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Toward Inclusive and Interdisciplinary Applied Mathematics in the Digital Age

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ABSTRACT: Applied mathematics has become increasingly essential in solving real-world problems across engineering and the natural sciences. This narrative review aims to synthesize recent literature on modeling techniques, AI integration, and pedagogical innovations in applied mathematics. Using Scopus, Web of Science, and PubMed, the study employed a structured keyword-based search strategy to identify peer-reviewed research from 2013 to 2024. Inclusion criteria focused on interdisciplinary applications of applied mathematics, original research, and evidence-based pedagogical insights. The review reveals that mathematical modeling, especially when combined with machine learning and physics-informed neural networks, significantly enhances computational accuracy and efficiency. Deep learning approaches to partial differential equations and optimization algorithms like Shehu duality or metaheuristics are proving transformative in dynamic system simulations. However, disparities in access, conceptual understanding among students, and a lack of inclusive educational practices limit the full potential of these innovations. Sociocultural and economic factors strongly influence the implementation of mathematical technologies across regions. The findings suggest that systemic curriculum reform, investment in teacher capacity, and stronger collaboration between academia and industry are key to closing these gaps. Future research should prioritize longitudinal evaluations and culturally responsive approaches. By aligning pedagogical strategies with technological progress, applied mathematics can serve as a pivotal force in advancing global scientific and engineering challenges.

Keywords: Applied Mathematics, Mathematical Modeling, STEM Education, Machine Learning, Interdisciplinary Collaboration, Educational Innovation, Neural Networks.

INTRODUCTION

In recent years, the field of applied mathematics has undergone substantial transformation, marking its pivotal role in advancing a broad spectrum of disciplines, notably engineering and natural sciences. This evolution is not merely characterized by theoretical developments but by the increasing application of mathematical techniques in real-world problem-solving. One prominent trend is the convergence of mathematical modeling with health and life sciences, a phenomenon highlighted through bibliometric analyses by Waltman et al. (2014), which emphasize the interdisciplinary nature of contemporary research. These findings underscore the essential link between engineering science and medical applications, pointing toward a future where mathematical models serve as the backbone of cross-disciplinary innovation. Furthermore, Amigó and Small (2017) argue that applied mathematics, particularly in domains such as neurology and cardiology, is indispensable in decoding complex biological phenomena. Their work illustrates how diverse mathematical tools, ranging from differential equations to computational algorithms, are actively employed to model medical conditions and optimize clinical outcomes(Karaca et al., 2023; Zhukov et al., 2018).

The increasing centrality of applied mathematics is further supported by trends in educational and technological development(González-Gaxiola, 2025; Korn, 2025). Rinneheimo and Suhonen (2022) emphasize the role of conceptual understanding in mathematical engineering as a determinant of student success, revealing the need for innovative and integrative teaching strategies in STEM education. This educational imperative aligns with findings by Ajibade et al. (2023), who document the rapid adoption of machine learning in renewable energy research, reflecting a broader societal shift toward sustainable technologies. Their bibliometric study illustrates a growing collaboration between scientific and technological sectors, reinforcing the necessity of strong mathematical literacy in shaping future-oriented, data-driven solutions. These converging streams of research suggest that applied mathematics is not an isolated academic pursuit, but a dynamic field interwoven with the pressing concerns of modern society(Klochko et al., 2024; Sigcho & Jadán-Guerrero, 2022).

From a curricular standpoint, interdisciplinary methodologies are now recognized as essential to effective STEM education. Tanyu et al. (2023) provide a compelling case for integrating partial differential equations into learning models that simulate natural and physical processes, bridging the gap between abstract theory and tangible phenomena. Similarly, Majda and Qi (2018) discuss uncertainty quantification in complex dynamical systems such as climate modeling, reaffirming the relevance of mathematical sciences in tackling high-impact global issues. These insights highlight the instrumental role of applied mathematics in equipping students with analytical tools to interpret and address multifaceted challenges in health, environment, and technology(Ekici et al., 2024; Sat & Cagiltay, 2022).

These developments underscore that mastery of applied mathematical methods contributes not only to theoretical advancement but also to practical innovations across diverse fields. In light of global imperatives such as climate resilience and public health optimization, the importance of applied mathematics in generating actionable, evidence-based solutions is more pronounced than ever. The ability to model, simulate, and optimize complex systems through mathematical frameworks is rapidly becoming a core competency in contemporary science and engineering(Beck, 2010; Zhang & Zhang, 2024).

Despite the recognized importance of applied mathematics, significant challenges persist in its broader implementation. One critical barrier is the conceptual gap experienced by students, especially within the realm of engineering mathematics. Rinneheimo and Suhonen (2022) note that many students encounter difficulties in grasping complex mathematical concepts, which subsequently hinders their ability to apply these concepts in practical settings. The lack of integration between mathematical reasoning and domain-specific problem-solving exacerbates this issue, pointing to a misalignment between educational curricula and real-world demands. Moreover, Mikhailova et al. (2022) highlight the limitations of conventional pedagogy, arguing that curricular content often fails to align with student interests and cognitive engagement, thereby diminishing learning outcomes(Kulkarni et al., 2025; Padma et al., 2025).

Beyond educational shortcomings, the failure to foster effective interdisciplinary collaboration remains a persistent obstacle. As Speth et al. (2023) assert, the strategic integration of mathematics, science, and technology in higher education is frequently underemphasized. This disjointed approach impedes the development of well-rounded professionals equipped to address contemporary challenges in agriculture, natural resources, and sustainability. The absence of interdisciplinary synergies within academic institutions not only stifles innovation but also restricts students' exposure to holistic problem-solving frameworks that mirror real-world complexity.

In the research arena, another pressing issue is the fragmented understanding of key topics within applied mathematics. Ajibade et al. (2023) reveal that although there is a growing body of work on machine learning in renewable energy, many aspects remain insufficiently explored. This literature gap may stem from the limited practical translation of existing mathematical methodologies or the lack of continuous methodological innovation. As a result, the development of more adaptable, context-sensitive mathematical tools is urgently required to enhance the applicability and effectiveness of research across domains.

Addressing these gaps requires a comprehensive and systematic review of the current landscape of applied mathematics, particularly as it intersects with engineering and natural sciences. The purpose of this review is to critically evaluate recent advancements in the field and to examine how these developments respond to both theoretical inquiries and practical exigencies. Key factors to be analyzed include the role of applied mathematics in interdisciplinary education, the integration of computational methods such as machine learning, and the implementation of mathematical modeling in climate and health-related sciences. This review also aims to assess pedagogical innovations and identify best practices in the teaching of applied mathematics to future STEM professionals(Brezovnik et al., 2025; Etman et al., 2025).

The scope of this study will focus primarily on literature published within the last decade, drawing from global and regional research with particular attention to contexts where applied mathematics interfaces directly with policy, education, and innovation. While the review includes global perspectives, it emphasizes applications relevant to developing regions where the integration of mathematical education and technological advancement is critically needed. Special consideration will be given to educational systems, industry-academia partnerships, and policy environments that shape the utilization of applied mathematics in solving real-world challenges(da Costa et al., 2025).

By synthesizing findings across multiple disciplines and geographies, this review intends to offer a comprehensive understanding of the transformative role that applied mathematics plays in engineering and natural sciences. In doing so, it seeks to bridge the divide between theory and practice, identify emergent trends, and inform future research and educational strategies. As the world becomes increasingly data-driven and interdependent, a robust foundation in applied mathematics will be indispensable to cultivating the next generation of scientists, engineers, and policy-makers capable of addressing the complexities of the 21st century.

METHOD

This study employs a narrative review methodology designed to synthesize and analyze scholarly literature on the recent advances in applied mathematics, particularly its applications in engineering and the natural sciences. The methodology aims to offer a structured, transparent, and reproducible account of how relevant studies were identified, selected, and analyzed. To this end, the review integrates comprehensive literature searches across several high-quality academic databases, defines clear inclusion and exclusion criteria, and focuses on specific types of studies to ensure academic rigor and relevance.

The primary data sources for this review included Scopus and Web of Science, which are widely acknowledged as two of the most comprehensive and multidisciplinary databases in the fields of science and engineering. Scopus provides access to an extensive array of peer-reviewed journals, conference proceedings, and book chapters, covering core disciplines such as applied mathematics, computational modeling, engineering systems, and environmental science. It also offers advanced search filters and citation tracking features that enhance the robustness of literature exploration. Web of Science, with its detailed citation indexing and analytical tools, complements Scopus by offering coverage of high-impact journals in both engineering and fundamental scientific disciplines. In addition to these two major sources, PubMed was selectively consulted, particularly when exploring literature at the intersection of mathematical modeling and health or life sciences. Although PubMed is primarily biomedical in focus, it was useful in identifying research that connects mathematical approaches to medical applications such as epidemiological modeling or bioinformatics. However, it was not the main source for engineering-related mathematical research.

To ensure a systematic and targeted search process, the review utilized a set of carefully selected keywords combined with Boolean operators. These keywords were derived from the core themes of the research, focusing on the interrelationship between applied mathematics, engineering problems, and scientific phenomena. Keywords included "applied mathematics," "engineering," "natural sciences," "mathematical modeling," "statistical analysis," and "machine learning." These were combined using Boolean operators such as AND, OR, and NOT to refine the search results. For example, the query "applied mathematics AND engineering" was employed to retrieve literature that specifically discusses mathematical applications in engineering contexts. Similarly, "natural sciences OR life sciences" was used to broaden the scope when examining literature that spans interdisciplinary applications. The operator NOT was employed to eliminate irrelevant entries, such as in the query "mathematical modeling NOT simulation," to focus on theoretical and statistical frameworks rather than computational simulations alone.

The literature search was conducted iteratively over several weeks to ensure a comprehensive gathering of relevant material. During the initial phase, broad searches were conducted to capture an overview of available literature. These searches produced several thousand entries, which were then screened using the title and abstract for relevance. Studies were selected for full-text review if they addressed the use of applied mathematical methods in solving engineering or natural science problems, especially those highlighting interdisciplinary integration or educational impact.

To refine the selection, inclusion and exclusion criteria were applied. Studies were included if they (1) were published in peer-reviewed journals between 2013 and 2024, (2) focused on applied mathematics in the context of engineering, natural sciences, or health sciences, (3) presented original research, systematic reviews, or meta-analyses, and (4) were written in English. The inclusion of systematic reviews and meta-analyses allowed for the capture of comprehensive insights into research trends and synthesized evidence. Studies were excluded if they (1) lacked a clear methodological description, (2) focused purely on abstract mathematical theory without any applied context, or (3) were opinion pieces, editorials, or non-peer-reviewed content.

This review emphasized the inclusion of diverse types of studies to ensure a holistic understanding of the topic. Original research articles formed the core of the dataset, particularly those employing experimental or computational methods to address real-world problems through mathematical tools. Studies using randomized controlled trials (RCTs), though less common in this domain, were included when mathematical techniques were evaluated for their effectiveness in controlled environments, such as modeling interventions in engineering education or environmental systems. Additionally, cohort studies and case studies were examined, especially those that documented longitudinal impacts of mathematical interventions or application models in complex systems. Studies employing qualitative methods were not excluded a priori but were considered only if they provided substantial theoretical insight into the integration of mathematical thinking in interdisciplinary contexts.

The literature selection process involved multiple stages to ensure quality and relevance. Following the initial screening based on titles and abstracts, full-text articles were reviewed to assess methodological rigor, data clarity, and alignment with the objectives of the review. Each selected article was evaluated for its contribution to one or more thematic areas identified during the preliminary scoping phase. These themes included the use of applied mathematics in energy systems, the role of mathematical modeling in biomedical and environmental sciences, pedagogical innovation in mathematical education, and the application of statistical and machine learning methods in scientific research.

In cases where the relevance or methodological clarity of an article was ambiguous, the article was discussed among the reviewers until a consensus was reached. This collaborative review process reduced bias and ensured that the final selection reflected both the depth and breadth of recent advances in the field. Bibliometric data such as citation counts and journal impact factors were consulted, but they did not constitute the primary basis for inclusion. Rather, emphasis was placed on content relevance, methodological soundness, and the potential to inform future research directions.

Throughout the review process, reference tracking and snowballing techniques were also applied. By examining the reference lists of selected articles, additional relevant studies were identified and assessed using the same inclusion criteria. This iterative approach allowed the identification of foundational literature as well as emerging research themes that may not have been captured through database searches alone.

To ensure transparency and reproducibility, a log of search queries, databases accessed, date ranges, and inclusion decisions was maintained. This audit trail provides a foundation for future researchers to replicate or build upon the present review. Moreover, all selected articles were organized thematically using qualitative coding techniques, facilitating synthesis across different study types and disciplinary approaches.

By integrating multiple data sources, applying precise search strategies, and adopting rigorous selection protocols, this review seeks to provide a reliable and insightful overview of how applied mathematics is contributing to innovation and problem-solving in engineering and the natural sciences. The methodology adopted herein aligns with established standards for academic literature reviews and ensures that the findings of this study are grounded in a well-curated and methodologically robust body of evidence.

RESULT AND DISCUSSION

The narrative review of recent literature in applied mathematics reveals a dynamic landscape marked by significant advancements in modeling techniques, artificial intelligence integration, and numerical optimization. The findings are organized into three key thematic areas: the development and effectiveness of mathematical models in solving engineering and natural science problems, the application of neural networks and artificial intelligence in PDE-based simulations, and the implementation of advanced numerical optimization and integral transformation methods. These thematic dimensions demonstrate both the theoretical sophistication and practical relevance of applied mathematics across diverse contexts.

Model and Mathematical Methods

Studies investigating the role and impact of mathematical models emphasize their centrality in addressing complex challenges in engineering and the natural sciences. One significant contribution in this area comes from Tanyu et al. (2023), who explored the use of deep learning approaches to solve partial differential equations (PDEs). Their research revealed that neural network-based modeling significantly outperforms traditional numerical methods by leveraging the inherent structure of PDEs. This advancement not only enhances the accuracy of solutions but also improves computational efficiency, positioning mathematical models as indispensable tools in solving real-world engineering and scientific problems.

In a comparative analysis of modeling approaches across different countries, it becomes evident that there is no universal strategy that guarantees optimal outcomes in all settings. Zhao and Perez-

Felkner (2022) examined how national educational policies and institutional support structures influence the adoption and success of STEM-based mathematical modeling. Their findings indicate that countries with strong interdisciplinary collaboration frameworks and robust research infrastructures are more successful in applying mathematical models effectively. This correlation underscores the significance of systemic support in optimizing the use of applied mathematics. Waltman et al. (2014) further support this claim, emphasizing the importance of cross-disciplinary scientific collaboration in enhancing the quality and relevance of mathematical modeling efforts. Their bibliometric analysis demonstrates that collaborative research networks contribute to the integration of applied mathematics into practical engineering and scientific domains. As such, the international effectiveness of mathematical modeling is largely shaped by local strategies, collaborative mechanisms, and technological readiness.

Application of Neural Networks and AI

The application of neural networks, particularly deep learning and physics-informed neural networks (PINNs), has transformed how researchers simulate complex systems described by PDEs. According to Tanyu et al. (2023), deep learning techniques enable more accurate modeling of nonlinear systems by exploiting the expressive capabilities of neural networks. These techniques are particularly effective in solving PDEs, which are central to modeling a wide range of phenomena in fluid dynamics, thermodynamics, and structural engineering. Guo et al. (2023) advance this perspective by showcasing the efficacy of PINNs in producing physically consistent results with limited training data. By embedding physical constraints directly into the loss function of the neural network, PINNs ensure that solutions not only fit the data but also adhere to the governing equations of the system. This hybrid approach significantly reduces the need for extensive data collection and computational resources, offering an efficient pathway for solving high-dimensional scientific problems.

However, the implementation and success of AI-driven mathematical modeling vary significantly across disciplines and geographic regions. Ajibade et al. (2023) explored the use of machine learning in renewable energy research and found considerable disparities in its application. Developed nations, benefiting from better access to research funding, computational tools, and international collaboration, have been able to leverage AI technologies more effectively. In contrast, developing countries often face limitations related to infrastructure and human capital, impeding their ability to fully harness AI for mathematical problem-solving. Additionally, Zhao and Perez-Felkner (2022) highlight that socio-economic and cultural factors influence the integration of AI in educational systems, affecting student engagement and institutional adoption of AI methodologies. These findings underscore the need for localized policies and investment strategies to bridge the digital divide and promote equitable access to AI-driven mathematical tools.

Numerical Optimization and Transformation

Recent literature on optimization techniques and integral transformations reveals a surge in innovative methods for addressing dynamic system challenges. Mlaiki (2025) introduces a novel application of Shehu-type duality in solving fractional-order differential equations, particularly those associated with fluidity and nonlinearity in natural processes. This approach extends classical duality principles to accommodate more complex mathematical structures, thereby enhancing the applicability of mathematical analysis in real-world scenarios. Similarly, Akgül et al. (2024) examine the use of advanced metaheuristic algorithms to optimize dynamic systems in the context of biocomposite material design. Their findings indicate that hybrid algorithms, which combine elements of chaos theory and swarm intelligence, offer substantial improvements in computational performance and solution quality.

In terms of real-world application, these advanced numerical methods have demonstrated superior performance compared to traditional approaches. Tanyu et al. (2023) documented that deep learning models used to solve PDEs not only yield more accurate results but also significantly reduce computational time. This is particularly relevant in industrial and engineering settings where quick, reliable solutions are paramount. Guo et al. (2023) also validate the robustness of PINNs by showing that integrating physical principles into model architectures enhances predictive stability and reduces error margins. These advantages stand in contrast to conventional numerical methods, which often struggle with scalability and precision when applied to complex systems. The new generation of mathematical techniques thus promises a more responsive and accurate modeling framework, critical for advancing scientific understanding and technological innovation.

Furthermore, the application of these methods in different national contexts reveals additional insights. Countries with active investment in AI research and interdisciplinary STEM education programs tend to report better outcomes in deploying advanced mathematical tools. For instance, regions in Europe and East Asia exhibit higher adoption rates of PINNs and metaheuristic optimization due to supportive research ecosystems and strong industry-academia partnerships. Conversely, in regions where STEM education lacks emphasis on computational mathematics, the uptake of such methodologies remains limited, despite their demonstrated effectiveness.

These findings collectively illustrate the evolving role of applied mathematics in addressing both theoretical and applied problems in engineering and the natural sciences. The integration of machine learning, neural networks, and advanced optimization techniques has redefined the boundaries of what can be modeled and predicted using mathematical frameworks. However, the variability in implementation success across regions and disciplines points to the importance of tailored strategies that consider local contexts, educational readiness, and resource availability.

In sum, the literature suggests that the future of applied mathematics lies in its adaptability and integration with emerging technologies. The effectiveness of mathematical models, the precision of neural network simulations, and the efficiency of novel numerical methods are shaping a new era of scientific inquiry and engineering practice. Yet, achieving uniform success across the globe will require targeted investment, interdisciplinary collaboration, and inclusive education policies that empower all regions to participate in the mathematical transformation of science and technology.

The findings of this narrative review confirm and expand upon existing literature concerning the evolving role of applied mathematics in engineering and the natural sciences. The increasing integration of mathematical methodologies with practical applications, particularly through interdisciplinary approaches, echoes earlier research by Waltman et al. (2014), who highlighted the significance of collaboration between academia and industry. Their bibliometric study established a foundational understanding of how cross-disciplinary networks enhance research output and practical relevance. This review builds upon that premise by documenting a surge in the use of modern technological tools such as deep learning and neural networks in mathematical modeling, thereby extending the scope of applied mathematics into new domains, including biomedical and environmental sciences.

The review also aligns with Amigó and Small (2017), who emphasized the importance of mathematical modeling in health sciences, particularly in neurology and cardiology. By incorporating findings from studies using advanced computational methods, including physics-informed neural networks, this review underscores how mathematical techniques have grown in complexity and applicability. The expansion into AI-integrated models confirms the trajectory of applied mathematics as not only a theoretical pursuit but a practical necessity in addressing intricate scientific problems. In this way, the current review adds value to previous findings by bridging the gap between traditional mathematical applications and emerging computational innovations.

Despite these advancements, the review also uncovers persistent gaps in the literature. One critical issue relates to the pedagogical dimension of applied mathematics, particularly at the university level. Rinneheimo and Suhonen (2022) reported that many engineering students continue to struggle with conceptual understanding of mathematics, a challenge that hampers their ability to apply mathematical thinking to real-world problems. This review corroborates their findings and further emphasizes the need for innovative pedagogical strategies that integrate context-based learning and modern digital tools to enhance comprehension and engagement.

Additionally, Zhao and Perez-Felkner (2022) provided evidence that socio-economic and demographic factors significantly impact access to and success in STEM education. These findings highlight the role of systemic inequality in shaping who benefits from advances in applied mathematics. While progress has been made in expanding mathematical applications, the benefits remain unevenly distributed across populations. The review reveals a continuing need to address equity in STEM education through policies that account for differences in cultural, social, and economic backgrounds.

The insights gathered from this review contribute significantly to policy and strategy development in STEM education. Ajibade et al. (2023) noted the increasing use of machine learning in renewable energy research, demonstrating the necessity of integrating new technologies into educational curricula. These findings support the proposition that exposure to AI and data-driven methods should be a fundamental component of modern STEM education, enabling students to develop skills that align with emerging industry standards.

Moreover, Mikhailova et al. (2022) emphasized the importance of aligning educational content with students' interests and backgrounds. Their study showed that student engagement increases when curricula are tailored to personal experiences and aspirations. The present review echoes this sentiment by arguing for a responsive and inclusive pedagogical framework that bridges the gap between theoretical content and practical relevance. In doing so, it reinforces the argument that mathematics education must evolve alongside technological and societal changes.

From a systemic perspective, the results of this review underscore the necessity of updating both research and educational policies in applied mathematics. The increasing reliance on interactive and technology-based learning methods calls for a fundamental reevaluation of curricular standards. As Rinneheimo and Suhonen (2022) argue, contemporary students require new modes of mathematical expression and problem-solving strategies that go beyond rote learning. Integrating these new pedagogies into national education policies can help address the widespread difficulties students face in mastering complex mathematical concepts.

Ajibade et al. (2023) demonstrated the potential of AI-based methods in renewable energy research. Although their focus was more technological than educational, their findings indirectly support the idea that research policy must encourage the development and deployment of computational methods in academic settings. If such methods are to be utilized effectively, educational systems must adapt to equip students with the relevant skills. This highlights a critical linkage between research innovation and curriculum design, suggesting that research institutions and universities must coordinate efforts to prepare students for evolving scientific landscapes.

The study by Zhao and Perez-Felkner (2022) also points to the influence of structural and contextual factors on STEM outcomes, suggesting that research and educational policy must consider a broader range of social determinants. Their work implies that equity in STEM education requires not only curricular reform but systemic interventions that address disparities in resource allocation, mentorship, and access to technology. For educational policy to be truly inclusive, it must account for the varied experiences of students and actively work to dismantle structural barriers.

Mikhailova et al. (2022) further underscore the importance of aligning pedagogy with student interests, noting that contextualized learning improves both motivation and academic performance. This reinforces the necessity for stakeholder collaboration in curriculum development. Involving industry professionals, educators, and policy-makers in curriculum design ensures that educational content is not only academically rigorous but also practically relevant and engaging. Such collaboration is vital for producing graduates who are well-prepared for contemporary challenges in science and engineering.

The literature also identifies several strategic solutions for overcoming identified challenges. One of the most promising involves increasing student engagement through context-driven learning experiences. Mikhailova et al. (2022) demonstrated that aligning mathematical content with real-life applications can significantly improve student outcomes. Their findings support the idea that curriculum development should be student-centered, taking into account learners' lived experiences and professional aspirations.

Another effective strategy involves diversifying pedagogical methods. Rinneheimo and Suhonen (2022) advocate for innovative instructional approaches that help students articulate mathematical thinking in more accessible ways. Techniques such as digital simulations, project-based learning, and flipped classrooms have shown promise in enhancing conceptual understanding and learner engagement. These methods encourage active learning and can be integrated into both secondary and tertiary STEM curricula.

Furthermore, the emphasis on interdisciplinary and collaborative strategies is a recurring theme in the literature. Speth et al. (2023) argue that fostering collaboration among educational institutions, research organizations, and industry is crucial for developing practical and adaptable STEM curricula. Their study suggests that curricula designed through multi-stakeholder collaboration are more likely to reflect industry needs and produce graduates equipped with both theoretical knowledge and applied skills.

While the review offers several insights, it also identifies important limitations in the existing literature. Many studies focus heavily on technological innovation without adequately addressing pedagogical implications. Others highlight structural disparities but fail to propose actionable solutions. There is also a lack of longitudinal studies that track the long-term impact of new mathematical teaching methods or modeling techniques. These gaps highlight the need for further research to evaluate the efficacy of proposed interventions and to explore the nuanced ways in which context affects the implementation and success of applied mathematics initiatives.

Future research should investigate how emerging technologies like AI and machine learning can be systematically integrated into STEM education, especially in under-resourced contexts. There is also a need for more cross-national comparative studies to identify best practices and to understand how cultural, economic, and institutional factors influence the adoption and effectiveness of mathematical applications. Addressing these questions will help shape more inclusive, adaptive, and future-ready policies in education and research.

CONCLUSION

This narrative review underscores the expanding role of applied mathematics in addressing complex challenges in engineering and the natural sciences through advanced modeling, neural networks, and numerical optimization techniques. The findings reaffirm that integrating mathematical methods with modern technologies such as machine learning and physics-informed neural networks enhances the accuracy and efficiency of problem-solving processes. Furthermore, the review confirms the importance of interdisciplinary collaboration and adaptive education in maximizing the impact of mathematical tools.

Despite these advancements, several barriers remain, particularly in the domain of STEM education, where students often struggle with conceptual understanding. Socio-economic disparities further compound this issue, limiting equitable access to technological innovations. Addressing these challenges requires a recalibration of educational policies to incorporate context-based learning, digital tools, and inclusive curriculum designs. Additionally, collaborative strategies between academia, industry, and policymakers are essential to ensure curriculum relevance and the development of practical competencies.

Future research should focus on longitudinal evaluations of innovative pedagogies and comparative studies across educational and economic contexts. This will help identify best practices and improve scalability of solutions in under-resourced settings. Importantly, increasing student engagement through relevance-driven content and implementing interdisciplinary, collaborative learning approaches remain crucial to bridging existing gaps. Strengthening these strategies will be vital to preparing future generations for the rapidly evolving landscape of science and technology.

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