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Developing Key Skills for Digital Transformation in Engineering Students: An Exploratory Study

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Abstract

Digital Transformation (DT) involves modifying processes, business models, products, services, and customer interactions to enhance efficiency and effectiveness. Companies must rely on a well-skilled workforce to lead this transformation and innovate to address present and future challenges. However, the growing digital skills gap between workers trained before the digital age and employees with digital knowledge has been exacerbated by the inefficacy of traditional IT training, given the complexity of new digital technologies. Professionals must be able to understand the digital economy, manage physical-virtual value chains and global logistics, design new digital business models, and manage digital projects. They must also develop both technical competencies and soft skills, such as communication, collaboration, creativity, critical thinking, and problem-solving. In higher education, courses and academic activities are required to integrate both a theoretical approach and active, dynamic experiences that prepare students to face the challenges of the digital environment. This raises questions about the skills developed during the training of future professionals and leaders who can address digital transformation in organizations.

The present study aims to investigate the skills that students acquire in the course "Management of Digital Transformation" (GTD) to achieve a Digital Transformation Plan (DTP). The methodological approach is based on an exploratory, descriptive research design, with a quantitative focus on students who have completed the GTD course across various engineering disciplines. The sample consists of students from the first semester of 2025, from both day and evening programs, enrolled in 8 sections (n = 285) within the industrial and informatics engineering disciplines at a Chilean university. The study aims to identify the most important skills developed under each criterion, essential for addressing a DTP in line with the planned activities, expected learning outcomes, and performance indicators established in the course syllabus. These results will help improve engineering education by guiding the redesign of the course to strengthen the digital skills needed to implement a DTP within an organization**.**

Keywords: Digital Transformation Plan, digital skills, Digital Project Management, Engineering Education

Introduction

Digital transformation is understood as an organizational change driven by digital technologies, which goes beyond the simple adoption of technological tools. This process involves a profound transformation of an organization's capabilities, structures, processes, and business models, affecting how it operates and responds to its changing environment. As several authors have pointed out [1], [2] Digital transformation is not only focused on technical aspects but also encompasses significant structural and cultural changes.

Management and organizational capabilities play a crucial role, as companies must adapt to the speed of change through more agile decision-making and flexible organizational structures [1]. In addition, digital transformation is a cultural challenge; organizations must foster a culture of continuous learning, experimentation, and collaboration so that their employees can adapt and take advantage of new opportunities[1], [2]. Finally, the work environment is changing with digitalization: remote work, virtual teams, and online collaboration are redefining workspaces and organizational policies, requiring adaptations that promote both employee productivity and well-being[1], [2].

Recruiting human talent with the necessary skills for Digital Transformation is not easy. These skills include not only technical competencies, but also soft skills such as communication, collaboration, creativity, critical thinking, and problem-solving [3] . This skill set is not built solely on knowledge and training, but also through experience. Information, communication, and innovation technology requires specific and essential competencies that employers look for in engineers.

Preparing engineering and STEM candidates with non-technical skills, including skills such as critical thinking, idea generation, and interdisciplinary ways of working, seems particularly important and a necessary task [4]. Today, the recent push towards the digital transformation that society requires has increased the number of soft skills frameworks and lists [4].

In this context, academic institutions need to prepare new generations of engineers to face the challenges of a highly dynamic, digitized world. Future engineering professionals must not only master the technical and digital competencies needed to implement and manage cutting-edge technologies, but also develop interpersonal skills such as leadership, communication, and collaboration, which are essential for integrating into multidisciplinary teams and adapting to rapid change.

Likewise, cultivating a mindset of continuous learning and adaptability is crucial for successfully navigating constant technological advances and market changes. By promoting comprehensive training in digital transformation, institutions can train engineers with the ability to innovate and lead organizational transformations, ensuring that their future graduates are agents of change in the digital evolution of their companies and industrial sectors.

In this sense, subjects or academic activities are required that focus on learning these new technologies, not only theoretically but also through active, dynamic learning. This can include case studies and business simulations, as well as practical approaches such as inaction, which allow students to interact with companies, access real information, and apply their knowledge in real-world situations.

All of the above leads us to reflect on the skills that are developed in the training process of future workers and/or leaders capable of facing a Digital Transformation (DT) in organizations, which is why in the Faculty of Engineering of a private Chilean University, a transversal subject is taught in the Engineering careers called Digital Transformation Management (GTD) that contributes to the development of the Transformation field of action Digital and establishes that students will be able to design a digital transformation plan with a focus on improving organizational value and compliance with external regulations, managing change in organizational culture, as well as successfully monitoring its execution.

This subject (Digital Transformation Management. GTD) develops certain activities in work teams that use information from real companies to understand them and make diagnoses that identify the technological gaps in their processes, not only production, but also commercial, supply, storage, etc., develop proposals that incorporate emerging technologies to transform chosen processes and develop digital strategies that close the gaps indicated, as well as the proposal of business models that allow them to allow traditional companies to move towards digital transformation, as well as identify the level of maturity of an organization.

Next, the work will be oriented towards the establishment of what are the most important skills developed by the Digital Transformation Management (GTD) subject, from the perception of Engineering students who take the subject during the second semester of the year 2024, taught in the careers of the period: Computer Engineering, Industrial Engineering and Computer Science Engineering, based on the expected learning, achievement indicators and content units established in the Syllabus of the subject.

Based on the above, the premise of the study is presented: What are the most important skills developed in the Digital Transformation Management subject that allow you to approach a Digital Transformation Plan, from the perspective of engineering students, as established in the syllabus of the subject? The objective of this research is to establish which are the most important skills that the Digital Transformation Management (GTD) subject of the Faculty of Engineering develops in Engineering students according to the student perception, allowing the approach of a Digital Transformation Plan (DWP), based on the expected learning, achievement indicators, and content units of the syllabus. The following sections present the literature review, the methodology applied, the analysis of data and results, the discussion of these results, the conclusions of the work, and the prospects for future work.

Theoretical Framework

The concept of digital transformation, as it is known today, has its roots in the organizational changes facilitated by information technology (IT) in the 1990s [1] [2]. In its early days, the focus was mainly on technological aspects, such as the implementation of IT systems to improve organizational efficiency [1]. However, over time, it was recognized that internal management and reorganization are also critical to achieving successful transformation [1] [2]. Likewise, research in the field of corporate entrepreneurship highlighted the importance of strategic renewal in the context of digital transformation [1]. This approach highlights that digital transformation involves not only adopting new technologies but also changing the mindset and processes across the organization.

Digital transformation (DT) can be understood as a process in which digital technologies create disruptions that trigger strategic responses aimed at reshaping value creation paths and

the associated organizational changes [5]. The digital transformation approach in organizations can be divided into two essential dimensions or perspectives: one focused on technology and the other on the actor or human factor [6] Considering the disruptive nature of many digital technologies today, we believe that organizations need to fundamentally renew and redefine the key ideas of their business to fully exploit the potential of digitalization and ultimately achieve a successful transformation [6]

The rapid development of technological innovation means that companies need to transform into digital companies, which is why digital transformation requires more than the introduction and implementation of digital technologies, and has effects on all areas of a company, they have to think about new business models, rethinking their operating models, and they have to attract smart talent that can cope with this digital transformation [7]. These skills are essential for addressing the digitalization every company needs. Consequently, digital talents must have extensive knowledge in different domains, such as technology or business [8].

Recruiting human talent with the necessary skills for Digital Transformation is not easy. These skills include not only technical competencies, but also soft skills such as communication, collaboration, creativity, critical thinking, and problem-solving [3]. This skill set is not built solely on knowledge and training, but also through experience.

In addition to technical skills, engineering students should acquire a broader set of essential skills through different student-centered learning approaches, where engineering disciplines should be integrated with ethics and sustainability approaches in a more multidisciplinary environment [4]. This includes technical skills such as foundational literacy, digital literacy, and global awareness; metacognitive skills like independent learning, locating and accessing information, and higher-order critical and innovative thinking; social skills including flexibility, adaptability, self-management, self-discipline, creativity, perseverance, resilience, and self-motivation; intrapersonal (interpersonal) skills such as communication, teamwork, empathy, responsibility, and conflict resolution; entrepreneurial skills to drive innovation, adapt to change, make decisions, and plan and manage ideas and opportunities; and problem-solving skills encompassing negotiation, problem identification and resolution, and reflection on underlying contributing factors.

Methodology

As mentioned above, it is necessary to explore the most important skills that the Digital Transformation Management (GTD) subject of the Faculty of Engineering develops in Engineering students according to the student perception, which allow the approach of a Digital Transformation Plan (PTD), based on the expected learning, achievement indicators, and content units of the syllabus.

This research is a quantitative study that seeks to identify the "Top 10" most important skills, as perceived by 267 engineering students who took the subject "Digital Transformation Management" (GTD) in the period 202420. The participants come from three daytime races:

- Computing and IT Engineering: 6th semester students (8-semester degree).
- Industrial Engineering: 6th semester students (8-semester degree).

- Computer Science Engineering (Civil Computing): 8th semester students (10-semester degree).

The definition of the skills was made based on the study carried out by [4], in which they addressed the development of the soft skills and transversal competencies of the 21st century necessary in the labor market for STEM (Science, Technology, Engineering, and Mathematics) candidates through innovative practices to improve their employability. They developed a survey to understand the skills needed, where users selected "TOP 10 SKILLS" they needed to earn or improve to achieve future skill levels, and selected the skill level they would like to achieve: basic, intermediate, or advanced. The survey was distributed to stakeholders in all partner countries.

To define the skills developed in the GTD course, we drew on the subject's syllabus, achievement indicators, and content units. The learning outcomes of this course are: (1) Design digital transformation plans, according to different strategies, to assess their impact on the organization's various processes, (2) Simulate the implementation of a digital transformation plan to assess its impact on the organization, and (3) Analyze change management techniques for the implementation of a digital transformation plan.

Based on the activities, tasks, and workshops that take place during the semester, as established in the syllabus, the skills associated with the expected learning and their respective indicators of achievement were defined. They were classified into ten (10) categories or dimensions; later, it became an instrument in a survey submitted for validation by the seven (7) teachers who teach the subject (experts). and then distributed to all students taking the subject via the virtual platform used to teach the subject, with the help of the teachers responsible for each subject. The definition of skills and their classification in the dimensions considered are as follows:

- Digital Strategy Management: Business strategic analysis, systems thinking, strategic planning, strategic management, strategic thinking, and strategy integration.
- Change management: Change agent, leadership in digital transformation, conflict resolution, and effective communication.
- Innovation in solution design: User-centered design, innovation, and technological innovation.
- Risk management: Risk analysis, risk assessment, risk management.
- Digital Business Models: Business model development, impact evaluation.
- Project Management: TD project management, technology resource management, informed decision making.
- Information Systems Integration: Information systems planning.
- Digital Evolution: Digital maturity diagnosis, digital maturity analysis, digital maturity assessment, digital evolution planning.
- Application of Frameworks: Understanding of TD frameworks, ability to apply them practically.

- Digital Organizational Design: Organizational design, collaborative work.

The designed survey consists of 12 items, of which the first 2 correspond to the student's personal data, and the following 10 address the dimensions considered, with their respective skills and definitions, using a Likert scale with five options ranging from "very low" to "very high". For this study, only the seven (7) sections or courses of the 3 careers that taught the subject in the second semester period of 2024 of the Faculty of Engineering were considered, which corresponds to 267 students during the day. A total of 118 valid surveys were received.

Numerical values were assigned to the levels of the scales, considering very low = 1 to very high = 5, using descriptive statistics with central trend measures to give average values to each skill, and then ordered them from highest to lowest and showed the "TOP TEN", according to the students' perception. For the safeguarding of the data from the ethical point of view, the courses were assigned with capital letters and a unique code for the identification of the students from 1 to 188, thus maintaining their anonymity in the publication. The data were accessible only to the principal investigator, and the survey included informed consent, allowing the student to choose whether to participate. To compare the dimensions, the ANOVA test and its interpretations and contextualizations were used in Microsoft Excel.

Results

From the study universe corresponding to 267 students who took the GTD subject, belonging to the 3 careers that taught the course in the period 202420 (second semester), 118 valid surveys were obtained, obtaining a margin of error of 4%, which were stratified according to career and sex, as shown in Table 1:

Table 1. Classification of Engineering students by major.

Degree	Number of Students	Percentage (%)	Women (%)	Men (%)	Total
Computer Science (Civil Computing)	63	53	5	95	100
Computing and IT	36	31	17	83	100
Industrial	19	16	10	90	100
Total	118	100	-	-	-

This breakdown shows higher male participation across all careers, with significantly lower female representation. It is also observed that the largest number of responses is from Computer Science students.

Table 2. Dimension: Digital Strategy Management.

Skill	Very Low (%)	Low (%)	Moderate (%)	High (%)	Very High (%)	Average	Standard deviation	Mode
Strategic Business Analysis	5.08	0.85	22.03	39.83	32.20	3.94	1.02	4
Systems Thinking	4.24	5.08	16.95	38.14	34.75	3.97	1.06	4
Strategic Planning	5.08	3.39	27.12	32.20	32.20	3.83	1.08	5
Strategic Management	4.24	5.08	20.34	38.98	31.36	3.89	1.05	4
Systems Thinking	5.08	2.54	28.81	28.81	34.75	3.86	1.09	5
Strategy Integration	5.93	4.24	18.64	33.05	37.29	3.93	1.13	5
Average	3.90							

On the Digital Strategy Management dimension (Table 2), the skills with the highest average were "Systems Thinking" (3.97) and "Strategy Integration" (3.93), which were considered fundamental by the students. The standard deviation is moderate, indicating a consistent perception of its relevance.

Table 3. Dimension: Change Management

Skill	Very Low (%)	Low (%)	Moderate (%)	High (%)	Very High(%)	Average	Standard deviation	Mode
Change Agent	3.39	5.93	19.49	41.53	29.66	3.89	1.02	4
Leadership in Digital Transformation	4.24	5.08	27.97	27.12	35.59	3.85	1.10	5
Dispute Resolution	5.08	7.63	28.81	36.44	22.03	3.64	1.08	4
Effective Communication	4.24	4.24	24.58	34.75	31.36	3.87	1.06	4
Average	3.81							

Source: Authors.

The Change Agent and Effective Communication skills had the highest scores (Table 3), with averages of 3.89 and 3.87, respectively. Students valued skills related to change management and communication.

Table 4. Dimension: Innovation in Solution Design

Skill	Very Low (%)	Low (%)	Moderate (%)	High (%)	Very High (%)	Average	Standard deviation	Mode
User-Centered Design	4.24	5.93	28.81	27.12	33.90	3.81	1.10	5
Innovation	4.24	5.93	15.25	33.90	39.83	4.01	1.09	5
Technological Innovation	4.24	2.54	16.10	32.20	44.07	4.11	1.04	5
Average	3.97							

The Technological Innovation skill (Table 4) achieved the highest score (4.11), indicating its significant relevance and its key role for students in the context of technological solutions.

Table 5. Dimension: Risk Management

Skill	Very Low (%)	Low (%)	Moderate (%)	High (%)	Very High (%)	Average	Standard deviation	Mode
Risk Analysis	3.39	5.08	26.27	30.51	34.75	3.88	1.06	5
Risk Assessment	3.39	4.24	27.12	37.29	27.97	4.01	1.01	4
Risk Management	5.08	4.24	22.88	33.05	34.75	4.11	1.10	5
Average	4.00							

The Risk Management skill (4.11) stood out as the most valued, with a uniform perception among students who identify risk management as crucial to digital transformation (Table 5).

Table 6. Dimension: Digital Business Models

Skill	Very Low (%)	Low (%)	Moderate (%)	High (%)	Very High (%)	Average	Standard deviation	Mode
Business Model Development	3.39	4.24	21.19	34.75	35.59	3.88	1.03	5
Impact Assessment	4.24	5.08	20.34	38.14	31.36	3.83	1.06	4
Average	3.86							

Source: Authors.

Both Business Model Development and Impact Evaluation skills have close averages (3.88 and 3.83, respectively). The ability to create and evaluate digital business models is very important (Table 6).

Table 7. Dimension: Project Management

Skill	Very Low (%)	Low (%)	Moderate (%)	High (%)	Very High (%)	Average	Standard deviation	Mode
Transformation Project Management	4.24	3.39	22.88	29.66	38.98	4.01	1.07	5
Technology Resource Management	5.08	4.24	22.03	31.36	36.44	4.11	1.11	5
Informed Decision Making	3.39	2.54	27.12	38.14	27.97	3.88	0.98	4
Average	4.00							

The "Technology Resource Management" skill (4.11) was the most valued, indicating that efficient resource management is key to digital transformation projects (Table 7).

Table 8. Dimension: Information Systems Integration

Skill	Very Low (%)	Low (%)	Moderate (%)	High (%)	Very High (%)	Average	Standard deviation	Mode
Information Systems Planning	4.24	2.54	22.03	33.90	36.44	3.83	1.04	5
Average	3.83							

Systems planning is seen as essential (Table 8), though its relevance is slightly lower than that of other dimensions.

Table 9. Dimension: Digital Evolution

Skill	Very Low(%)	Low (%)	Moderate (%)	High (%)	Very High (%)	Average	Standard deviation	Mode
Digital Maturity Diagnosis	3.39	4.24	27.12	30.51	34.75	4.01	1.04	5
Digital Maturity Analysis	4.24	3.39	26.27	37.29	28.81	4.11	1.03	4
Organizational Maturity Assessment	4.24	3.39	25.42	37.29	29.66	3.88	1.03	4
Digital Evolution Planning	4.24	3.39	24.58	26.27	41.53	3.83	1.09	5
Average	3.96							

The skills highlighted were Digital Maturity Analysis (4.11) and Digital Maturity Diagnosis (4.01), which represent the ability to assess and plan digital maturity as essential (Table 9).

Table 10. Dimension: Applying Frameworks

Skill	Very Low (%)	Low (%)	Moderate (%)	High (%)	Very High (%)	Average	Standard deviation	Mode
Understanding Digital Transformation Frameworks	5.93	8.47	30.51	23.73	31.36	4.01	1.18	5
Practical Application Capacity	5.08	8.47	27.97	28.81	29.66	4.11	1.14	5
Average	4.06							

The Practical Application Ability skill stood out with an average of 4.11, so the practical ability to implement frameworks is highly valued (Table 10).

Table 11. Dimension: Digital Organizational Design

Skill	Very Low (%)	Low (%)	Moderate (%)	High (%)	Very High (%)	Average	Standard deviation	Mode
Organizational Design	3.39	3.39	24.58	33.05	35.59	3.88	1.02	5
Collaborative Work	4.24	4.24	21.19	34.75	35.59	3.83	1.06	5
Average	3.86							

The skills Organizational Design and Collaborative Work have similar values (3.88 and 3.83), and are shown to be essential for organizational transformation (Table 11).

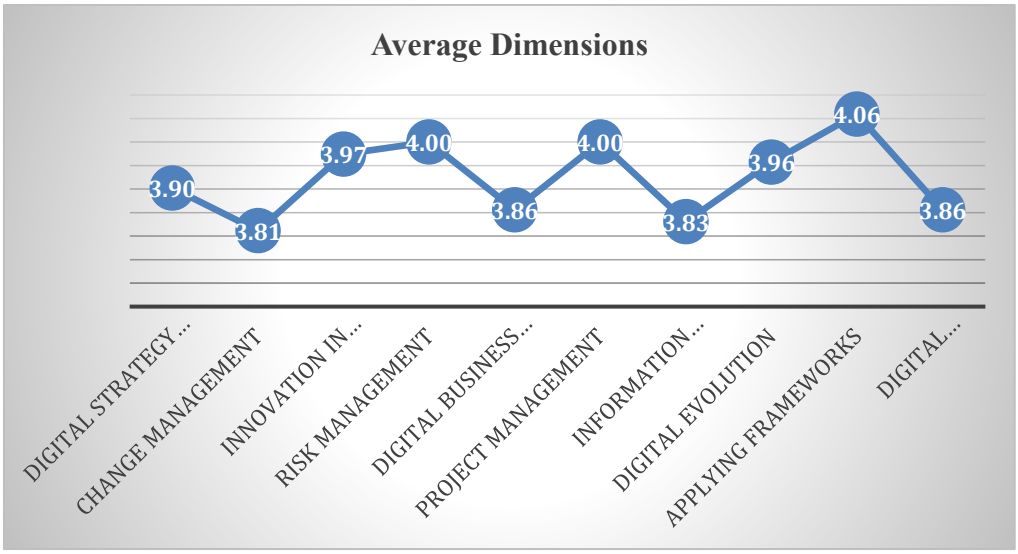

Figure 1. Considered Dimensions

It can be seen that the most developed dimensions correspond to the application of the framework (4.06) (Fig. 1), followed by project management and risk management with the same average (4.00). In contrast, the dimension with the lowest average is change management (3.81).

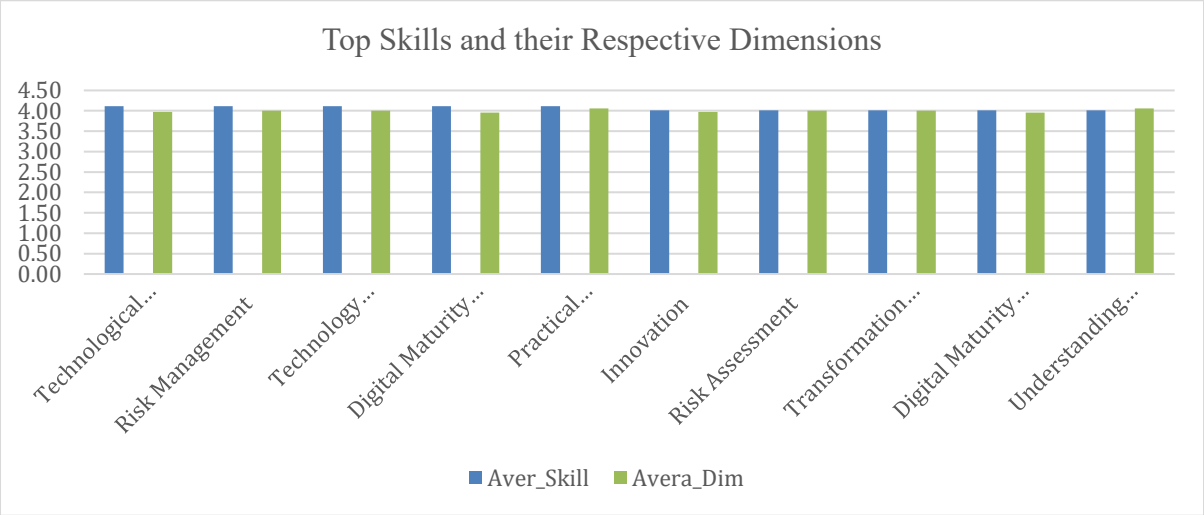

Figure 2. Top Ten Skills and Their Respective Dimension

It can be observed that the skills with the highest average indeed belong to the most developed dimensions (Fig. 2); therefore, they are aligned. It should be noted that the average grade of the participating courses was compared, using a scale of 1 to 5, and matched to the skill scales (Table 12).

Table 12. Comparison of average grades per course vs. the average skill scale

Course	Average of assessed skills	Course grade average	Error
A	3.6	4.4	0.8
B	3.7	4.6	0.9
C	3.9	4.9	0.9
D	3.8	4.8	1.0
E	4.4	5.0	0.6
F	3.6	5.0	1.4
G	3.9	4.5	0.6
Average	3.9	4.7	0.9

As observed in Table 12, the average grade for all courses (4.7) is consistently higher than the perceived skills. Course F shows the highest discrepancy (1.4), suggesting a lower perception of skill development relative to high academic grades, while courses E and G show the lowest discrepancy (0.6). Additionally, the comparison is made by gender and by career, based on the average skills and the grade for each career.

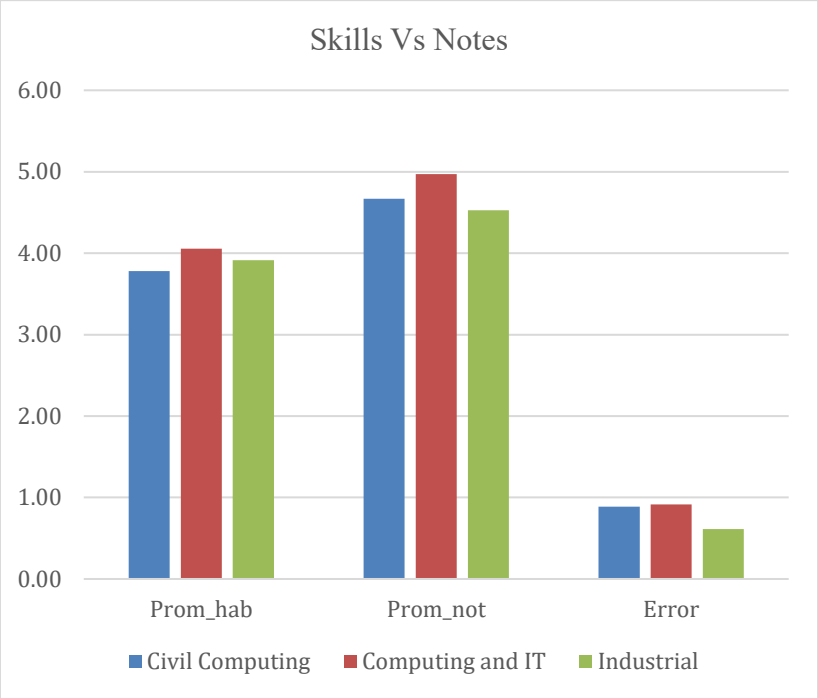

Figure 3. Average skills by major vs. average grade

Figure 3 illustrates the relationship between perceived skill averages, academic grades, and error (discrepancy) by major. Perceived skills (Prom_hab) are lower across all careers than in grades. In Civil Computing, the lowest average of perceived skills is observed, while Computer Computing, IT, and Industrial have similar averages. Likewise, all careers have a similar grade point average, close to 5.

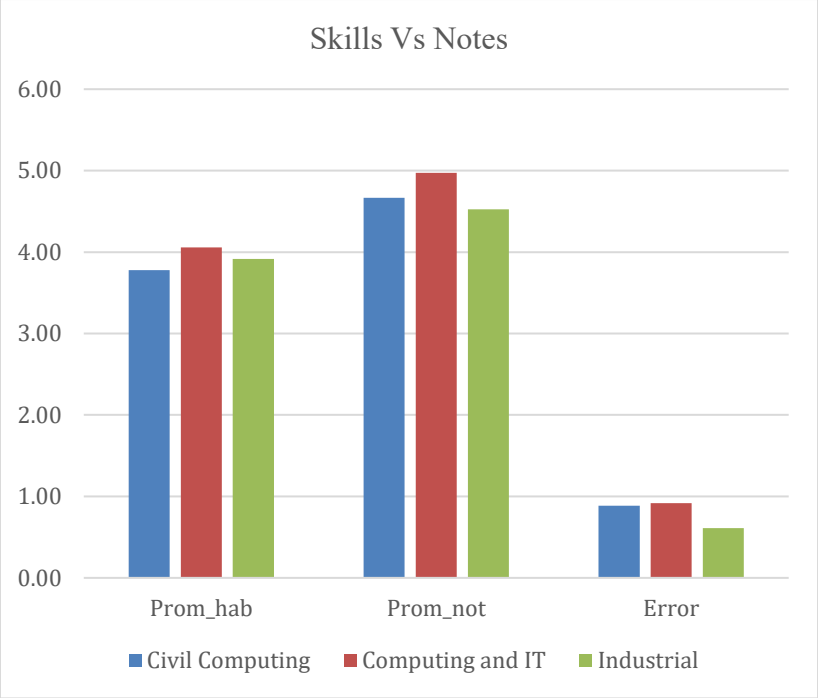

Figure 4. Average Skills by Gender and Majors.

Fig. 4 shows the relationship between gender averages and careers. In Civil Computing, women have a higher average skill level than men; in Computing and IT, men have a significantly higher average than women; and in Industrial, women again show higher averages than men.

Discussion

The research addressed the development of skills in Digital Transformation Management (GTD) from the student perspective, highlighting the following as the most valued skills: Technological Innovation, Risk Management, Management of Technological Resources, Digital Maturity Analysis, and Practical Application Capacity. These competencies, with an average of 4.11, emphasize the importance of integrating a technical-practical approach in the training of engineers. This finding coincides with the literature (e., [8]) which underscores the importance of introducing new technologies and digital skills into training to foster deep learning in these fields. It is also aligned with the conclusions of [4], who highlight the importance of practical and transversal skills for employability in STEM.

On the other hand, the results also show that the Change Management dimension had the lowest average (3.81), which reveals a gap in soft skills such as leadership, communication, and adaptability. This contrasts with the conclusions of [3], who emphasize that skills related to change management and working in multidisciplinary environments are essential for digital transformation. The low rating in this dimension suggests that, although the program successfully addresses technical competencies, it should strengthen the development of soft skills to achieve a more balanced training. In addition, the observed discrepancy between perceived skills (3.9) and academic grades (4.7) reinforces the hypothesis that current assessments may not reflect the comprehensive development of practical competencies.

The work also reveals a significant difference in the perception of skills by gender and career. While women stand out in Civil Computing and Industrial Engineering, men have higher averages in Computing and IT Engineering, reflecting an interesting dynamic in perceptions of skills across academic contexts. This finding could be related to adaptive and diversified learning approaches to meet better the specific needs of students with different backgrounds and profiles [9].

Despite the valuable findings, the study has important limitations. The sample's partial representativeness, with only 44% participation, limits the generalizability of the results. In addition, reliance on subjective perceptions and variations in course implementation across sections could have introduced bias. This had already been pointed out as a challenge [2], emphasizing the need for standardized methodologies to assess competencies in educational programs related to digital transformation.

Possible sources of error include the survey design, which, although validated by experts, may not have fully captured certain skills relevant to today's market, such as those associated with emerging technologies. Likewise, the low female representation in the sample could have biased the results towards a predominantly male perspective, highlighting the importance of inclusion and diversity in STEM programs [10].

In summary, the results confirm the importance of many of the technical and practical competencies addressed in the GTD subject, but also underscore the need to strengthen soft skills and the integration of emerging technological competencies. These observations offer a solid basis for redesigning the curriculum, ensuring comprehensive training aligned with the demands of a constantly evolving work environment. Incorporating more objective assessments and diversified approaches could be key to overcoming discrepancies and better preparing future engineers to lead digital transformation in their organizations.

Conclusions

This study examined the key skills fostered in the Digital Transformation Management (DTM) course and found that students highly value competencies such as technological innovation, risk management, management of technological resources, digital maturity analysis, and the ability to apply knowledge in practice, reinforcing the need for a technical, hands-on engineering education aligned with labor-market expectations. However, the comparatively weaker development of change-management skills, including leadership, effective communication, and adaptability. This is an opportunity to strengthen curricular design and teaching strategies focused on soft skills essential for leading transformation in complex organizations. The study also notes a mismatch between students' perceived skill development and academic grades, suggesting current assessments may not fully capture practical competence. Differences in skill perceptions by gender and program point to the value of more inclusive and adaptive learning approaches, while comparisons with prior research indicate the curriculum could be expanded to include emerging areas such as artificial intelligence and digital security. Despite limitations related to sample representativeness and reliance on self-reported perceptions, the findings support redesigning programs through case studies, simulations, problem-based learning, and project-based learning to deliver a more comprehensive preparation that blends technical expertise with interpersonal and adaptive capabilities for real-world digital transformation.

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