STEM graduates in aviation” refers to individuals who have completed academic programs in non-STEM tracks such as humanities, business, or technical-vocational strands and are currently enrolled in aviation-related courses or training programs.

Accordingly, this review explores the specific mathematical knowledge required for aviation careers, identifies the prevalent challenges faced by non-STEM graduates, analyzes existing research on addressing these challenges, and suggests avenues for future research. The lack of dedicated studies focusing on this specific learner group necessitates synthesizing findings from related domains such as adult education, vocational training, and mathematics education reform. This review underscores the need for pedagogical innovation and curriculum development that reflects the contextual demands of aviation, particularly for learners who may not have a strong mathematical foundation.

By bridging the gap between theoretical literature and practical application, this review contributes to the growing discourse on inclusive and context-sensitive mathematics education, ensuring that all aviation professionals, regardless of their academic background, are equipped with the necessary quantitative skills to thrive in their roles. This research is grounded in the context of aviation-focused education, particularly within institutions like the Philippine State College of Aeronautics (PhilSCA), where diverse student populations, including those from non-STEM backgrounds, are trained for technical aviation roles that demand applied mathematical competence.

2 Methodology

This study employed a systematic literature review to identify and analyze the challenges faced by non-STEM graduates pursuing aviation careers in mathematics education. The review followed a structured process to ensure relevance, rigor, and comprehensiveness in capturing the current academic discourse. Relevant peer-reviewed articles were sourced from multiple reputable academic databases, including Google Scholar, IEEE Xplore, ResearchGate, ScienceDirect, Scopus and Springer. The selection criteria included studies published within the last 10 to 15 years that addressed mathematical competencies, teaching strategies, curriculum design, and technological integration in mathematics education. Keywords such as non-STEM learners, aviation education, mathematics instruction, pedagogical approaches, and applied mathematics were used to filter and identify literature relevant to the research scope. Studies focusing on broader mathematics education were included if they offered transferable insights applicable to non-STEM aviation contexts. The articles were thematically coded to identify recurring challenges, interventions, and research gaps. The results were synthesized to provide a comprehensive understanding of the current educational landscape and propose directions for future research and curriculum development.

3 Literature Review

3.1 Mathematical Requirements in Aviation

Aviation professionals, including those in non-STEM roles, require a foundational understanding of mathematical concepts. These include, but are not limited to, algebra, trigonometry, geometry, and basic calculus [6]. For example, navigation and flight planning rely heavily on trigonometry and geometry to calculate distances, bearings, and altitudes [7]. Understanding aircraft performance and fuel efficiency necessitates a grasp of algebraic relationships and calculus for more advanced calculations [8]. Although the depth of mathematical knowledge required may vary based on specific roles, a solid foundation is crucial for competent and safe operations within the aviation industry. The specific mathematical skills required are often not explicitly stated in job descriptions, creating a hidden barrier to entry for those lacking confidence or a clear understanding of these requirements [9].

The aviation industry necessitates a diverse range of mathematical skills that extend beyond the advanced calculus and theoretical physics typically emphasized in STEM-focused mathematics curricula. While pilots and engineers require high-level mathematical expertise, non-STEM roles within the aviation sector also demand specific mathematical competencies. These competencies often involve the practical application of mathematical concepts in real-world scenarios, emphasizing numerical fluency and problem-solving skills rather than abstract mathematical theories. [10]

For instance, air traffic controllers must rapidly calculate aircraft separation distances, predict flight paths, and manage complex airspace configurations. These tasks demand proficiency in geometry, trigonometry, and spatial reasoning [10], requiring quick and accurate calculations under pressure. Similarly, flight operations personnel responsible for scheduling and route planning utilize mathematical models to optimize flight routes by considering factors such as fuel efficiency, weather conditions, and air traffic density. [11] This involves proficiency in data analysis, statistical modeling, and optimization techniques.

Maintenance technicians responsible for aircraft repair and servicing rely on mathematical calculations for tasks such as weight and balance calculations, component sizing, and fluid dynamics [12]. They must interpret technical manuals, apply formulas, and ensure precise measurements to maintain aircraft safety and operational efficiency. Even administrative roles within the aviation industry require mathematical skills for tasks such as budget management, financial forecasting and performance analysis [13]. This highlights the diverse mathematical demands across the aviation sector, underscoring the need for tailored mathematics education for non-STEM graduates. The practical nature of these mathematical applications differs significantly from the theoretical emphasis often found in STEM-focused mathematics education curricula. This difference necessitates a shift in pedagogical approaches to ensure effective learning outcomes for non-STEM aviation graduate students.

3.2 Identified Challenges

3.2.1Foundational Mathematical Skills Deficiencies

Many non-STEM graduates enter their academic or training programs with inadequate foundational mathematical skills [14]. This deficiency is often rooted in a combination of factors, including inconsistent exposure to mathematics in previous educational settings, avoidance of math-intensive courses, and reliance on rote memorization rather than conceptual understanding. In many cases, these students may have completed only the minimum required mathematics coursework during high school. which rarely includes algebra, trigonometry, or problem-solving strategies directly relevant to aviation. Consequently, they begin their aviation education at a disadvantage, lacking the numerical fluency and reasoning skills essential for understanding technical materials, performing calculations, or interpreting data.

Additionally, individual learning styles and cognitive differences, such as anxiety toward mathematics, preference for visual or hands-on learning, or slower processing speeds, can further exacerbate these challenges [4]. The absence of a strong mathematical foundation creates compounding difficulties as students attempt to engage with more complex, aviation-specific mathematical concepts, such as fuel consumption rates, flight path optimization, or weight and balance calculations [3].

Limited prior mathematical preparation significantly hinders learners' ability to transition from general education to the technical demands of aviation, making it difficult to contextualize or apply new information effectively. This underscores the urgent need for structured, scaffolded learning interventions that bridge the gap between previous learning and the mathematical demands of aviation training. Without targeted support, students may struggle with retention, experience low confidence, and encounter barriers to their academic and professional success. Ultimately, addressing foundational skill gaps is a prerequisite for ensuring that non-STEM graduates can competently engage with the quantitative demands of their future roles in aviation.

3.2.2. Abstract vs. Applied Learning

This disconnect often stems from a lack of contextualized learning experiences during prior education, where mathematical concepts are rarely framed within meaningful or relevant settings. Consequently, students may fail to recognize the value of what they are learning, leading to disengagement and limited knowledge transfer. This not only impairs their problem-solving abilities but also undermines their confidence and readiness for aviation roles that demand on-the-spot decision-making supported by mathematical reasoning.

Research suggests that hands-on problem-based learning (PBL) approaches are significantly more effective in closing this gap [7]. These methods encourage learners to engage with realistic scenarios that mirror actual aviation challenges, thereby promoting a deeper conceptual understanding and long-term retention. For example, simulating flight planning exercises or using real aviation data for calculations enables students to see the relevance of mathematical tools in real-world applications. However, despite their proven benefits, the implementation of PBL and other experiential learning strategies remains limited in many aviation education settings due to curricular constraints, lack of instructor training, and resource limitations [15].

Consequently, the lack of integration between theory and application continues to hinder learners' ability to internalize and confidently apply mathematical concepts in real-time operations. This contributes to the broader issue of underdeveloped problem-solving skills and reduced professional adaptability, which are critical attributes in aviation careers where mathematical precision and quick decision-making are often linked to safety and performance. Bridging this gap requires intentional curriculum design, increased investment in instructional innovation, and a shift toward teaching mathematics as a tool for solving authentic aviation-related problems.

3.2.3 Lack of Specialized Aviation Mathematics Curriculum

There is a notable scarcity of mathematics curricula specifically designed to meet the unique needs of non-STEM graduates [16]. Most existing mathematics courses are structured around generalized content that prioritizes abstract concepts and theoretical problem sets, such as algebraic manipulation, calculus procedures, and geometric proofs, without adequate reference to the practical demands of aviation roles. For non-STEM learners entering aviation-related programs, this disconnects results in a learning experience that often feels irrelevant, inaccessible, or disengaging [9].

Unlike STEM students, who are typically conditioned to handle abstract reasoning and advanced symbolic mathematics, non-STEM learners frequently benefit more from context-rich, application-oriented instruction that explicitly links mathematical principles to real-world scenarios. However, standard curricula rarely include aviation-specific applications, such as fuel consumption modeling, load distribution calculations, or navigational problem-solving. The absence of aviation-aligned learning contexts not only reduces motivation but also inhibits the transfer of learning into professional practice.

This gap in curricular relevance directly affects students' ability to internalize and apply mathematical skills, leading to persistent difficulties in mastering essential aviation-related competencies in the field. As aviation roles often require rapid, high-stakes decision-making informed by quantitative reasoning, the inability to confidently apply math concepts can undermine both academic performance and future job readiness. Furthermore, without a tailored curriculum, instructors are left to adapt generalized materials on their own, often without sufficient guidance, tools, or support. This results in inconsistent teaching quality and fragmented learning experiences for the students.

Addressing this issue requires the intentional development of aviation-specific mathematics curricula designed collaboratively by educators, aviation professionals, and curriculum specialists. Such curricula should incorporate industry-relevant examples, simulations, case studies, and assessment methods that reflect real-world tasks and responsibilities of a data analyst. Without this targeted approach, the knowledge gap created by generalized mathematics education will continue to disadvantage non-STEM graduates, limiting both their educational outcomes and long-term professional development.

3.2.4 Teaching Methodologies and Teacher Training

The effectiveness of teaching methodologies plays a critical role in shaping the academic success of non-STEM graduates [14]. Although traditional lecture-based instruction has long been the default approach in many educational settings, it often falls short of meeting the diverse cognitive, motivational, and learning needs of this particular demographic. Lecture-heavy formats tend to prioritize passive absorption of information rather than active engagement, which can be especially problematic for learners who struggle with abstract reasoning or require contextual and experiential learning to grasp mathematical concepts [4].

Research consistently emphasizes that individual learning styles and preferences whether visual, auditory, kinesthetic, or multimodal significantly affect how students absorb and apply knowledge [17], [11], [18]. For example, students with a preference for kinesthetic or experiential learning may find it difficult to follow abstract mathematical instructions without interactive demonstrations or practical applications. In aviation contexts, where mathematical reasoning is often applied in dynamic and situational environments, interactive, hands-on approaches such as simulations, case-based learning, and real-world problem-solving activities are far more effective in facilitating deep understanding and skill transfer.

Moreover, the integration of varied pedagogical strategies, including blended learning, flipped classrooms, game-based learning, and computer-aided instruction, can address a broader range of learner needs and enhance overall instructional effectiveness. However, the adoption of such approaches remains limited, particularly in technical or vocational education settings, where instructors may lack the pedagogical training or institutional support to implement innovative methods effectively [19].

Many educators working with non-STEM graduates were trained under traditional systems and may not be adequately equipped to adapt to the differentiated instruction required by today's diverse learners. The absence of sustained professional development, instructional coaching, and exposure to evidence-based teaching innovations further exacerbates this challenge. As a result, students may find themselves in suboptimal learning environments where their unique needs are not addressed, leading to reduced engagement, lower academic performance, and limited confidence in applying mathematics in aviation.

To foster better outcomes, educational institutions must invest in both faculty development and pedagogical reform, equipping instructors with the tools, resources, and support necessary to deliver student-centered instructions. Addressing pedagogical gaps and training limitations is essential for creating inclusive, effective, and responsive learning environments that can nurture mathematical competence among non-STEM graduates.

3.2.5 Technology Integration and Resources

While technology holds significant potential to enhance mathematics education, particularly for non-STEM learners in aviation, its successful implementation is often hindered by systemic limitations [1], [2], [20]. Digital tools such as graphing software, simulations, learning management systems, and interactive platforms can offer dynamic, visual, and applied representations of mathematical concepts that are especially beneficial for learners who struggle with traditional abstract instruction. These technologies are particularly valuable in aviation education, where mathematical understanding is tied to spatial reasoning, real-time data analysis, and technical decision-making. When effectively integrated, educational technology can improve student engagement, support individualized learning paths, and bridge the gap between theory and practice.

However, the effective integration of educational technology requires more than access, it demands strategic planning, adequate infrastructure, and well-trained educators [5]. In many academic institutions, especially those with limited budgets or underdeveloped digital ecosystems, access to essential tools such as updated computers, simulation software, or internet connectivity remains inconsistent. This digital divide not only limits the learning opportunities of students in underserved contexts but also contributes to inequities in mathematical achievement and digital literacy [21].

Moreover, teacher training and support are critical yet often overlooked components of technology integration. Many instructors may be unfamiliar with emerging educational technologies or lack confidence in using them effectively for instructional purposes. Without proper professional development, even well-resourced institutions may fail to leverage technology's full instructional potential. Teachers must be equipped not only with the technical know-how to use digital tools, but also with the pedagogical strategies necessary to align these tools with learning objectives and student needs. In the absence of such support, technology is often underutilized or used ineffectively, reducing it to a superficial add-on rather than a transformative instructional resource.

This lack of training and institutional support results in missed opportunities to enhance mathematics learning particularly for non-STEM graduates who would benefit most from interactive and applied learning experiences. Thus, ensuring equitable access to technology, coupled with sustained investment in teacher training, is essential for unlocking the full benefits of digital tools in mathematics education. Without these, the promise of technology as a catalyst for improved learning outcomes will remain unrealized for many students in aviation and technical education pathways.

3.2.6 Motivation and Engagement

Motivation and engagement are critical factors in the success of non-STEM graduates in mathematical education. Many of these learners may lack the intrinsic motivation often observed in STEM majors, making it essential for instructors to design engaging and contextually relevant learning experiences for them. The perceived irrelevance of mathematics to their future careers can further demotivate students, resulting in reduced effort and poorer academic performance [6], [22]. To address this, educators must integrate real-world aviation scenarios and practical applications into instruction, as this has been shown to significantly enhance student motivation and improve learning outcomes [8], [12]. Innovative teaching strategies that connect mathematical concepts to aviation-specific tasks, such as flight planning, fuel consumption, and navigational calculations, can foster deeper engagement and relevance. This pedagogical shift requires moving away from purely abstract content toward applied experiential learning that aligns with the operational realities of aviation professions.

3.2.7 Existing Research and Interventions

Several studies have explored the challenges in mathematics education and proposed interventions [1], [2], [3], [4], [5]. These include the use of technology-enhanced learning [14], implementation of blended learning approaches [17], and adoption of active learning strategies [19]. However, these studies often focus on broader mathematics education contexts and lack a specific focus on the challenges faced by non-STEM graduates [9]. While the general principles and findings of these studies are relevant, their direct applicability to the specific context of non-STEM aviation students requires further investigation.

Existing research on mathematics education challenges has revealed a wide spectrum of difficulties across various student populations. Studies have explored learning difficulties, effective teaching strategies, and interventions targeting diverse demographics, including students with learning disabilities [24], underprepared students [25], and adult learners [26]. These studies provide valuable insights into broader mathematics education challenges that can inform the development of tailored strategies for non-STEM graduates.

Research on students with learning disabilities highlights the importance of individualized instruction and adaptive learning technologies [24]. These findings emphasize the need for flexible and adaptable pedagogical approaches that cater to diverse learning styles and needs. Studies on underprepared students emphasize the need for remedial support and foundational skill development [25]. These students often require targeted interventions to address specific knowledge gaps before successfully engaging with more advanced mathematical concepts. Research on adult learners highlights the importance of contextualized learning and real-world applications [26]. Adult learners often benefit from instructions that directly connect mathematical concepts to their professional experiences and personal goals. This emphasizes the need for relevant and practical examples in mathematics education for non-STEM graduates, connecting theoretical concepts to real-world aviation scenarios.

4 Research Gaps and Future Directions

Future research should prioritize several key areas. First, studies must assess the effectiveness of instructional materials tailored to non-STEM learners by integrating real-world aviation scenarios and addressing specific knowledge gaps. Second, evaluations of teaching methodologies, such as technology-enhanced learning, blended learning, flipped classrooms, co-teaching, game-based learning, and computer-aided instruction, are essential. These approaches should be tested against well-defined learning outcomes related to both theoretical understanding and practical applications.

Third, aviation-focused mathematics curricula that combine theory with real-world relevance must be developed. Such efforts should involve collaboration among mathematics educators, aviation professionals, and industry experts to ensure their relevance and impact. These curricula should undergo rigorous evaluations to determine their effectiveness in improving both academic outcomes and career readiness.

Additional research should explore the influence of factors such as motivation, self-efficacy, and learning preferences on academic performance [23]. Mixed-methods approaches are recommended to capture the complex relationship between learner characteristics and learning outcomes. Finally, longitudinal studies are needed to evaluate the sustained impact of interventions on academic success and professional performance in the field.

Addressing these gaps will help refine mathematics education practices in aviation, ultimately enhancing safety, efficiency, and success among non-STEM graduates.

5 Results and Discussion

The results of this systematic literature review revealed several interconnected challenges that non-STEM graduates face in aviation-related mathematics education. Key among these is the widespread deficiency in foundational mathematical skills, which limits students' ability to engage with complex aviation concepts such as flight planning, fuel computation, and load balancing. This foundational gap is often exacerbated by prior educational experiences that emphasize rote learning over conceptual understanding.

Another critical finding was the mismatch between abstract mathematical instruction and real-world aviation applications. Traditional curricula often fail to contextualize mathematics in aviation-specific scenarios, resulting in disengagement and difficulty in knowledge transfer. Research supports the use of problem-based learning (PBL) and applied methods to bridge this divide, although implementation remains inconsistent because of resource and training constraints.

The review also highlights the lack of specialized curricula tailored to non-STEM graduates. Current instructional content rarely reflects the mathematical demands of aviation careers, and instructors frequently lack the training to adapt the materials accordingly. Additionally, while promising, the integration of technology is uneven and hindered by limited infrastructure and insufficient professional development.

Pedagogical strategies such as blended learning, flipped classrooms, gamification, and computer-aided instruction show potential but require further validation in aviation-specific contexts to determine their effectiveness. Finally, motivation and engagement emerged as vital but under-addressed factors. The perceived irrelevance of mathematics discourages effort and learning unless teaching approaches emphasize real-world aviation relevance.

These findings suggest the need for targeted curriculum development, educator training, and context-sensitive interventions to enhance mathematics education for non-STEM graduates.

6 Conclusion

Modern mathematics education for non-STEM graduates in aviation faces a range of challenges, including gaps in foundational skills, a disconnect between abstract concepts and practical applications, a lack of specialized curricula, ineffective teaching methods, limited technology integration, and low classroom motivation. Although broader mathematics education research offers useful insights, there is a clear need for studies specifically focusing on this population.

This review identified several key challenges: limited prior mathematical preparation, diverse learning styles, motivation-related barriers, and the need for effective and context-appropriate pedagogical approaches. These findings underscore the importance of tailored interventions that emphasize foundational skill development, real-world relevance, and inclusive teaching methods, such as blended learning, flipped classrooms, game-based learning, and computer-aided instruction.

Future research should prioritize the development and evaluation of instructional materials that address the specific needs of non-STEM aviation learners. This includes exploring the influence of prior academic experiences and assessing the effectiveness of practical and outcome-based assessment strategies. Long-term success will depend on collaboration among educators, aviation professionals, and industry stakeholders to build a more responsive and supportive learning environment for students.

Addressing these gaps will lead to improved mathematics education and better learning outcomes, ultimately contributing to a more competent, efficient and safety-focused aviation workforce. Further research in this area is essential to ensure that all aviation professionals, regardless of their academic backgrounds, are equipped with the mathematical competencies required for modern aviation operations.

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