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Multidisciplinary Integration In Engineering: Advances And Challenges In Mechanics, Electrical, Environmental And Civil Safety

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Abstract:
Contemporary engineering faces complex challenges that require a holistic and integrated approach. Multidisciplinary integration, which encompasses collaboration between different areas of knowledge, becomes crucial for solving complex problems and creating innovative solutions. To conduct this research, we adopted the systematic literature review approach, a methodology that aims to collect, select and synthesize in a rigorous and reproducible manner the knowledge produced on multidisciplinary integration in engineering. The search strategy included internationally recognized academic databases, such as Scopus and Web of Science, as well as repositories focused on Latin American reality, such as SciELO, and broad-spectrum search engines, such as Google Scholar.
Multidisciplinary integration in engineering is essential to address contemporary challenges and ensure sustainable and efficient solutions. Although technological advances have promoted greater collaboration between different specialties, there are still significant barriers that need to be overcome, such as communication difficulties, conflicts of priorities and gaps in professional training.
Key Word*: Engineering; Technological Development; Interdisciplinary Communication; Systems Integration.*
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I. Introduction

Modern engineering faces complex challenges that require collaboration between different disciplines. With the increasing complexity of projects and the search for sustainable and safe solutions, multidisciplinary integration has become essential. Sectors such as mechanical, electrical, environmental and civil engineering often intersect in initiatives that require diverse knowledge to achieve effective results.[1]

However, the implementation of a collaborative approach still faces significant obstacles, such as differences in technical language, difficulties in interdepartmental communication and limitations in academic training that favor specializations. [1,2] This article aims to review the main advances and challenges associated with multidisciplinary integration in engineering, with an emphasis on mechanics, electrical, environmental and civil safety.

Contemporary engineering faces complex challenges that require a holistic and integrated approach. Multidisciplinary integration, which encompasses collaboration between different areas of knowledge, is crucial for solving complex problems and creating innovative solutions.[2] The growing interdependence between different areas of engineering requires professionals with comprehensive skills and knowledge, capable of integrating different perspectives and disciplines to achieve more efficient and effective results.[3]

The development of engineering projects that involve different areas, such as mechanical, electrical, environmental and civil safety, requires an integrated vision to optimize performance, reduce costs and minimize negative impacts.[4] This multidisciplinary approach allows for the identification and resolution of problems more effectively, considering the interactions between different systems and the overall optimization of the project.[5]

II. Metodologia

To conduct this research, we adopted the systematic literature review approach, a methodology that aims to collect, select and synthesize in a rigorous and reproducible manner the knowledge produced on multidisciplinary integration in engineering. A systematic review involves “explicit, systematic and reproducible

methods to identify, evaluate and synthesize the available evidence on a well-defined research question".[6] There are guidelines that must be followed and that emphasize the importance of clear inclusion and exclusion criteria, as well as a predefined search protocol.[7]

The search strategy included internationally recognized academic databases, such as Scopus and Web of Science, as well as repositories focused on Latin American reality, such as SciELO, and broad-spectrum search engines, such as Google Scholar. The documents analyzed included academic articles published in journals specializing in engineering and technology available in institutional repositories, from 2019 to 2025.

III. Technological Advances And Multidisciplinary Practices

In recent decades, technological advances have facilitated collaboration between different engineering disciplines. Tools such as 3D modeling, geographic information systems (GIS), and building information modeling (BIM) platforms have enabled engineers from different specialties to work in an integrated manner.[8,9] For example, in civil infrastructure projects, the use of BIM allows mechanical, electrical, and environmental engineers to simulate scenarios and optimize solutions before implementation.[9]

Environmental engineering has contributed significantly to the incorporation of sustainable practices.[10] Studies show that collaboration between civil and environmental engineers has resulted in reduced environmental impacts of large projects, such as the adoption of stormwater management technologies and the use of recyclable materials in construction.[11]

In recent years, several technological tools have facilitated the integration between engineering disciplines. The use of modeling and simulation software, such as BIM, allows civil, electrical and environmental engineers to collaborate in real time in the development of complex projects.[12,13] In addition, solutions based on the Internet of Things (IoT) have integrated mechanical and electrical systems more efficiently, while life cycle analysis techniques promote a more holistic approach in environmental assessments.[14,15]

A significant example is the advance in urban infrastructure projects, which require the coordination of safe electrical systems, durable civil structures and sustainable environmental solutions. The implementation of solar panels in urban buildings, for example, is a case in which the integration between electrical and civil engineers has promoted greater energy efficiency.[16,17]

IV. Challenges In Multidisciplinary Integration

Despite the advances, multidisciplinary integration faces significant challenges. One of the main challenges is communication between professionals from different areas, due to differences in technical language and methodologies. In addition, conflicts of priorities may arise. For example, while electrical engineers may prioritize energy efficiency, environmental engineers may emphasize minimizing ecological impacts.[18]

Another challenge is related to professional training. Engineering training often occurs in a compartmentalized manner, making it difficult to understand the needs and contributions of other areas. Finally, organizational barriers, such as the lack of structures that promote collaboration, also limit the potential of multidisciplinary integration.[19]

Despite the progress, several challenges still hinder effective integration. We can also mention the fragmentation of knowledge and excessive specialization that can limit the overall understanding of problems. Professionals from different areas often find it difficult to align their expectations and methodologies.[18,19]

Another obstacle is cultural and organizational resistance to collaboration. Many companies maintain hierarchical structures and silos that make it difficult to exchange information between departments. [20] In addition, the lack of interdisciplinary training during higher education contributes to the shortage of professionals capable of working in an integrated manner.[21]

Furthermore, the implementation of integrated systems can generate high costs and require investment in training, which can be an impediment for smaller organizations. There are also legal and regulatory issues that need to be considered, especially in projects involving electrical safety and environmental impacts.[18,20]

V. Success Stories

Academic training plays a crucial role in promoting multidisciplinary integration. Educational programs that encourage collaborative projects between students from different engineering fields have shown positive results. In addition, academic research also contributes to the generation of new knowledge and technological solutions that facilitate integration between disciplines.[22]

Urban infrastructure projects have benefited greatly from the multidisciplinary approach. One example is the development of integrated public transport systems, where civil engineers work together with mechanical and electrical engineers to ensure the efficiency and safety of vehicles, while minimizing environmental impact.[23]

In the field of electrical safety, collaboration with civil engineering has ensured the implementation of solutions that prevent accidents in industrial and urban areas. Studies show that integrated approaches

significantly reduce the risks of short circuits and other electrical problems, ensuring compliance with technical standards.[23,24]

VI. Conclusion

Multidisciplinary integration in engineering is essential to address contemporary challenges and ensure sustainable and efficient solutions. Although technological advances have promoted greater collaboration between different specialties, there are still significant barriers that need to be overcome, such as communication difficulties, conflicts of priorities and gaps in professional training. Overcoming these challenges requires the implementation of organizational policies that encourage collaboration and investment in ongoing training. By doing so, engineering will be better positioned to meet the demands of the future and contribute to more integrated and sustainable development.

The increasing complexity of contemporary challenges requires professionals with comprehensive skills and knowledge, capable of integrating different areas of knowledge to find innovative and efficient solutions. The multidisciplinary approach allows the creation of more complete, efficient and sustainable projects that meet the demands of society.

The training of engineers with a multidisciplinary profile, the promotion of collaboration between teams of different specialties, and the development of technologies that facilitate the integration of different areas of knowledge are essential factors for the success of the multidisciplinary approach. Multidisciplinary integration is a path to building a more sustainable and prosperous future for society.

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