ORIGINAL ARTICLE

Professional Competencies in Engineering Undergraduate Students: A case study at two Colombian Universities

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Abstract
In the 21st century, engineering education must respond to a highly technological and globalized environment, demanding professionals with strong technical competencies, innovation capacity, and problem-solving skills. Digital transformation and industrial evolution require engineers capable of handling advanced tools, working collaboratively, and managing resources efficiently. This study analyzes the level of professional competencies in engineering students from two Colombian universities as part of a broader research project (*n*=265). Technical, management, communication, and ethical competencies were assessed through a self-administered online questionnaire. The results reveal strengths in technical and management skills (M= 3.864; SD= 0.791) but significant deficiencies in English communication (M= 2.509; SD= 1.000). These findings highlight the need for pedagogical strategies that reinforce comprehensive education, ensuring the balanced development of all competencies. The study concludes that the type of institution influences training, while age and gender have a limited impact.

Introduction

Engineering Competencies for the 21st Century

Currently, the practice of engineering requires a set of competencies that enable professionals to face the challenges of a highly technological and globalized world (Hissey, 2000; Munir, 2021; Vera, 2024a). First, critical thinking and problem-solving skills are essential, as engineers must analyze complex situations and propose innovative solutions. Additionally, creativity and adaptability are fundamental in an environment that is constantly evolving due to advances in artificial intelligence, automation, and digitalization. For this reason, engineering education has evolved to integrate active learning methodologies, promoting the development of practical and applied skills (Vera et al., 2024). However, challenges remain in the implementation of pedagogical approaches that effectively foster these competencies at all levels of education.

The training of engineers in the 21st century is undergoing an unprecedented transformation driven by rapid technological evolution, globalization, and the need for new skills to address modern world challenges. Engineering education has transitioned from a knowledge-based approach to a competency-development model, marking a fundamental paradigm shift in the discipline (Sangwan et al., 2022). Consequently, globalization has redefined the role of engineers, requiring communication skills and collaborative work in multidisciplinary and multicultural teams (Jiang et al., 2023; Zhang, 2024). In this context, proficiency in a second language, especially English, has become a key requirement for accessing international academic and professional opportunities.

Furthermore, leadership and project management skills are crucial, as engineers must coordinate complex processes, optimize resources, and make strategic decisions in diverse scenarios. However, although many universities have incorporated these skills into their curricula, gaps remain in the comprehensive training of students. Therefore, it is necessary to strengthen interdisciplinary education strategies that allow for the effective integration of technical and socio-emotional competencies.

Sustainability and professional ethics have also gained greater relevance in engineering practice. Given the significant environmental impact of technological and infrastructure projects, 21st-century engineers must be trained to design sustainable solutions that minimize ecological damage (Quelhas et al., 2019). Likewise, social responsibility and professional ethics are essential to ensuring that technological innovations align with human well-being and equitable development. Consequently, educational institutions must prioritize values-based education, promoting a holistic vision that combines technical excellence with social responsibility. Only in this way will it be possible to prepare engineers capable of responding to future challenges with knowledge, innovation, and commitment.

Similarly, global collaboration has become an essential aspect of professional engineering practice. New engineers are expected to have intercultural competencies that enable them to work effectively in diverse, multidisciplinary, and geographically dispersed teams (Rawboon et al., 2021). In this sense, programs such as International Virtual Engineering Student Teams (InVEST) have been specifically designed to foster the development of skills for functioning in virtual and intercultural environments, thereby promoting a comprehensive, globally oriented education that prepares students for the demands of international collaboration (Ndubuisi & Marzi, 2021).

To address these challenges, this study poses the following research questions:

1. What is the level of development of technical and disciplinary competencies among students?
2. Are there significant differences in the development of these technical and professional competencies according to the academic semester?
3. Are there variations in the development of technical and disciplinary competencies based on students' institutional affiliation?
4. Do age and gender influence the development of technical and disciplinary competencies?

Engineering Education in Colombia

Engineering education in Colombia has been a fundamental pillar for the country's economic and social development (Pulido et al., 2024). Since the establishment of the first engineering faculties in the 19th century, education in this discipline has evolved significantly, integrating emerging technologies such as artificial intelligence, blockchain, and the Internet of Things (Zabaleta & Rodríguez, 2023) to adapt to the needs of the productive sector and technological advances.

This has generated the need for interdisciplinary training, as modern engineering increasingly overlaps with other scientific and technological disciplines. The growing convergence of engineering with these areas requires study programs to be adapted and updated to foster systems thinking, problem-solving abilities, and effective collaboration among diverse fields (Gołuch et al., 2024). In this sense, the concept of Industry 4.0, based on automation, robotics, and data analysis, calls for a fundamental rethinking of engineering education. This shift prioritizes challenge-based learning, hands-on experiences, and the seamless integration of emerging technologies to ensure graduates are prepared for the evolving demands of the workforce (Caratozzolo et al., 2022).

Currently, the availability of engineering programs is broad and diverse, offering multiple specializations that address contemporary challenges in infrastructure, technology, sustainability, and digitalization (Pertuz et al., 2020). These programs aim to equip students with the technical knowledge and problem-solving skills required to navigate an increasingly complex and evolving professional landscape. However, significant challenges persist regarding education quality, curricular relevance, and graduates' employability. Many institutions struggle to align their curricula with industry demands, resulting in gaps between academic preparation and labor market expectations. Additionally, as the global workforce becomes more competitive, engineering graduates must develop interdisciplinary skills, adaptability, and international competencies to successfully integrate into a fast-changing and technologically driven world.

On the other hand, the regulation of engineering education in Colombia falls under the Ministry of National Education and the National Accreditation Council (CNA), entities responsible for establishing guidelines to ensure quality standards in academic programs. High-quality accreditation has become a key goal for many HEIs, as it not only strengthens universities' reputations but also facilitates graduates' integration into the international academic and labor market (Gabalán-Coello et al., 2019; Suárez-Landazábal & Buendía, 2020). Despite these efforts, significant gaps persist between elite universities and those with fewer resources, affecting equity in access to quality engineering education.

Additionally, engineering program curricula in Colombia have undergone transformations to align with international standards and industrial sector demands (Burbano, 2016; Ulloa et al., 2018). Traditionally, engineering education has focused on mathematical and scientific fundamentals, but in recent years, a more integrative approach has been promoted, including transversal competencies such as project management, innovation, and entrepreneurship. This curricular evolution aims to meet labor market needs and prepare engineers with the skills to face the 21st-century challenges, including digital transformation (Malik et al., 2021) and environmental sustainability (Vera, 2022).

Furthermore, technology and globalization have significantly impacted engineering education (Tsakalerou, 2019). Digitalization has driven the adoption of advanced learning-teaching tools, such as simulations, virtual laboratories, and artificial intelligence applied to education. Likewise, globalization has led many Colombian universities to establish partnerships with foreign institutions and international academic networks, allowing for academic mobility and joint project development. These dynamics have favored the continuous updating of study programs and strengthened the internationalization of engineering education (Figure 1).

Figure 1: Impact of technology and globalization on engineering education
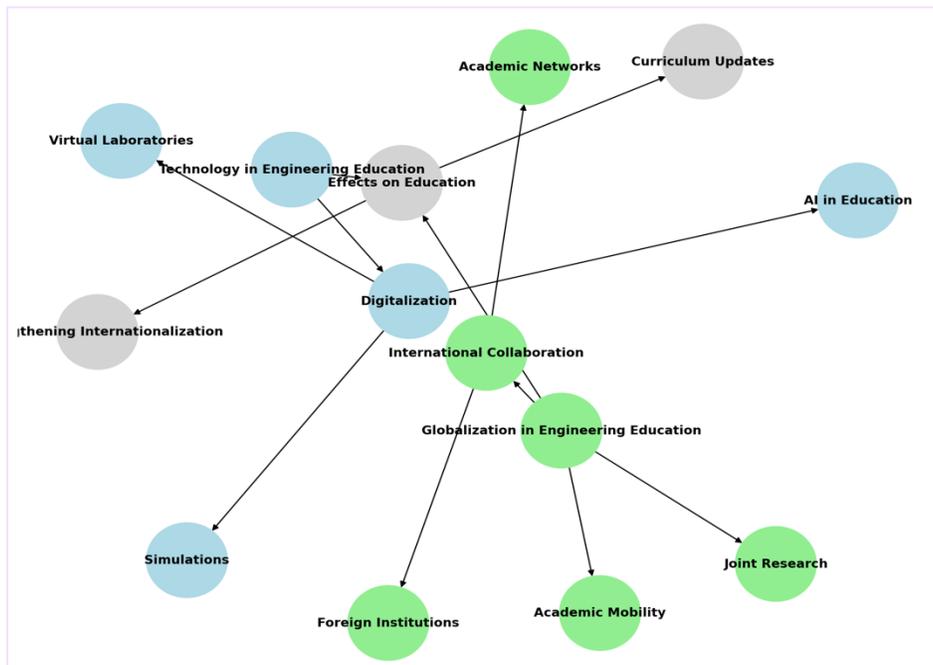
Source: Own elaboration.

However, despite advances in engineering education in Colombia, fundamental challenges remain that need urgent attention. One of the main issues is the gap between academia and industry (Aguirre-Álvarez et al., 2023), as discrepancies still exist between the training received by students and the skills required in the labor market. Although programs such as professional internships and dual education have sought to narrow this gap (Hernández & Goe, 2015), their implementation remains uneven across universities, limiting practical learning opportunities for many students.

Additionally, training in soft skills (Vera & Tejada, 2020) and critical thinking (Vera, 2020; Vera, 2023) remains a pending task in many academic programs. The lack of a comprehensive approach in these areas can affect future engineers' ability to adapt to dynamic and highly competitive work environments. Therefore, it is crucial to strengthen pedagogical strategies that promote the development of these key competencies.

On the other hand, engineering education in Colombia also faces the challenge of student dropout (Arias et al., 2023; Casanova et al., 2021). Factors such as course difficulty, lack of proper career guidance, and socioeconomic problems have led many students to abandon their studies before completing their degrees. In this regard, strategies such as academic support, mentoring, and strengthening basic education in mathematics and science have proven effective in reducing dropout rates. However, their implementation remains inconsistent across the country, as not all institutions have the necessary resources or policies to ensure their effectiveness. Additionally, psychological and emotional support programs play a crucial role in student retention, yet they are often underutilized. Addressing these challenges requires a comprehensive approach that integrates institutional commitment, public policies, and greater access to educational resources to enhance student success and retention in engineering programs.

As seen, engineering education in Colombia has achieved significant progress in terms of quality and curricular relevance, but structural challenges remain that require attention. In this context, strengthening ties with the productive sector, ensuring equity in access to quality education, and integrating new technologies into the learning-teaching process are key aspects for enhancing engineering training in the country (Pulido et al., 2024). Only through integral and sustainable strategies can engineering graduates be fully prepared to contribute to national development and address the challenges of an increasingly technological and globalized world.

Innovation and Entrepreneurship in Engineering Education

The integration of creativity into engineering education is positioned as a critical factor for developing leadership and adaptability skills in today's dynamic technological environment (Higuera Martínez et al., 2020). In this context, fostering creativity among engineering students becomes substantially relevant, enabling them to lead innovative projects and effectively respond to the constant evolution of the technological landscape. Additionally, creative thinking enhances problem-solving abilities, critical analysis, and interdisciplinary collaboration (Šuligoj et al., 2020), which are essential for future engineers. By integrating innovation-driven methodologies, engineering programs can empower students to design and implement groundbreaking solutions for emerging challenges in diverse fields.

In addition to fostering technical proficiency, these initiatives encourage interdisciplinary collaboration, creativity, and leadership—key attributes for future engineers. By engaging in hands-on projects, industry partnerships, and startup incubators, students gain exposure to real-world challenges and develop entrepreneurial mindsets. Furthermore, integrating these elements into engineering curricula ensures that graduates are not only equipped with theoretical knowledge but also practical experience, better preparing them for dynamic job markets.

This holistic approach enhances employability and empowers future professionals to lead technological and industrial transformations with confidence and adaptability. By combining technical expertise with essential soft skills, students are better positioned to navigate uncertainty, work collaboratively across disciplines, and innovate in complex environments. Such integration not only benefits individual career trajectories but also contributes to the broader advancement of society by cultivating engineers who are capable of addressing global challenges through sustainable, inclusive, and forward-thinking solutions.

Moreover, they equip students with the adaptability and problem-solving abilities necessary to navigate an increasingly complex and technology-driven world (Figure 2).

Figure 2: Innovation & entrepreneurship in engineering education
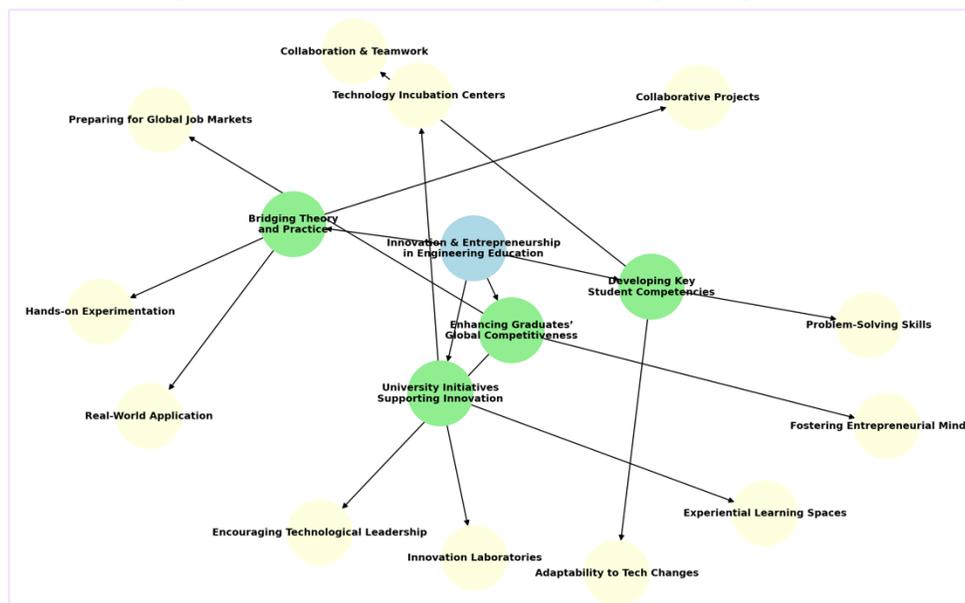
Source: Own elaboration.

Recent evidence supports the idea that educational programs incorporating project-based learning methodologies and immersive experiences in real work environments significantly enhance students' capacity for innovation (Caratozzolo et al., 2022). These approaches allow students to develop critical thinking, problem-solving skills, and adaptability, which are essential for success in a rapidly evolving technological landscape. Additionally, entrepreneurship training within the engineering curriculum provides graduates with essential tools for creating technology startups, fostering business innovation, and strengthening the industrial ecosystem. By integrating these elements into engineering education, universities can better prepare students to lead technological advancements, drive economic growth, and respond effectively to emerging global challenges.

Internationalization of Engineering Education

The internationalization of engineering education has gained increasing relevance in an interconnected and highly technological world (Kassler & Zeng, 2024; Luna et al., 2023; Tossavainen, 2009). Higher education institutions have implemented strategies to expand student and faculty mobility, promote dual-degree programs, and establish partnerships with foreign universities. As a result, students have greater opportunities to access academic experiences in diverse contexts, allowing them to develop intercultural skills and strengthen their professional training.

Furthermore, the adoption of international standards in curricula, such as the Accreditation Board for Engineering and Technology (ABET) criteria, facilitates global recognition of degrees awarded by local universities, enabling graduates to access job and academic opportunities in different countries (Ahmad & Qahmash, 2020). However, significant challenges persist, including economic and administrative barriers that limit many students' participation in internationalization programs, affecting their access to educational experiences abroad. Additionally, differences in credit and certification validation can hinder student mobility. Therefore, it is essential for institutions to design inclusive strategies that ensure equitable access to these opportunities, fostering financial aid policies and international partnerships that strengthen the global training of future professionals.

On the other hand, globalization is an unavoidable process in education, representing one of the main development trends in this context (Li, 2022). As a result, it has driven the need to train engineers with an international perspective, enabling them to tackle complex problems from a multidisciplinary approach. In this regard, curricula have evolved to broaden their scope, incorporating active learning methodologies, advanced digital competencies, and collaborative experiences with institutions from other countries. Moreover, the internationalization of engineering education not only benefits students but also enhances institutional development and scientific production (Fomunyam, 2020). Through academic cooperation networks, universities can participate in joint research projects, share best teaching practices (benchmarking), and access international funding.

As a result, an innovation ecosystem is created, boosting educational quality and the generation of knowledge applied to solving global challenges. Additionally, the presence of students and faculty from different countries enriches cultural diversity in classrooms, fostering the exchange of ideas and perspectives. Therefore, it is essential for universities to implement sustainable policies that allow for the long-term consolidation of internationalization processes. Only through a strategic and inclusive approach can engineering education effectively respond to the demands of a constantly evolving world.

Indeed, while these initiatives strengthen the preparation of future engineers, gaps still exist in program validation and competency certification across different educational systems. To overcome these limitations, it is necessary to reinforce international agreements and ensure that students receive training adaptable to different job markets, thus consolidating their employability in a globalized context.

Materials and Methods

This study is based on the positivist paradigm and employs a strictly quantitative methodology (Johnson et al., 2007). A non-experimental, cross-sectional design was adopted (Green et al., 1989), utilizing a descriptive approach that allows for analyzing the phenomenon of interest without manipulating variables. To ensure applicability and relevance in real-world contexts, the research follows a field-based design, collecting data directly from participants in their natural educational environments. This facilitates the observation and measurement of variables as they naturally occur, thereby enhancing the validity of the findings.

As a non-experimental study, it avoids the influence of controlled conditions that might introduce bias, offering a realistic representation of the phenomenon in its current state. This methodological approach ensures that the results are reliable and objective, allowing for the collection of measurable and verifiable data.

This study includes a comparative case study conducted at two Colombian universities, each representing a distinct educational modality. One institution follows a hybrid learning model, combining online and in-person instruction, while the other operates under a traditional face-to-face format. By examining these two different educational settings, the study seeks to identify potential variations in the development of professional competencies among engineering students.

This dual-case approach enables a more comprehensive understanding of how institutional learning environments, pedagogical strategies, and access to resources influence the acquisition of technical, managerial, communicative, and ethical competencies. Furthermore, it provides insights into how hybrid and in-person educational models impact student learning experiences, allowing for a more nuanced analysis of the factors contributing to competency development in engineering education.

Participants

This study is based on a convenience and voluntary sample of 265 university students from various engineering disciplines, with an average age of 23 years and a standard deviation of 4.52 years. The participants are primarily enrolled in Industrial Engineering, Systems Engineering, and Food Engineering programs and come from HEIs offering both in-person and hybrid learning modalities.

Regarding gender distribution, the sample consists of 168 men (63%) and 97 women (37%), reflecting a prevalent trend in engineering programs where male students tend to outnumber their female counterparts. Before participating, students were informed about the objectives of this research project, ensuring transparency and voluntary engagement. This gender composition is relevant for analyzing potential differences in competency development and professional skills acquisition, contributing to a broader understanding of engineering education dynamics.

To ensure sample homogeneity in terms of academic experience, inclusion and exclusion criteria were established. Only students from the second semester onward were considered, ensuring that participants had a prior educational background in professional competencies. As a result, first-semester students were excluded, as their initial level of training would not allow for a representative evaluation of competency development throughout the degree program.

This selection allowed for a more precise analysis of professional competency levels among students with established academic progress, providing a comprehensive perspective on their development within the context of engineering education. By focusing on students who have advanced beyond the initial stages of their studies, the research captures a clearer picture of how competencies evolve over time. This approach ensures that the findings reflect not only foundational knowledge but also the integration of practical and technical skills.

Study context

In this study, two Colombian universities with distinct educational models were analyzed. The first institution operates under a hybrid learning modality, combining online and face-to-face instruction. This approach offers greater flexibility and accessibility, allowing students to engage in their studies through digital platforms while also participating in periodic in-person sessions. As a result, students benefit from self-paced learning opportunities, while still having access to academic support and structured activities that enhance their professional training.

In contrast, the second university follows a traditional face-to-face educational model, emphasizing on-campus instruction, where students and faculty interact directly in a physical classroom setting. This conventional approach facilitates immediate feedback, fosters direct engagement with faculty, and strengthens a sense of academic community. By examining these contrasting educational environments, the study seeks to assess how different instructional modalities impact the development of professional competencies among engineering students, providing insights into the effectiveness of hybrid and face-to-face learning experiences.

Instrument

The instrument used in this study was the *Engineering Professional Competencies Questionnaire (EPCQ)* (Vera, 2024b), consisting of 21 Likert-scale questions designed to assess the development of professional competencies in engineering students. The questionnaire is structured into four key dimensions, covering different areas of professional performance:

- *Technical and disciplinary competencies:* Assess the student's mastery of engineering-specific knowledge, research abilities, technological tool usage, and problem-solving skills within their field of study.
- *Interpersonal and communication competencies:* Evaluate the ability to collaborate effectively in teams, communicate complex ideas clearly (both written and oral), and interact in multidisciplinary and multicultural environments.

- *Cognitive and decision-making competencies:* Measure analytical thinking, critical reasoning, adaptability to new challenges, and the ability to make informed decisions based on data and evidence.
- *Ethical and social impact competencies:* Focus on the understanding of professional ethics, social responsibility, sustainability considerations, and the impact of engineering solutions on society and the environment.

This structure allows for a comprehensive evaluation of students' profiles, considering both technical skills and key transversal aspects essential for their performance in the professional environment. By integrating various competency dimensions, the instrument ensures a well-rounded assessment that reflects the multifaceted nature of professional readiness. Additionally, the questionnaire includes six sociodemographic questions aimed at collecting information on participants' age, gender, academic program, semester, institutional affiliation, and country of residence. This data enables a deeper analysis of how different contextual and personal factors may influence competency development and professional growth.

However, for the purposes of this study, only the technical and disciplinary competencies dimension was analyzed, with the objective of evaluating the level of development of specific skills within the field of engineering. This dimension includes five sub-competencies: Knowledge of the profession, Research capacity, Management and organizational skills, English communication skills, and Use of advanced technological tools. This study is part of a broader research project that aims to assess all four dimensions of the instrument employed, providing a comprehensive understanding of students' professional competencies and their alignment with current industry demands.

Regarding internal consistency, the questionnaire demonstrated an overall Cronbach's alpha of 0.9, indicating an exceptional level of reliability. This result confirms that the instrument exhibits high coherence in measuring the assessed competencies, ensuring the precision and validity of the collected data. Additionally, the self-administration of this instrument was considered a pilot test, allowing researchers to evaluate its effectiveness in real application settings. The positive reliability results obtained in this phase suggest that the questionnaire is a robust tool for competency assessment, supporting its potential for broader implementation in future studies.

Results

The data analysis provided a detailed overview of the development of professional competencies among engineering students. It allowed for identifying key strengths and areas requiring improvement, offering valuable insights for curriculum enhancement. Table 1 presents the descriptive statistics for the main evaluated items in the sample, including the number of participants (N), the mean (M), and the standard deviation (SD) for each sub-competency, facilitating a clearer understanding of competency distribution across different domains.

Table 1: Descriptive statistics for the 'Technical and Professional Competencies' Dimension

Sub-competencies	N	M	SD
1. Knowledge of the profession	265	3.517	0.817
2. Research capacity	265	3.589	0.853
3. Management and organizational skills	265	3.864	0.791
4. English communication skills	265	2.509	1.000
5. Use of advanced technological tools	265	3.868	0.854
Total	265	3.469	1.000

Source: Own elaboration.

As observed, the strongest sub-competencies are in technical, management, and technological areas, whereas English communication remains one of the weakest areas. These results are displayed in the following Figure 3, which shows the distribution of the mean scores by sub-competency.

Figure 3: Distribution of mean development levels by sub-competency
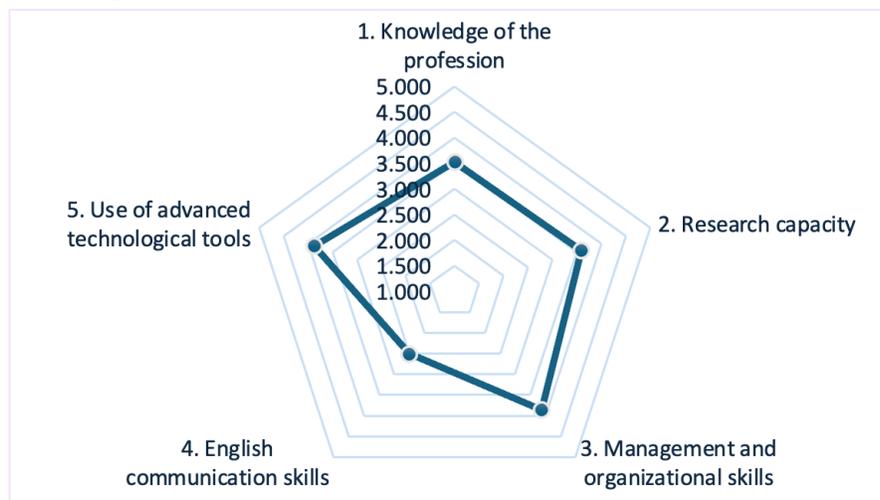
Source: Own elaboration.

Based on the obtained results, we proceed to answer each of the research questions posed in this study. To achieve this, professional competencies are analyzed across different sub-competencies, considering their overall level of development as well as variations observed according to variables such as academic semester, institutional affiliation, age, and gender. This approach enables a deeper understanding of how contextual and demographic factors influence competency acquisition, offering insights into the effectiveness of current educational strategies and their alignment with professional expectations in the engineering field.

This analysis will help identify key trends, strengths, and areas for improvement in the training of engineering students, providing valuable information for decision-making in educational and curricular development. By pinpointing specific competency gaps, this study can inform targeted interventions aimed at enhancing students' preparedness for the workforce. Additionally, the findings may contribute to broader discussions on competency-based education, ensuring engineering programs remain relevant and responsive to industry demands.

Detailed breakdown of research questions and findings

1. What is the level of development of technical and professional competencies among students?

Overall, the data analysis reveals that the professional competencies of this group of students exhibit a high level of development (M = 3.469; SD = 1.000), with heterogeneous distribution. The general findings indicate:

Table 2: Results by Sub-competencies

Sub-competencies	Achieved Level	Interpretation
Knowledge of the profession	Moderate - High	Students demonstrate a functional level in their professional knowledge, although some still require reinforcement.
Research capacity	High - Moderate	A strong development in this competency is evident, with some students reaching high levels, but variability in proficiency remains.
Management and organizational skills	High	Students exhibit a good level of autonomy and proficiency in management and organization, benefiting their professional performance.
English communication skills	Low - Moderate	This is the least developed competency. Most students struggle with English, highlighting an opportunity for improvement.
Use of advanced technological tools	Very High - High	This is the best-developed competency in this group, reflecting strong proficiency in technology use.
Total	Moderate - High	Overall, the group demonstrates an acceptable level of professional competencies, with strengths in technology and management but challenges in English communication.

Note: Interpretation range in Likert scale (1-5):
Very Low= 1.00 – 1.80; Low = 1.81 – 2.60; Low-Moderate = 2.61 – 3.4; High = 3.41 – 4.20; Very High = 4.21 – 5.00.

2. Are there significant differences in the development of these competencies according to the academic semester?

A Kruskal-Wallis test was conducted to analyze whether the academic semester influences competency development.

*   Significant differences were found in technical and management competencies (p = 0.02997 and p = 0.04319), indicating that these competencies improve as students advance in their academic journey.

- No significant differences were found in communication and ethical competencies (p > 0.05), suggesting that their development is not directly related to the academic semester.
- These findings indicate that students improve in technical and management aspects as they progress, but no clear improvement is observed in communication or ethics.

3. Are there variations in the development of technical and disciplinary competencies based on institutional affiliation?

The results indicate that institutional affiliation influences certain competencies, while others remain unaffected. This suggests that factors such as academic programs, learning and teaching methodologies, faculty expertise, and access to institutional resources may play a significant role in shaping specific skills. On the other hand, some competencies appear to develop independently of the university environment, possibly driven by personal motivation, prior experience, or extracurricular engagement, highlighting the multifaceted nature of skill development in higher education contexts.

A Mann-Whitney (Wilcoxon) test was conducted to compare the performance of students from universities with hybrid and in-person learning modalities, identifying significant differences in some areas:

- Technical and communication competencies showed significant differences (p < 0.05), suggesting that students from different institutions have varying competency levels in these areas.
- No significant differences were found in ethical and management competencies (p > 0.05), indicating similar development of these skills in both institutions.

These variations in training may be linked to specific resources available in each institution, particularly in technical and communication areas.

4. Do age and gender influence the development of technical and disciplinary competencies?

A Kruskal-Wallis test and post-hoc Dunn test were conducted to assess the influence of age and gender.

- *Gender:*
  - No significant differences were found in technical, communication, or management competencies (p > 0.05). This implies that institutional or demographic variables may have had limited influence on these particular areas of competency.
  - Significant differences were found in ethical competencies (p = 0.00472), with women scoring higher than men. This finding supports existing research suggesting that gender may influence ethical awareness, potentially due to differences in socialization, values, or professional expectations within educational and workplace environments.

- *Age:*
  - No significant differences were found in any competency ($p > 0.05$), indicating that age does not significantly impact competency development. This suggests that skills acquisition occurs consistently across age groups within the studied population.

These results indicate that gender influences ethical competencies, while age does not significantly impact any of the evaluated sub-competencies. This finding suggests that ethical awareness and decision-making processes may be shaped by gender-related factors, potentially due to socialization patterns or cultural expectations. However, the lack of a significant correlation between age and the other sub-competencies implies that professional competencies develop similarly across different age groups. Future research should explore whether external variables, such as educational background or professional experience, contribute to shaping ethical competencies differently.

Moreover, these findings highlight the need for tailored educational strategies that address ethical competency development more effectively. Institutions could integrate ethics-focused training programs, mentorship initiatives, and interdisciplinary discussions to enhance ethical awareness among all students. Additionally, exploring how institutional culture, curriculum design, and faculty influence ethical competency formation could provide deeper insights for improving engineering education.

Recommendations

Based on the results of this study, the following key strategies are proposed to enhance strengths and address weaknesses in the development of professional competencies among engineering students:

Strengthening technical and disciplinary competencies
- Integration of advanced technological tools into the curriculum through virtual laboratories, simulations, and specialized software, ensuring their practical application in different engineering fields.
- Promotion of project-based learning (PBL) and active methodologies that allow students to apply technical knowledge to real-world problem-solving.
- Development of industry partnerships to facilitate access to technological certifications and complementary training programs.

Improving English communication skills
- Implementation of specialized technical English courses focused on terminology and communication in engineering contexts.
- Creation of English interaction spaces, such as seminars, conversation clubs, and tutoring sessions with international professionals.
- Encouragement of article and conference paper publication in English, with institutional support for writing and review.

Promoting ethics and professional responsibility
- Incorporation of ethical dilemmas and case studies into engineering courses to encourage reflection and critical analysis of professional decisions.
- Development of mentoring programs where experienced professionals share their perspectives on ethical decision-making in the workplace.
- Regular assessments of ethical competencies through surveys or simulations that measure decision-making in real-world contexts.

Strategies to reduce gender gaps in competencies
- Promotion of leadership programs for women in engineering, including mentorship and networking opportunities for professional development.
- Visibility of female role models in engineering through talks, conferences, and educational materials.
- Encouragement of inclusive educational environments by implementing teaching strategies that ensure equitable participation for all students.

Adaptability and personalized learning
- Utilization of artificial intelligence and educational data analytics to identify learning patterns and tailor teaching strategies.
- Implementation of adaptive tutoring systems that provide individualized support for areas of difficulty.
- Continuous and flexible assessments, offering detailed feedback and allowing adjustments in teaching methods.

These recommendations aim to ensure a more balanced development of key competencies in engineering students, strengthening their preparedness for a highly demanding and constantly evolving job market. By fostering both technical and transversal skills—such as communication, ethics, leadership, and adaptability—institutions can better equip graduates to navigate professional challenges, contribute to innovation, and assume responsible roles in multidisciplinary and global work environments.

Discussion

The findings of this study indicate that professional competencies among engineering students exhibit uneven development, with strengths in technical skills, management, and innovation, but deficiencies in English communication. This trend aligns with Munir (2021), who highlights that engineering programs have strengthened technical competencies but have not effectively integrated communication and collaborative skills in international contexts. Additionally, the results are consistent with Jiang et al. (2023), who found that a lack of English proficiency limits engineers' participation in multidisciplinary teams and global projects. This reinforces the importance of implementing internationalization strategies in engineering education, promoting English learning as a transversal competency.

Regarding the evolution of competencies throughout the academic career, the results show significant differences in technical and management dimensions, whereas communication and ethical competencies do not exhibit notable changes across semesters. This is consistent with Vera (2024), who states that engineering programs have improved technical training but still show deficiencies in integrating soft skills. Similarly, Zhang (2024) highlights that the development of ethical and leadership skills in engineering often depends more on extracurricular experiences and the organizational culture of institutions than on the formal curriculum. This finding underscores the importance of providing students with meaningful opportunities outside the classroom—such as mentoring programs, student organizations, and community engagement projects—that foster these competencies. It also suggests the need to rethink and redesign study plans to ensure the balanced and intentional development of all essential competencies required for responsible and effective professional practice.

Furthermore, the differences in technical and communication competencies based on institutional affiliation highlight the gap between universities with varying levels of resources and infrastructure. This finding aligns with studies by Pulido et al. (2024) and Gabalán-Coello et al. (2019), who emphasize that the quality and pedagogical approach of engineering education differ substantially across institutions, directly impacting student learning and training outcomes. Additionally, the lack of age-related effects on competency development supports the findings of Burbano (2016), suggesting that variations in student performance are more closely tied to institutional policies, curricular design, and instructional methodologies than to personal or demographic characteristics.

Finally, the difference in the perception of ethical competencies between men and women is an aspect that requires further exploration. Previous studies, such as Quelhas et al. (2019), suggest that women tend to demonstrate greater ethical awareness in professional contexts. This indicates that gender may influence ethical decision-making, potentially shaped by socialization processes, cultural expectations, and diverse professional experiences. Understanding these dynamics is crucial for designing more inclusive and effective ethics education, ensuring that all students are equally prepared to navigate complex moral challenges in their future careers, regardless of background.

These results suggest the need to strengthen pedagogical strategies that integrate technical competencies with communication, management, and ethical skills in a transversal manner. Furthermore, it is essential to promote active learning environments that foster interdisciplinary collaboration, creativity, and critical thinking. Such approaches not only enhance student engagement but also facilitate the practical application of knowledge in real-world contexts. In parallel, reducing institutional disparities in engineering education is crucial to ensure equitable access to quality resources, mentorship, and learning opportunities. Ultimately, these combined efforts support the comprehensive development of future professionals equipped to address complex societal, environmental, and technological challenges with confidence and responsibility.

Conclusions

The findings of this study reveal that professional competencies among engineering students show differentiated development, with strengths in technical skills, management, and innovation, but notable deficiencies in English communication. This suggests that, while engineering programs have successfully consolidated problem-solving training and advanced technological tool proficiency, gaps persist in the integration of communication skills, which are essential for graduates' insertion into a globalized workforce. In this sense, the need to reinforce English instruction and effective communication strategies becomes imperative to enhance employability and foster collaboration in international environments.

Additionally, the study confirms that academic progression influences the development of technical and management competencies but does not necessarily impact communication and ethical competencies. This indicates that higher education institutions must review their curricular strategies to ensure that all dimensions of an engineer's professional profile evolve in a balanced manner. Furthermore, the differences in competency development based on institutional type suggest that educational resources and pedagogical methodologies significantly influence students' training, highlighting the importance of promoting equitable quality standards in engineering education.

On the other hand, the lack of significant differences based on age, as well as gender influencing only ethical competencies, reinforces the idea that professional competency development is more influenced by institutional and methodological factors than by individual characteristics. This underscores the need for universities to design training programs that incorporate inclusive and adaptive approaches, ensuring that all students have equal opportunities to strengthen their professional growth. Ultimately, these results provide valuable insights for improving engineering curricula, guiding future educational reforms to ensure the training of professionals capable of responding to the demands of a constantly evolving world.

Note:

- This study is part of a broader research project developed by the Research Center on Professional Competencies (NuCOPO) of *Red Internacional de Investigadores en Educación/International Education Researchers Network (REDIIE).* Its objective is to evaluate engineering students' professional competencies based on four key dimensions: technical and disciplinary competencies, interpersonal and communication competencies, cognitive and decision-making competencies, and ethical and social impact competencies.
- In accordance with the Artificial Intelligence Usage Policy of *Revista Electrónica Transformar/Transformar Electronic Journal*, we employed artificial intelligence tools, specifically ChatGPT-4o, to enhance the clarity, coherence, and readability of complex texts. This AI-assisted approach was used to refine the structure and language of manuscripts while maintaining the original meaning and academic rigor of the content. This methodology aligned with ethical guidelines on AI-assisted writing, ensuring that human expertise remained central to content validation and decision-making. The integration of artificial intelligence in scholarly writing demonstrates its potential as a support tool for academic editing while reaffirming the importance of authorial responsibility in the final output.

References

Aguirre-Álvarez, Y., Montoya-Peláez, M., Trujillo-Cabezas, R., & Hurtado, C. (2023). Competency Development in Industrial Engineering and Related Academic Programs Regarding the Optimization of Production and Logistics Processes: The Case of Medellín. *Trilogía Ciencia Tecnología Sociedad*. https://doi.org/10.22430/21457778.2717

Ahmad, N., & Qahmash, A. (2020). Implementing Fuzzy AHP and FUCOM to evaluate critical success factors for sustained academic quality assurance and ABET accreditation. *PLoS ONE,* 15. https://doi.org/10.1371/journal.pone.0239140

Arias, A., Linares-Vásquez, M., & Rocío-Héndez, N. (2023). Undergraduate Dropout in Colombia: A Systematic Literature Review of Causes and Solutions. *Journal of Latinos and Education*, 23, 612 - 627. https://doi.org/10.1080/15348431.2023.2171042

Burbano, A. (2016). Integrated Curriculum Design for an Industrial Engineering Undergraduate Program in Latin America. https://doi.org/10.18260/p.25767

Caratozzolo, P., Lara-Prieto, V., Martinez-Leon, C., Rodríguez-Ruiz, J., Ponce, R., & Vázquez-Villegas, P. (2022). Developing Skills for Industry 4.0: Challenges and Opportunities in Engineering Education. https://ieeexplore.ieee.org/document/9962444

Casanova, J., Vasconcelos, R., Bernardo, A., & Almeida, L. (2021). University Dropout in Engineering: Motives and Student Trajectories.. *Psicothema*, 33 4, 595-601 . https://doi.org/10.7334/psicothema2020.363

Fomunyam, K. G. (2020). Globalization and Internationalization in Engineering Education in Africa. *International Journal of Innovative Technology and Exploring Engineering (IJITEE, 9*(12), 71-76. https://rediie.cl/wp-content/uploads/GLOBALISATIONANDINTERNATIONALISATIONINENG.pdf

Gabalán-Coello, J., Balcero-Molina, A., Rizo, F., Martínez-González, A., & Fonseca-Grandón, G. (2019). An Analysis of Accredited Colombian Universities, Based on Performance Variables Associated with Their Quality. *Journal of Latinos and Education*, 21, 379 - 387. https://doi.org/10.1080/15348431.2019.1665523

Gołuch, P., Stec, M., Gańczorz, P., Białek, K., & Kiljan, A. (2024). An Analysis of the Challenges and Opportunities Facing the Interdisciplinary Engineer of the 21st Century Based on the Concept of Industry 4.0. https://journals.prz.edu.pl/hss/article/download/1728/1308/

Greene, J. C., Caracelli, V. J., & Graham, W. F. (1989). Toward a Conceptual Framework for Mixed-Method Evaluation Designs. Educational Evaluation & Policy Analysis, 11, 255-274. https://doi.org/10.3102/01623737011003255

Hernández, R., & Goe, L. (2015). La formación dual en Colombia. El caso de la Fundación Universitaria de la Cámara de Comercio de Bogotá Uniempresarial: los desafíos actuales en la percepción de egresados y empresarios. , 13, 145-181. https://doi.org/10.21830/19006586.21

Higuera Martínez, Ó. I., Fernández Samacá, L., & Alvarado Fajardo, A. C. (2020). Fomento de la creatividad en estudiantes de primer año de ingeniería a través de proyectos. Encuentro Internacional de Educación en Ingeniería https://doi.org/10.26507/ponencia.719

Hissey, T. (2000). Education and careers 2000. Enhanced skills for engineers. *Proceedings of the IEEE*, 88, 1367-1370. https://doi.org/10.1109/5.880089

Jiang, D., Dahl, B., & Du, X. (2023). A Systematic Review of Engineering Students in Intercultural Teamwork: Characteristics, Challenges, and Coping Strategies. *Education Sciences*. https://doi.org/10.3390/educsci13060540

Johnson, R. B., Onwuegbuzie, A. J., & Turner, L. A. (2007). Toward a Definition of Mixed Methods Research. *Journal of Mixed Methods Research*, *1*(2), 112-133. https://doi.org/10.1177/1558689806298224

Kassler, J., & Zeng, Q. (2024). Preface: 6th International Symposium on Education, Culture and Social Sciences (ECSS 2024). *Transactions on Social Science, Education and Humanities Research*. https://doi.org/10.62051/4retr041

Li, Z. (2022). Research on the Path of Education Globalization in Engineering Universities of China. *2022 11th International Conference on Educational and Information Technology (ICEIT)*, 170-174. https://doi.org/10.1109/ICEIT54416.2022.9690727

Luna, A., Chong, M., & Djurica, D. (2023). Higher Education Internationalization: A Peruvian University Experience. *2023 IEEE World Engineering Education Conference (EDUNINE)*, 1-6. https://doi.org/10.1109/EDUNINE57531.2023.10102851

Malik, H., Chaudhary, G., & Srivastava, S. (2021). Digital transformation through advances in artificial intelligence and machine learning. *J. Intell. Fuzzy Syst.*, 42, 615-622. https://doi.org/10.3233/JIFS-189787

Munir, F. (2021). More than technical experts: Engineering professionals' perspectives on the role of soft skills in their practice. *Industry and Higher Education*, 36, 294 - 305. https://doi.org/10.1177/09504222211034725

Ndubuisi, A., & Marzi, E. (2021). InVEST: Equipping Engineering Students with Professional Competencies and Interpersonal Skills. 10.1109/FIE49875.2021.9637174

Pertuz, A., González-Estrada, O., & Graciano, C. (2020). Investigación en ingeniería en Colombia (2020). *Revista UIS Ingenierías, 19*(1), pp. 7-10 Universidad Industrial de Santander Bucaramanga, Colombia. https://ieeexplore.ieee.org/document/10436232

Pulido, J., Rodriguez, D., & Rueda, W. (2024). Proposal to Characterize the Effectiveness of Engineering Education in Colombia. *Proceedings of the 22nd LACCEI International Multi-Conference for Engineering, Education and Technology (LACCEI 2024): "Sustainable Engineering for a Diverse, Equitable, and Inclusive Future at the Service of Education, Research, and Industry for a Society 5.0."*. https://doi.org/10.18687/laccei2024.1.1.1334

Quelhas, O., Lima, G., Ludolf, N., Meiriño, M., Abreu, C., Anholon, R., Neto, J., & Da Silva Goulart Rodrigues, L. (2019). Engineering education and the development of competencies for sustainability. *International Journal of Sustainability in Higher Education*. https://doi.org/10.1108/IJSHE-07-2018-0125

Rawboon, K., Yamazaki, A., Wongsatanawarid, A., & Oda, S. (2021). Global Competencies for Engineering Program Graduates from an Industry Perspective. https//doi/10.18178/ijlt

Sangwan, D., Sangwan, K. S., & Raj, P. (2022). 21st-century competencies in engineering education: initiation, evolution, current, and now whither to. http://hdl.handle.net/2117/383631

Suárez-Landazábal, N., & Buendía, A. (2020). Effects of the evaluation and accreditation processes on academics. A case study of a Colombian higher education institution. *Education Policy Analysis Archives*, 28, 113. https://doi.org/10.14507/EPAA.28.5353

Šuligoj, V., Zavbi, R., & Avsec, S. (2020). Interdisciplinary critical and design thinking. *International Journal of Engineering Education*, 36, 84-95. https://www.ijee.ie/1atestissues/Vol36-1ª/07_ijee3858.pdf

Tossavainen, P. (2009). Institutionalising internationalisation strategies in engineering education. European Journal of Engineering Education, 34, 527 - 543. https://doi.org/10.1080/03043790903154457

Tsakalerou, M. (2019). *Globalization and Engineering Education: The Pendulum Has Swung Again.* https://doi.org/10.33422/2nd.educationconf.2019.11.795

Ulloa, G., Pachón, Á., & Arboleda, H. (2018). Active Learning and CDIO Implementation in Colombia. https://doi.org/10.1109/GLOCOMW.2011.6162378

Vera, F. (2020). Concepciones de docentes universitarios chilenos sobre el pensamiento crítico. *Transformar*, *1*(1), 20–41. https://revistatransformar.cl/index.php/transformar/article/view/14

Vera, F. (2022). La perspectiva de docentes sobre la infusión de la sostenibilidad en el currículo de la educación superior. *Transformar*, *3*(2), 17–37. https://www.revistatransformar.cl/index.php/transformar/article/view/57

Vera, F. (2023). Aprendizaje activo y pensamiento crítico: Impulsando el desarrollo estudiantil en una universidad privada chilena. *Transformar*, *4*(3), 31–44. https://revistatransformar.cl/index.php/transformar/article/view/101

Vera, F. (2024a). Desarrollo de competencias genéricas en carreras de Ingeniería: Análisis crítico de propuestas formativas en Chile. Transformar, 5(1), 37–60. https://revistatransformar.cl/index.php/transformar/article/view/116

Vera, F. (2024b). *Engineering Professional Competencies Questionnaire (EPCQ).* Red International de Investigadores en Educación/International Education Researchers Network (REDIIE). https://rediie.cl/engineering-professional-competencies-questionnaire-epcq/

Vera, F., & Tejada, E. (2020). Developing soft skills in undergraduate students: A case at a Chilean private university. *Transformar*, *1*(1), 57–67. https://revistatransformar.cl/index.php/transformar/article/view/12

Vera, F., Buyones-González, H., Parodi-Camaño, T., & Romero Torres, M. E. (2024). Perception of Construction Engineering Students concerning Professional Competencies at a Chilean Private University. *Transformar*, *5*(4), 17–38. https://revistatransformar.cl/index.php/transformar/article/view/146

Zabaleta, J. M. O. & Rodríguez, C. M. A. (2023). Engineering in education, with an impact on the implementation of Agtech in the agricultural sector *2023 IEEE Colombian Caribbean Conference (C3)*, Barranquilla, Colombia, 2023, pp. 1-5. https://ieeexplore.ieee.org/document/10436232

Zhang, B. (2024). Cross-cultural Engineering Team Management in The Context of Globalization. *Frontiers in Business, Economics and Management*. https://doi.org/10.54097/61mpwd46