

EDUCACIÓN, CREATIVIDAD E INTELIGENCIA ARTIFICIAL: NUEVOS HORIZONTES PARA EL APRENDIZAJE. ACTAS DEL VIII CONGRESO INTERNACIONAL SOBRE APRENDIZAJE, INNOVACIÓN Y COOPERACIÓN, CINAIC 2025

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Integrating Data-Driven methodologies and Generative AI to foster creativity and innovation in engineering education

Integración de metodologías basadas en datos y de inteligencia artificial generativa para fomentar la creatividad y la innovación en la educación en ingeniería

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Abstract- This paper examines the integration of data science tools and generative AI, into engineering education to enhance both technical and soft skills, such as creativity and innovation. The methodology is applied to two distinct use cases: one in materials science, focusing on graphene-reinforced cement, and another in graphical engineering, emphasizing requirement elicitation and design optimization. Students use AI tools to analyze experimental results and collaborate across experimentation phases. The results show that this approach could enhance students' analytical skills, foster interdisciplinary learning, and encourage the development of data-driven engineering solutions. The study concludes that incorporating AI into engineering curricula is not only transferable to various fields, but also promotes a more innovative, adaptable, and ethically aware workforce, making it a valuable addition to modern engineering education.

Keywords: *Artificial Intelligence, data driven innovation, User Centered Design, education challenges*

Resumen- Este artículo examina la integración de herramientas de ciencia de datos e IA generativa en la educación en ingeniería para mejorar tanto las habilidades técnicas como las habilidades blandas, como la creatividad y la innovación. La metodología se aplica a dos casos de uso distintos: uno en ciencia de materiales, centrado en el cemento reforzado con grafeno, y otro en ingeniería gráfica, con énfasis en la identificación de requisitos y la optimización del diseño. Los estudiantes utilizan herramientas de IA para analizar los resultados experimentales y colaborar durante las distintas fases experimentales. Los resultados muestran que este enfoque puede mejorar las habilidades analíticas de los estudiantes, fomentar el aprendizaje interdisciplinario y promover el desarrollo de soluciones de ingeniería basadas en datos. El estudio concluye que incorporar IA en los programas educativos de ingeniería no solo es transferible a diversos campos, sino que también promueve una fuerza laboral más innovadora, adaptable y éticamente consciente, lo que lo convierte en una valiosa adición a la educación en ingeniería moderna.

Palabras clave: *Inteligencia Artificial, innovación basada en datos, Diseño Centrado en el Usuario*

1. INTRODUCTION

Engineering education has evolved alongside technological advancements, and its modern development cannot be fully understood without considering the profound impact of various industrial revolutions on the training of future engineers. Just as the steam engine brought about a paradigm shift in the technical and practical education of engineers in the 19th century, the advent of electricity, chemistry, and digital electronics during the 2nd and 3rd industrial revolutions reshaped the landscape of engineering education. Similarly, the increasing accessibility of data and its utilization have revolutionized engineering practices in the early 21st century (Elayyan, 2021). The integration of data-driven technologies such as artificial intelligence (AI), cyber-physical systems, and the Internet of Things (IoT), from which the concept of Industry 4.0 has emerged, has fundamentally reshaped traditional pedagogical approaches in technical universities (Miranda et al., 2021). However, beyond the singularity of contemporary technological advancements, society faces significant global challenges as underscored by the United Nations' Sustainable Development Goals (SDGs) and the 2030 Agenda. In response to these challenges, Industry 5.0 has emerged, emphasizing the need for more human-centered technologies (Golovianko et al., 2023).

Traditionally, engineering education has focused predominantly on developing technical expertise and practical skills, often with limited emphasis on human factors, creativity, adaptability, ethical decision-making, and emotional intelligence. The rise of Industry 5.0 has led to an increasing demand for engineers who possess not only technical proficiency but also the ability to integrate soft skills into their professional repertoire, in line with the SDGs. This shift calls for a reevaluation of curricula, incorporating interdisciplinary approaches like Design Thinking (DT) and User Centered Design (UCD) to equip engineers with the necessary skills.

Concurrently, the advent of generative AI technologies, exemplified by applications like ChatGPT, and data-driven innovation, as demonstrated by tools like WEKA or Orange, present an opportunity to integrate these new skills into engineering students' education. These technologies have the potential to facilitate the adoption and acquisition of adaptable soft skills by offering personalized learning experiences, supporting the development of critical thinking, and enhancing creativity. AI-driven platforms can provide instant feedback, adapt to individual learning needs, and foster deeper engagement with the material. However, the integration of generative AI also causes ethical considerations, including concerns about academic integrity and the potential for misuse. Addressing these challenges is crucial to controlling the benefits of AI while maintaining educational standards. Despite the promising advantages, there is a significant gap in educational materials and frameworks to effectively integrate data-driven methodologies and generative AI into engineering curricula. This highlights the need for strategies that not only incorporate these technologies but also emphasize ethics and the development of soft skills like creativity and data-driven innovation, with focus on human design and society challenges (Bahroun et al., 2023).

This paper explores the necessity for engineers, whose training may not traditionally include data science, to adopt data-driven strategies. It examines how tools like WEKA, Orange, and generative AI can enhance soft skills such as creativity and innovation. Through research and case studies, the paper aims to provide a structured approach for incorporating these technologies into engineering education, fostering a more innovative and ethically aware workforce.

2. CONTEXT & DESCRIPTION

To support the design, development, and implementation of new societal systems aligned with industrial needs, next-generation engineers are expected to understand various technologies, methods, and interdisciplinary methodologies. Interdisciplinary approaches involve integrating knowledge and practices from different fields to address complex challenges. As AI and data-driven methods are not typically part of most engineering programs outside computer science, they need to be incorporated transversally. Additionally, the ethical considerations, biases, and social implications of these technologies must be integrated. Furthermore, access to data presents two major challenges: insufficient or low-quality data, and the need for future efforts to integrate and improve data. Finally, social, environmental, and economic viability, in line with the SDGs, should be considered to address the need for a sustainable, resilient, and human-centered Industry 5.0. These dimensions form the basis for proposed activities to incorporate AI-driven innovation and enhance creativity and critical thinking through technological integration in current engineering curricula (Ahmad et al., 2024).

This section outlines a proposed methodology for embedding AI-driven innovation within the common curricular structure of engineering disciplines, such as mechanical and industrial design engineering, which traditionally may not focus on data-centric subjects. The methodology will be demonstrated through its application in two distinct case studies, each involving students from mechanical engineering and industrial design courses. These case studies will illustrate how the integration of AI-driven innovation can enhance students'

abilities to address real-world challenges, fostering interdisciplinary skills and promoting data-driven problem-solving in traditionally non-data-focused disciplines.

A. Common methodology for Data-Driven Innovation in Engineering Education

This methodology is designed to empower engineering students to tackle real-world challenges using a structured, interdisciplinary approach. It merges engineering design principles with data-driven methodologies, fostering creativity, critical thinking, and adaptability. The proposed methodology integrates problem-based learning, engineering design, and data science methodologies to foster creativity, critical thinking, and technical proficiency. By incorporating interdisciplinary work and focusing on the ethical, social, and environmental impact of engineering solutions, this approach aligns with the evolving needs of the engineering profession and prepares students to innovate and lead in a rapidly changing technological landscape. The combination of traditional engineering methods with modern data-driven tools, as it is outlined in Figure 1 ensures that students are equipped to tackle real-world challenges while developing the soft skills necessary for success in Industry 5.0.

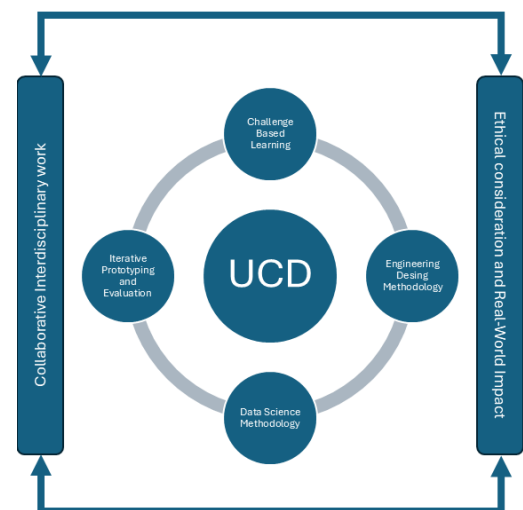


Figure 1 Graphical schema of the proposed methodology

Integrating User-Centered Design (UCD) as a core component within a transdisciplinary approach further enhances the methodology, aligning with the human-centered focus required for Industry 5.0. The methodology has six core components:

- **Challenge-Based Learning (CBL):** The proposed pedagogical approach integrates Challenge-Based Learning (CBL) with a strong User-Centered Design (UCD) core, ensuring that engineering education emphasizes human needs and experiences from the outset. Students are guided to engage with real-world challenges by initiating the process with user research, empathy-building exercises, and direct observations to gain a comprehensive understanding of end users, their environments, and specific pain points. UCD principles are embedded throughout the process, with students defining user personas, mapping user journeys, and

continually referencing the user's perspective during each design phase.

- *Integration of Engineering Design Methodology:* Students apply engineering-specific tools and frameworks for identifying constraints, generating ideas, prototyping, and testing.
- *Incorporating Data Science Methodology:* Students are taught to integrate data analysis with user-centered design (UCD) principles to create solutions that are both evidence-based and human-centered. By learning to analyze, process, and interpret data, they validate hypotheses, refine prototypes, and enhance overall performance, ensuring their decisions are grounded in measurable outcomes. This approach bridges theoretical knowledge with practical application, helping students understand how data science not only optimizes engineering solutions but also enriches the user experience by aligning technical performance with human priorities.
- *Iterative Prototyping and Evaluation:* Through iterative processes, students develop critical problem-solving and adaptability skills essential for engineers in Industry 5.0, where data-informed decisions and user-centered approaches are paramount. Prototyping remains central, enhanced by a continuous cycle of user testing, feedback, and refinement. Low-fidelity prototypes are tested not only for technical performance but also for user satisfaction, comfort, and usability. Each iteration integrates insights from both technical and human perspectives, ensuring the solution progressively aligns with identified user needs. This pedagogical approach fosters a hands-on learning environment where testing, learning, and improving drive the development of truly user-centered solutions.
- *Ethical and real-world impact:* Integrating ethical and social dimensions into engineering projects ensures that the solutions developed are not only technically sound but also responsible and sustainable. Students are guided to explore the societal, environmental, and ethical implications of their designs, aligning their work with broader societal needs and the principles of Industry 5.0. At each stage of the project, students critically evaluate factors such as data privacy, accessibility, environmental impact, and social responsibility. These considerations are embedded into the design and decision-making processes, fostering a mindset that prioritizes accountability and sustainability. By addressing these dimensions, students gain a holistic understanding of how their engineering solutions can positively impact society.
- *Collaborative Transdisciplinarity work:* Transdisciplinarity is achieved by incorporating diverse perspectives and data from external sources. Students leverage databases, case studies, and real-world datasets from fields such as social sciences, healthcare, or environmental studies to contextualize and enrich their solutions. Additionally, students are encouraged to adopt multiple roles within their teams, such as technical analyst, user advocate, or data researcher, fostering an internal simulation of interdisciplinary collaboration. Guest lectures and workshops from experts in fields

outside engineering can further broaden students' understanding, helping them to integrate technical and human-centered approaches seamlessly into their projects.

This comprehensive methodology equips engineering students and professors with the tools, mindsets, and competencies needed to address complex, real-world challenges in a meaningful and impactful way. By integrating user-centered design, data-driven decision-making, ethical considerations, and transdisciplinary collaboration, students develop solutions that are not only innovative but also sustainable and socially responsible.

3. RESULTS

Two use cases were established as part of the practice and development of methodology, applying various AI techniques to distinct scenarios, methodologies, and learning objectives. The aim was to test the versatility of the proposed methodology.

A. Graphical Engineering Experiment

This use case was been developed focusing on product design through the integration of Design Thinking (DT) and Computational Thinking (CT) techniques within an environment enhanced by artificial intelligence (AI) tools. The students, second-year Mechanical Engineering undergraduates, are tasked with iterating toward a final sketch design based on a minimal set of initial specifications using tools like ChatGPT and Midjourney. This approach aims to train the 105 participants in the critical and strategic use of AI tools, embedding CT cycles into each phase of DT (Empathize, Define, Ideate, Prototype, and Validate). By breaking problems into smaller subunits and creating iterative prompting algorithms, students leverage AI as a link to enhance their creativity and streamline the design process.

The applicability of User-Centered Design (UCD) techniques in this case is evident, as students used genAI to iteratively design a mechanical system aimed at solving a real-world problem. Throughout the process, they identify user needs and requirements in each iteration, refining their design based on the AI-generated feedback, with the final deliverable being a sketch of the mechanical system. The challenge-driven approach is integral to the process, as students apply the Challenge-Based Learning (CBL) methodology, constantly refining system components and user needs while benefiting from continuous feedback loops generated by AI, embedded iterative prototyping techniques to further refining the mechanical system. Ethical considerations are thoroughly integrated into the whole process by ensuring that the design meet real-world needs, emphasizing user accessibility, sustainability, and the detection of potential AI biases in the design process, especially at requirement elicitation phase. While the students are from the mechanical engineering discipline, the process encourages the integration of knowledge and tools from other fields, such as AI and user experience design, promoting collaboration to ensure that user-centered principles are embedded throughout the design process. This transdisciplinary approach provides the students with valuable insights from various disciplines, enriching their solutions. Through this process, students develop essential skills in using genAI for design iteration, analyzing user feedback, and producing mechanical system sketches, while also enhancing

their problem-solving and iterative design skills, all of which are key competencies in modern engineering practice.

B. Advanced new materials experiment

This use case aims to introduce students, who were traditionally unfamiliar with AI or data-driven decision-making, to data analysis through open-source tools and similar technologies. It also requests to familiarize them with the analysis of experimental results describing the behavior of advanced materials. Students work with Ordinary Portland Cement (OPC) reinforced with graphene in an experimental approach to address challenges related to urban furniture in their neighborhoods. AI played a key role in fostering collaborative learning between students and the end users of these building solutions, ultimately, the citizens. During the experiment, students follow several key stages, beginning with material selection and the preparation of OPC samples reinforced with graphene. They create mixtures with different graphene proportions to evaluate its impact on the material's mechanical properties and durability. To analyze the results, students utilize open-source artificial intelligence and data science tools, including ORANGE and WEKA. These tools enable them to perform exploratory data analysis, apply machine learning models, and visualize patterns in the material's behavior. By leveraging these technologies, students assess the suitability of graphene-reinforced cement for urban furniture applications, optimizing the mixtures and identifying correlations between material composition and mechanical properties. A crucial aspect of the experiment is community engagement. Through workshops students collect insights into citizens' needs and preferences regarding urban furniture in their neighborhoods. This information guides them in designing solutions better suited to real-world conditions and testing optimized models of graphene-reinforced cement structures.

Although the students primarily came from mechanical and materials engineering, the experiment encouraged them to integrate knowledge and tools from other disciplines, such as artificial intelligence and user-centered design. This fostered interdisciplinary collaboration, ensuring that usability and functionality are incorporated into the construction solutions. Additionally, they refine their problem-solving and iterative design skills, which are key competencies in modern engineering and the development of innovative and sustainable urban solutions.

C. Evaluating the impact of the use cases

To assess the impact of the project, Key Performance Indicators (KPIs) were established to measure critical aspects such as the participation engagement, the effectiveness of the methodology, the development of specific abilities and the overall satisfaction of all participants. These indicators provide a structured framework to evaluate both quantitative and qualitative outcomes. In this context, students prepare a detailed report describing the novel techniques and methodologies learned through the participation in these use cases. Additionally, they complete a satisfaction survey to assess their learning experience and the relevance of the acquired skills. To further quantify the project outcomes, data analysis techniques such as WEKA and ORANGE are applied, enabling an objective evaluation of key trends and correlations. The main results of the experiments include the refinement of workshop guides based on participant feedback and the student reports

documenting experimental methodologies and general guidelines to ensure a scalable and transferable model of the proposed methodology to diverse engineering educational initiatives. These materials were shared with the broader educational community through various channels provided by UPM. Beyond this, the project fostered an interdisciplinary network and enriched UPM's curriculum.

4. CONCLUSIONS

The proposed methodology lies in its ability to integrate AI tools, technical knowledge and interdisciplinary collaboration into engineering education and fostering innovation. The methodology is highly adaptable to diverse engineering fields as demonstrated in the proposed use cases, where experimental approaches and data analysis techniques can be tailored to suit diverse contexts, from graphical engineering and industrial design to urban planning. This initiative explores the impact of AI and open-source tools incorporated into educational curricula and encourages the promotion of collaborative learning between academia and other relevant societal actors. Adapting the methodology based on feedback and evolving challenges will further enhance its effectiveness and relevance in diverse educational and research environments. The study aims to continue the integration of AI into engineering education for promoting a workforce that is more creative, adaptable, and ethically aware, making it a crucial addition to future engineering curricula.

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