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Soft Skills in Engineering Education: From the Macro Curriculum to International Standards

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Abstract: Soft skills are increasingly important in the current context of engineering education because disciplinary learning is now greatly facilitated by technology, and students (on their own) have access to an almost infinite amount of information and knowledge. To acquire these skills, engineering students need to work on their emotions, ethics, and other personal areas. This article analyzes the case of the Instituto Tecnológico Metropolitano (ITM) in Medellín, Colombia, more specifically, its Faculty of Engineering, whose educational project acknowledges that it has a shortcoming in terms of teaching soft skills. Therefore, document analysis was carried out using the documents that compose ITM's macro curriculum to identify the soft skills that this Higher Education Institution (HEI) proposes for its engineering students and graduates—all of them were compared to the competencies suggested by international associations.

This study combined two methodologies, i.e., conceptual cartography and document analysis (for collecting information) and explored the skills that the labor market is currently demanding from engineering graduates. As a result, it was possible to link the generic skills in ITM's engineering macro curriculum with the generic competencies currently needed by professionals in different engineering fields. It was found that said macro curriculum meets current educational standards in this regard. Nevertheless, the ITM still suffers from gaps in terms of (1) ensuring that professors and directors comply with what is established in its institutional documents and (2) identifying the parts of the educational chain that can destabilize its institutional plan.

Keywords: Transversal skills, soft skills, curriculum, engineering skills.

1. Introduction

Soft skills encompass Social, Emotional, and Intercultural (SEI) competencies (Delors et al, 1996). Social and emotional competencies, which are intertwined, can be divided into five capacities: self-control, self-awareness, social awareness, relationship skills, and responsible decision-making (CASEL, 2018). In turn, the intercultural competency focuses on the ability to communicate effectively and appropriately in intercultural situations (Deardorff, 2004). The European Higher Education Area (EHEA) has called on Higher Education Institutions (HEIs) to implement educational models based on the development of skills that enable individuals to

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continue learning on their own and find new alternatives to solve problems (Sierra & Cabezuelo, 2009). There is evidence that indicates that transversal competencies should be included in the curriculum in order to achieve the well-rounded education required by today's society and allow future engineers to meet the social and professional requirements of a globalized world. Engineering graduates should be prepared for continuous learning, good communication, teamwork, and social responsibility, among other aspects, because technical skills are not enough anymore (Giuliano, 2013).

The engineers of the twenty-first century must be professionals at the service of humanity, who create, design, and provide humane and responsible solutions to complex problems involving daily needs, using resources and dynamic actions. They should identify the sources of their materials and energy so that they not only use them but also ensure their conservation. They should be upright individuals that base their practice on being, knowing, and doing, as well as competence, research, professionalism, social awareness, and innovation. All these aspects should be embedded and improved in the college education of engineering students so that they can put all their capacity at the service of society; offer different points of view on multiple community needs to change social, political, cultural, economic, and technological situations; and construct a better future (Montoya et al. 2018).

Curricula are road maps that institutions draw to define the learning experience that their students should have. At their macro level, curricula propose an academic and graduate profile, describing their conception of man and education and establishing institutional purposes (Casanova & Inciarte, 2016). According to Oppenheimer (2018), there is a trend in engineering education toward emotions, morality, and values because technology will take over the acquisition of disciplinary knowledge and the development of cognition. However, students cannot improve their cognition separated from their emotional competencies—as it was done in the past (Moreno et al., 2018).

The new trends in engineering education have led to academic discussions inside associations, such as the Ibero-American Association of Engineering Education Institutions (ASIBEI), on the general raison d'être of engineering. These discussions have highlighted the importance of engineering education that aims to solve social problems by connecting innovative science, technique, and dignified work. Consequently, engineering graduates should have not only specific knowledge but also social skills that enable them to understand the importance and impact of research and technological development on current society and the future (Giordano, 2016).

In general, HEIs have devoted all their efforts to complying with theoretical, worldwide standards, which place them in privileged positions in relation to regulation agencies and society. However, many of these declared processes and procedures do not establish a real-life approach in the classrooms or for the education of future graduates. The Colombian Association of Engineering Faculties (ACOFI) and other associations and/or entities at the international level have worked to provide guidelines for engineering programs in terms of their social responsibility, the Sustainable Development Goals (SDGs), and their particular institutional goals.

Additionally, different lists of the competencies or skills that engineers should possess have been compiled by multiple organizations: the Accreditation Board of Engineering and Technology (ABET), the Federal Council of Deans of Engineering (CONFEDI), the Conceive Design Implement Operate (CDIO) initiative, and the Tuning Project, among others. All of them agree on one point: the purpose of engineering education is to provide students with the knowledge they will need in the future (Crawley et al., 2007).

More than a profession, engineering is a vocation, which implies a responsibility to oneself and society.

Consequently, HEIs that offer engineering programs should improve their teaching processes based on the needs of the environment and the guidelines for engineering education that have been provided by entities, associations, and other organizations. Unfortunately, their recommendations have remained on paper and not reached the classroom in a way that enables students to develop all the skills listed in their graduate profile, one that describes the socially responsible engineer that society needs today.

This study implemented an ethnographic research design, which seeks to explore, examine, and understand a social system and analyze the meaning, in the context of society, of actions written in

documents. The scope of this study is descriptive-correlational, i.e., it aims to describe the relationship between two or more categories in a specific context and learn about the influence that they could have on each other (Hernández-Sampieri & Mendoza, 2018). The main objective of the study was to evaluate how the consistency and articulation of the curriculum components impact the development of the SEI competencies declared in the graduation profiles of the programs of the Department of Electronics and Telecommunications, to provide feedback on modifications that allow improvement. educational processes and professional performance of graduates. For this, we began by determining the macrocurricular attributes that are related to the SEI competencies and that exert the greatest influence on the graduation profile of the Department's programs, through a consistency matrix. Subsequently, the development of SEI competencies in undergraduate students of the Electronic Engineering and Telecommunications Engineering programs of the ITM was evaluated. To finally proceed to estimate the correlation of the professional profile and the development of SEI competencies in the undergraduate students of the programs.

2. Methodology

This study investigated the institutional documents that compose ITM's macro curriculum adopting two methodologies: Conceptual Cartography (CC) and Document Analysis (DA). CC is a strategy used to construct and communicate concepts based on complex thinking through verbal, non-verbal, and spatial elements. Its purpose is to support the construction of knowledge inside the general framework of the acquisition of cognitive skills. CC is a precise method to define academic concepts and communicate them by describing their relationships and organization, which enables others to understand them (Tobón, 2004). In turn, DA (according to Bernal, 2018) consists of extracting information from several related documents that are analyzed for a certain purpose. This produces a categorization of the information that generates relevant, reliable knowledge. In DA, the document is conceived as a medium (Clausó, 1993).

The flowchart in Figure 1 shows the steps followed in this study to analyze the institutional documents that compose ITM's macro curriculum, which discusses Social, Emotional, and Intercultural competencies (SEI). Following these steps, we extracted information related to ITM's engineering graduate profile. This analysis was based on the methodology proposed by Clausó (1993) and in accordance with the procedures and instruments described by Pinto (1991).

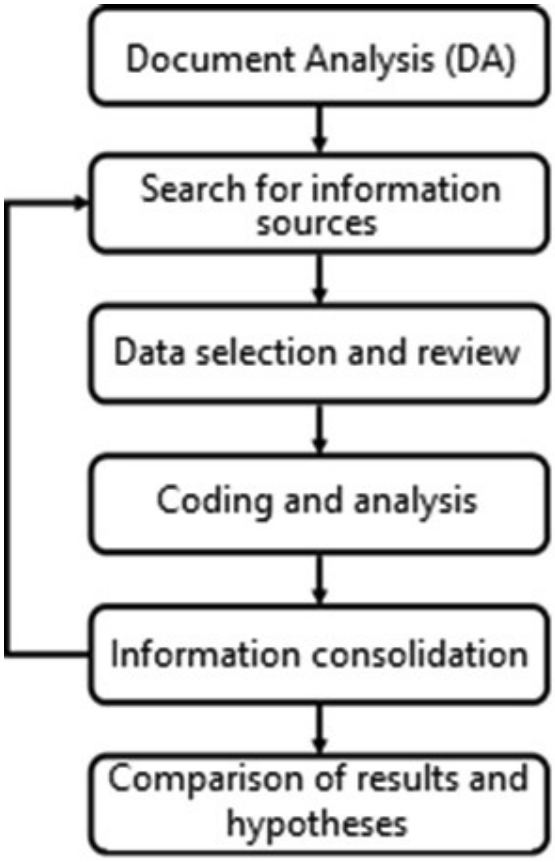

Fig. 1: Steps followed in this study for qualitative data analysis. Adapted from (Hernández-Sampieri & Mendoza, 2018).

In this study, the primary sources were the institutional documents that compose ITM's macro curriculum; and the secondary sources, scientific publications with keywords related to SEI competencies. All the sources were selected considering the components of a macro curriculum and the definitions of SEI competencies.

The DA was conducted according to the methodology, procedures, and instruments proposed by Clausó and Pinto. In particular, a template (Figure 2) was created to consolidate the information in the documents considering their main themes, (1) Institutional code, (2) document title, (3) document abbreviation or code, (4) year, (5) perspective or focus, and (6) definition or meaning. A final review

was carried out to summarize the main statements and conclusions as results.

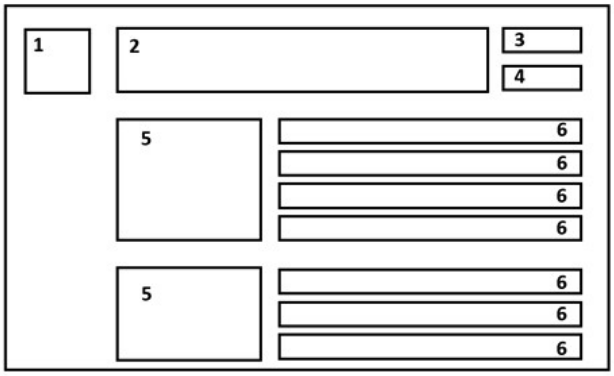

Fig. 2: Template used in this study to consolidate the information collected by Document Analysis.

Afterward, we reviewed several lists of soft skills proposed by ABET, CONFEDI, CDIO, and the Tuning Project (see Table 1). After the disciplinary competencies were left out, we compared the rest with the SEI competencies described by Yepes and Montes (2021). Using ATLAS.ti software and the procedures described by Strauss and Corbin (2002), we loaded each institutional document independently to analyze its content and add citations. Then, inductive coding was carried out to establish the main elements in each document with their respective comments.

3. Results

Multiple institutional documents that compose ITM's macro curriculum were reviewed here: the Institutional Educational Project (IEP), the Educational Project of the Faculty of Engineering (EPFE), and the Educational Project of the Engineering Program (EPEP). It was found that they revolve around two themes: (1) human dignity as the central pillar of institutional documents and the point of convergence of ethics; social, environmental, and moral awareness; and sustainability and (2) plurality, which is literally declared in said documents as the point of convergence of multi-disciplinary knowledge, creativity, teamwork, relationship skills, self-management, and decision-making. This makes it clear that the development of transversal skills at the ITM is focused on (a) the being component of the being-knowing-doing framework and (b) students' capacity to pose questions and propose solutions with arguments, tolerance, respect, and social responsibility, which goes hand in hand with SEI competencies.

Table 1: Engineering competencies proposed by different organizations.

ABET (1996)	CONFEDI (2016)	CDIO (2001)	Tuning Project (2004)
An ability to identify, formulate, and solve engineering problems. An ability to function on multi-disciplinary teams. An understanding of professional and ethical responsibility. The broad education necessary to understand the impact of engineering solutions in a global, *economic*, *environmental*, and societal context. A recognition of the need for, and an ability to engage in lifelong learning. A knowledge of contemporary issues. An ability to design a system, component, or process to meet desired needs within realistic constraints such as *economic*, *environmental*, *social, political*, *ethical*, *health* and *safety*, *manufacturability*, *and sustainability.* An ability to use the techniques, skills, and modern engineering tools necessary for engineering practice.	Identify, formulate, and solve engineering problems. Effectively use engineering techniques and tools. Contribute to technological developments and/or innovations. Effective teamwork. Effective communication Continuous, autonomous learning. Entrepreneurial spirit. Act in an ethical, professionally responsible, and socially committed way considering the economic, social, and environmental impact of their activity in the local and global context.	Engineering reasoning and problem solving. Experimentation and knowledge discovery. System thinking. Personal skills and attitudes. Professional skills and attitudes. Teamwork. Communication. Communication in foreign languages.	Capacity for applying knowledge in practice. Research skills. Capacity to learn. Capacity to adapt to new situations. Capacity for generating new ideas (creativity). Leadership. Understanding of cultures and customs of other countries. Ability to work autonomously. Project design and management. Initiative and entrepreneurial spirit. Concern for quality. Will to succeed.

ITM's mission and vision define its institutional values and principles: respect for life, well-rounded education, autonomy, social relevance, equity, pluralism, leadership, social responsibility, entrepreneurial spirit, and sustainable development. All the different parts of its macro curriculum accept and adopt these principles for education, and each one of them contributes to the development of generic competencies in its students.

ITM's Institutional Educational Project (IEP) focuses on well-rounded education and research, defining the former as "a continuous process of construction of the relationship between being, knowing, doing, and context guided by the principles of respect for human

dignity, the public, private good, the environment, and society, which we conceive as the scenario for the materialization of being, knowing, learning, doing, and living together" (ITM, 2021). Note the emphasis on respect, care for the environment, and coexistence. Additionally, research complements ITM's graduate profile because it can offer solutions to real problems of society, communities, the institution, and the productive sector, which is demanding skills such as autonomy, active participation, teamwork, and social responsibility.

The Educational Project of the Faculty of Engineering (EPFE) describes a pedagogical model that adopts a bio-psycho-social perspective to teach students to be flexible, investigative, inclusive, interdisciplinary, and globally aware. The latter means educating upright, critical, creative, participatory citizens and professionals who have initiative and social sensitivity thanks to their well-rounded education—which is based on the four pillars of education: learning to know, learning to do, learning to be, and learning to live together (ITM, 2021).

On the other hand, the Educational Project of the Engineering Program (EPEP) defines, in its teleological principles, some attributes of the education it provides well-rounded; transversal; innovative; investigative; and socially, environmentally, locally, and globally aware. The EPEP establishes a graduate profile with a focus on environmental and curricular aspects. According to it, graduates should be able to work in a team and solve different engineering problems with ethical, professional, and social responsibility; effective communication; autonomy; and sustainability awareness.

Although it is not the only document in ITM's macro curriculum that refers to the four pillars of education, the EPEP defines in more detail what is expected from each one of them in well-rounded education. Learning to know is learning to be autonomous, investigative, and intercultural. Learning to do focuses on job performance, upholding institutional values, respect, and human dignity. Learning to live together is not only about people but also about sustainability awareness and knowing the effect of one's actions on others and the environment—not only in the national context but also around the world. Learning to be (ITM, 2021).

From an educational and pedagogical perspective, ITM's pedagogical model focuses on soft skills, such as research, internationalization, sustainability awareness, and ethical behavior, based (again) on the four pillars of education. It also proposes polyvalent education, i.e., a type of interdisciplinary education that to aims teach students to solve problems autonomously by conducting research (ITM, 2021).

As a result of the document analysis of ITM's macro curriculum described above, we compiled a list of the generic competencies, skills, and abilities that ITM engineering graduates should develop (Table 2). Figure 3 links these generic competencies to their SEI counterparts. Some of these competencies are associated with the graduate profile, such as problem-solving and social and environmental awareness, which are not related to a single SEI competency but two of them (i.e., intercultural, and social). The same goes for ethics, which is connected to social and emotional competencies.

In general, ITM's macro curriculum covers the three SEI competencies because its institutional

Table 2: Transversal competencies and attributes found in ITM's macro curriculum.

Transversal competencies and attributes
Multidisciplinary knowledge - Has, shares, and respects knowledge in different disciplines.
Nationally and globally aware - Considers the effects of his or her actions at the national and international levels*
Human dignity - Affirms rights and fulfills duties, behaving ethically with him-of herself and with others.
Investigative - Passionate about discovering or solving problems and seeking to obtain more knowledge.
Creative - Imaginative thinking and unique ways to connect information. - Innovative ideas to solve various problems (Corminas, 2001).
Socially-environmentally aware - Knowledgeable about national and international social and environmental issues and aware of the social and environmental effects that he or she can generate.
Team player - Participatory, provides ideas and suggestions. Establishes objectives with the work team, distributing tasks to achieve them. - Effective communicator (speaks at the right time) and good listener (Corminas, 2001).
Decision-maker and problem solver - Balances rationality and intuition. - Identifies problems and knows how to classify themaccording to their level of importance, finding their cause and evaluating the best way to solve them (Corminas, 2001).
Ethical - Respectful, kind, and solidary*

* Own definition based on the literature review.

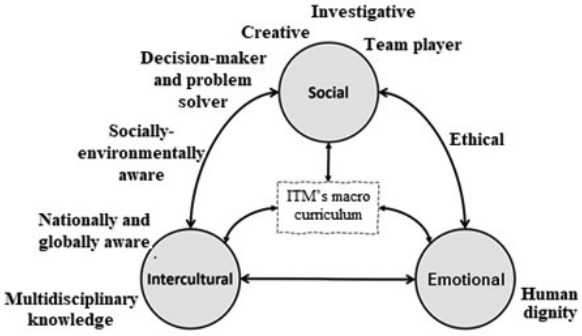

Fig. 3: Relationship between SEI competencies and ITM's graduate profile.

values and attitudes have a social and emotional focus (that includes sustainability, pluralism, and social relevance) and it aims to develop skills such as teamwork, which is related to the intercultural competency but closer to its social counterpart.

Comparing the SEI competencies suggested by international associations (Table 1) with those proposed in ITM's macro curriculum (Table 2), it is evident that they coincide in the importance of developing transversal competencies, but without discounting the relevance of their disciplinary counterparts. Likewise, the soft skills proposed by ABET, CONFEDI, CDIO, and the Tuning Project are in line with the current needs of engineering education in an increasingly globalized world.

HEIs, which are part of the triple helix model of industry-government-university, are responsible for identifying social needs in order to contribute to meeting them. In this triple helix, HEIs have two functions: (1) discussing and defining their institutional mission and (2) monitoring and ensuring full compliance with what is defined in their institutional documents. The latter establish the general and specific competencies developed in each of the study programs that they offer, which should be reflected in well-rounded education for their students. In that sense, this study found that (from a of educational and pedagogical perspective) ITM's pedagogical model focuses on soft skills, as well as research, internationalization, and sustainability. Furthermore, it proposes multipurpose, interdisciplinary education that aims to teach students to solve problems autonomously by conducting research.

Thus, according to its teleological documents, ITM's principles are closely related to SEI competencies and in line with the soft skills proposed by ABET, CONFEDI, CDIO and the Tuning Project. This close relationship enables the ITM to offer well-rounded education with an orientation toward social responsibility. In particular, two attributes listed in ITM's engineering graduate profile, i.e., problem-solver and socially and environmentally aware, have a direct relationship with social responsibility. Likewise, ITM's IEP suggests ethical behavior (which has a direct relationship with social and emotional competencies), constantly referring to pluralism, human dignity, social relevance, and interculturality.

Two themes were identified in ITM's macro curriculum: (1) human dignity and (2) plurality. Human dignity—based on ethics; social, environmental, and moral awareness; and sustainability—enables students develop soft skills to contribute to local and national social transformation. In turn, plurality involves discussion, critique, and social responsibility to solve problems using applied engineering; foreseeing the impacts that the development of a technology or another may have; and counteracting and/or mitigating said effects.

According to the document analysis presented above, ITM's macro curriculum meets the demands of today's engineering education. However, this HEI has yet to ensure that its professors and directors comply with everything that is set forth in its institutional documents. The fundamental role of college professors is motivating, guiding, and focusing students and their learning process—defined as a succession of cognitive and emotional elements that lead to well-rounded education (Moreno et al., 2018). In this context, professors are no longer the main source of knowledge but guides, providing students with tools so that they are not overwhelmed by the large amounts of information available these days. Not all this information is relevant to students and its utilization depends on the context and their level of understanding and assimilation.

To find out how to subsequently assess SEI skills in students, we recommend referring to (Yepes et al., 2022) and (Herrera et al., 2022).

Conclusions

Even though all the competencies and attributes found in ITM's institutional documents are related to social responsibility, said documents do not refer to self-awareness, which allows engineers to foresee the

possible risks and impacts of their decisions. Therefore, ITM's macro curriculum should be reviewed, adjusted, or changed to satisfy current social needs—which are also changing and dependent on the context, history, and the unforeseen future of society.

Unfortunately, engineering education at the ITM is not as described in its institutional documents. Despite the significant influence of social responsibility on its macro curriculum, its professors work independently and not toward a common objective. Furthermore, ITM students complete a final year project applying criteria established by professors alone, which may leave no room for critical thinking or decisions that take into account social responsibility. This is reflected in a low level of appropriation and implementation of the concept of social responsibility in the final year projects of engineering students. Several competencies that engineering students should acquire are fundamental to the concept of social responsibility: plurality, self-management, relationship skills, self-awareness, sustainability, ethics, morality, social awareness, and dignified work.

All the elements in ITM's macro curriculum are based on institutional principles, especially well-rounded education, autonomy, social responsibility, and sustainable development. These concepts are defined and used repeatedly in ITM's institutional documents. Well-rounded education is linked to the four pillars mentioned above; nevertheless, in some parts of said macro curriculum, it is more closely related to some pillars than others. Still, the four pillars fully support ITM's engineering graduate profile—from the cognitive aspects to the emotional parts.

One of the drawbacks found in the document analysis presented above was a lack of standardized terminology. Since the macro curriculum is a set of documents written by multiple people and institutional departments, terminology is not used consistently, which becomes a problem because it hinders the identification and understanding of terms, thus extending the process.

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