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# CRITICAL ASSESSMENT OF THE MAIN STAKEHOLDERS' PERSPECTIVES ON THE EDUCATION OF ENGINEERS PROVIDED BY THE DEPARTMENT OF MECHANICAL ENGINEERING AT UFSC

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***Abstract.*** *The Mechanical Engineering Department at the Federal University of Santa Catarina (EMC/UFSC) is responsible for graduating Mechanical and Materials Engineers as well as Masters and Doctors. Since the first class in 1966, approximately 3000 professionals have been in the working place, positions ranging from professors and researchers to executives of large companies in at least 16 countries, with high performance. The demand for candidates for the entrance exam, which has historically remained high, has experienced a significant drop in recent years. The accelerated digital transformation in all areas, intensified by the COVID era, has modified pedagogical structures and stakeholder views in general, worldwide, altering the status quo of the professional education process. In Brazil, several universities and engineering schools have been revising their strategic plans and operational procedures vis-à-vis international movements and National Curricular Guidelines (DCN). The EMC/UFSC is committed to modernizing its courses in every way possible. Discussions with experts, information surveys, and opinions from students, professors, graduates, and employers have been conducted. With this knowledge, the educational process is being rethought, and new guidelines and consequent procedures are being developed. This article presents the result of this ongoing process at EMC/UFSC.*

***Keywords:*** *Engineering Education, Digital Education, Industry 5.0.*

## 1. INTRODUCTION

The socio-economic transformations that have taken place since the second half of the 20th century, accentuated by globalization and understood as a political, economic, and cultural movement, have contributed to the emergence of new educational strategies, impacting higher education in different fields of knowledge, especially in engineering. In this context of higher complexity, it is observed that the modern engineer should not only be able to perform the functions related to their field in the market but also possess cross-cutting knowledge, skills, and attitudes. For over 10 years Castro (2010) has asserted that the new engineer must be capable of proposing solutions that are not only technically correct but also have the ambition to consider problems in their entirety, in their insertion within a chain of causes and effects of multiple dimensions.

In Brazil, the new National Curricular Guidelines *(Diretrizes Nacionais da Educação* - DCNs) were established in 2019 to be implemented mandatorily. However, it is perceived that the majority of higher education institutions (HEIs) are reluctant or point out difficulties in meeting the socio-economic and technological demands required by society (Vilaça; Araújo, 2016). The DCNs establish the profile of the engineer with an emphasis on a generalist, humanistic, critical, and reflective approach. Moreover, students are expected to become protagonists of their professional education from the beginning of their university journey, added with the demand for greater digital competence.

In order to verify the adequacy of what is established in these guidelines and other applicable regulations and legislation, a research was conducted in the Mechanical Engineering undergraduate course at the Federal University of

Santa Catarina, in Florianópolis, Brazil. This survey involves not only students in the final stages of the course but also practicing engineers in the workforce and the professors themselves, with the objective of identifying and clarifying the main points regarding the teaching method and quality. In addition to knowledge based on literature, as well as observations of successful national and international cases in education, this article highlights the positive aspects of the course, points out what requires change, and adds some recommendations.

## 2. THEORETICAL REFERENCE

This section presents the theoretical framework that underpins the current research. It provides insights into three subjects that are central to this study: the influence of the National Curricular Guidelines (DCNs) and digital transformation in education, and how Brazil, specifically UFSC, responds to these changes.

### 2.1 Engineering Education and the National Education Guidelines

Given the various aspects of engineering education, one of the references used in this research is the extensive and highly topical report published by the higher education consultancy firm Ruth Graham in collaboration with MIT (Massachusetts Institute of Technology) in 2018. Titled "The global state of the art in engineering education," it identifies leading and emerging universities in Engineering Education based on different criteria. The factors, which are difficult to measure and somewhat subjective, are (Graham, 2018): (I) Quality and impact of alumni careers, including career prospects in 10 years' time and whether they meet industry requirements both now and in the future. (II) Value added to students during their undergraduate education ("delta" between input and output), acknowledging that effective data to measure this are scarce and finding a way to do so is decisive. (III) The institution's capacity to deliver world-class education, considering: (1) Institutional leadership and commitment to education (such as recognition and reward processes for teaching excellence and investment in support for teaching and learning); (2) Educational culture (including openness to innovation and experimentation and the extent to which faculty are informed and actively discuss teaching with their colleagues); and (3) The institution's capacity to influence practice elsewhere (analyzing whether the university actively intervenes to inform and improve regional or global-level teaching and how feasible it is to transfer its educational practices to other universities or courses worldwide).

Among the leading institutions are Olin College of Engineering, MIT, Stanford University, Aalborg University, and TU Delft. The emerging ones include Singapore University of Technology and Design, University College London, Pontifical Catholic University of Chile, and Iron Range Engineering (Graham, 2018). Thus, it can be observed that the leading universities in engineering education are predominantly located in the United States of America (USA) and Europe.

In Brazil, in April 2019, the Ministry of Education (MEC) approved the new National Curricular Guidelines for Undergraduate Engineering Courses (DCNs) through the MEC/CNE/CES Resolution No. 2 of April 24, 2019. Its objective is to "meet the future demands for more and better engineers" (MEC/CNE/CES, 2019b). Compared to the previous version of the document from 2002, these new Engineering DCNs emphasize competency-based education, with focus on practical and active learning, and greater flexibility in curriculum composition. Specifically, the competencies referred to as professional competencies are defined as follows:

> *[...] the ability to mobilize, articulate, and put into action the values, knowledge, and skills necessary for the efficient and effective performance of activities required by the nature of the work" (Brasil, 1999 – CNE/CEB Resolution No. 04/1999) and "[...] the personal capacity to mobilize, articulate, and put into action the knowledge, skills, attitudes, and values necessary for the efficient and effective performance of activities required by the nature of the work and technological development" (Brasil, 2002c -MEC/CNE/CP, Resolution No. 03/2002, emphasis added).*

In summary, the main highlights of the changes brought about by the new DCNs are: (1) competency-based education; (2) curriculum flexibility; (3) increased focus on practice and active learning; (4) continuous and comprehensive assessment. This means forming professional engineers with a holistic, multidisciplinary, and transdisciplinary vision, with the ability to develop and apply technologies, in addition to an entrepreneurial mindset. To achieve this goal, each course can balance subjects conveniently, as long as it does not exclude basic, professional, and specific content, as well as mandatory laboratory work and real-world experience.

As General Guidelines, the focus of the analyzed document on the DCNs highlights the following requirements to be verified in the conception and particularly in the implementation of the Pedagogical Course Project *(Projeto Pedagógico do Curso - PPC*): (a) laboratory activities; (b) integration of theory and practice; (c) integration with companies and the community; (d) student-centered focus as the main protagonist in the learning process; (e) interdisciplinarity and transdisciplinarity; (f) scientific initiation, academic competitions, technical visits, tutoring, extension projects in general, entrepreneurship, participation in junior companies, incubators, and other activities. In general, good complementary practices involve keeping students close to the professional environment.

One of the reasons for these changes is the expansion of Industry 4.0, a concept that encompasses the adoption of technologies capable of integrating the physical, digital, and biological worlds, such as the Internet of Things and Additive Manufacturing. The concept has already evolved into 5.0, where the main difference is the inclusion of the human aspect as central. In this sense, the proposal is for the new engineering undergraduate curriculum to be more practical and interdisciplinary, focused on student autonomy.

### 2.2 Digital Transformation and Its Impact on Education

In March 2020, the COVID-19 pandemic brought new protocols and challenges to the world as a whole, and education was not exempt. When it comes to engineering education, Digital Transformation "is the broadest term used to describe an intensive approach to the effective development of entirely new organizations, based on digital technologies, new tools, and best business practices. This transformation is a challenge that organizations face nowadays, and higher education institutions are no exception" (Matkovic *et al.*, 2018). According to Broo *et al.* (2022), the intellectual skills required for the 21st-century job market are the 3S: Searching, Sharing, Simulation. Searching refers to just-in-time learning, Sharing emphasizes the importance of transdisciplinary teamwork, and Simulation involves working with simulation technologies through computers. The engineers of the future must be fluent in digital technologies and data manipulation, but while these topics are common in computer science curricula, they are often overlooked in engineering programs.

These changes in the skills required for engineering professionals and the tools used in the job market make it essential to reformulate engineering education to ensure that courses remain attractive and competitive. According to the World Economic Forum (2023), over 75% of companies intend to adopt new technologies in the next five years, including artificial intelligence, cloud computing, big data, virtual and augmented reality, the Internet of Things, and automation. The benefits brought about by Digital Transformation are not only for the job market but also for universities, which need to adapt and implement an educational model that incorporates the aforementioned technologies and skills. In summary: (1) improved operational efficiency through process automation and data digitization; (2) data-driven decision making allows companies to better understand customers and markets, for example; (3) enhanced personalized customer experience; (4) increased agility and adaptability to changes and responsive to change; and (5) innovation of products and services and the creation of new business models.

### 2.3 National Movements and Current Diagnosis

In Brazil, several actors are working on the development of programs to modernize the study and learning of engineering, such as the National Academy of Engineering (ANE), the Brazilian Association of Engineering Education (ABENGE), and the Fulbright Commission Brazil. The latter represents a program led by the United States government, which, together with the Coordination for the Improvement of Higher Education Personnel (CAPES) and with the support of the National Council of Education (CNE), published the Call for Proposals 23/2018, related to the Brazil-United States Program for the Modernization of Higher Education in Undergraduate Studies (PMG - USA). The program consists of 8 Institutional Modernization Projects (PIM): (1) Control and Automation Engineering (Pontifical Catholic University of Paraná - PUCPR); (2) Mechanical Engineering (Integrated Manufacturing and Technology Campus - SENAI CIMATEC); (3) Production Engineering (Federal University of Rio Grande do Sul - UFRGS); (4) Environmental Engineering (Federal University of Rio de Janeiro - UFRJ); (5) Materials Engineering (Federal University of São Carlos - UFSCar); (6) Electronics Engineering (Federal University of Itajubá - UNIFEI); (7) Civil Engineering (University of the Vale do Rio dos Sinos - UNISINOS); and (8) Chemical Engineering (University of São Paulo - USP).

Furthermore, other institutions and courses are developing independent modernization programs, such as IME (Military Institute of Engineering), INSPER (Institute of Education and Research), PUCRJ (Pontifical Catholic University of Rio de Janeiro), PUCRS (Pontifical Catholic University of Rio Grande do Sul), including the courses at the Technological Center of UFSC.

### 2.4 Mechanical Engineering at the Federal University of Santa Catarina

The Department of Mechanical and Materials Engineering at the Federal University of Santa Catarina seeks to guide its management actions with the academic freedom that permeates and encourages professors to be protagonists in university administration and the development of research and extension activities. This is done through projects aimed at supporting the structuring of laboratories, groups, and nuclei focused on science, technology, and innovation for the benefit of society, as well as coordinating institutional projects. The proactive role of the faculty in the Mechanical Engineering Department has gained national and international recognition in various fields of knowledge, with a positive impact on student selection, government evaluations, and private sector perception (EMC, 2015).

The vision for the department's education is based on the principles of quality, opportunity, and flexibility, which are non-negotiable premises. These principles should be developed through appropriate methods, infrastructure, and environment, and built by a prepared and engaged faculty, support staff, and students. The modernization of the course, a topic extensively discussed in the 2016-2025 Strategic Planning (EMC, 2015), aligns with the maintenance of the global competitiveness of the engineers graduated from the course, while also meeting the Institutional Development Plan 2020-2024 of UFSC (Duarte and Fey, 2020). In fact, the need to review the sequencing of disciplines and prerequisites, reduce the number of mandatory courses while increasing elective options, and encourage participation in extracurricular activities with practical exercises had already been mentioned (EMC, 2015).

Therefore, the perspective for the future of Mechanical Engineering courses is based on the fact that training for a profession in an era of rapid, constant, and profound changes necessarily requires strengthening the connection between theory and practice, promoting actions aimed at the internationalization of education, and developing pedagogical, scientific, and technological innovations (Duarte and Fey, 2020).

The main challenges identified in the 2015 Strategic Planning, which still persist in the institution, include: a) demotivation of professors in initial courses, b) professor-dependent students, c) rigid curriculum with limited space for electives and in-depth education and with little integration with postgraduate programs, d) high dropout rates and student demotivation, e) deficient laboratory infrastructure and monodisciplinary laboratories and groups, f) difficulty in asset management and engage professors in administrative positions in the department.

## 3. METHODOLOGICAL PROCEDURE

After presenting the main theoretical foundations that underpin this study, the methodological procedure that made it possible is presented. The research design uses a qualitative method in terms of its approach, through data collection carried out via questionnaires sent to current students, alumni, and professors of the Mechanical Engineering course at UFSC.

In the questionnaire applied to the students, the target population consisted of students who have completed more than 50% of the course, in other words, the "experts" required by the Delphi Method (Marques; Freitas 2020). The total number of students in the Mechanical Engineering course varies from semester to semester, usually ranging from 600 to 700 students (excluding the effects of the pandemic), according to data from CAGR (Undergraduate Academic Control System) between 2006 and 2020. Considering the regular students among the experts, the population of interest corresponds to an approximate number of 300 students - the value fluctuates slightly each semester. Therefore, a minimum sample size of 61 respondent students can be considered.

Regarding the questionnaire aimed at the alumni of the Mechanical Engineering program, a sample group of 17 participants was obtained, considering the 70 members of the ALUMNI EMC UFSC who have been in the workforce for less than ten years. Lastly, in the questionnaire for the professors, 34 out of a total of 66 professors from the department responded to it.

## 4. RESULTS

From the 34 professors approached, it was found that 64% of them would like to use Artificial Intelligence in their classes, while 14% already make use of this technology. Similarly, when it comes to Virtual Reality, 64% of the professors expressed interest in using the technology, but only 5% claimed to already use it.

Regarding the use of technology in the classroom, it was observed that its applications are dependent on the specific discipline being taught. For example, when it comes to Analytics and Big Data, there was a split among the participants, with 50% expressing interest in using the technology and the other 50% stating that it does not apply to the discipline they teach. Some professors also mentioned the use of programming, simulators, and visual resources such as PowerPoint. However, they also shared that despite their strong interest in applying the aforementioned technologies, there is not enough time within the course schedule to incorporate these tools effectively.

Regarding teaching and learning methodologies, it was found that individual activities were the most commonly chosen by the professors, accounting for 61%, while group work and case studies were utilized by 52% of the participants. Additionally, 20% of the professors reported using the flipped classroom approach, which yielded positive results in undergraduate and postgraduate classes. Figure 1 presents the professors’ responses regarding the topic of technologies used in the classroom.

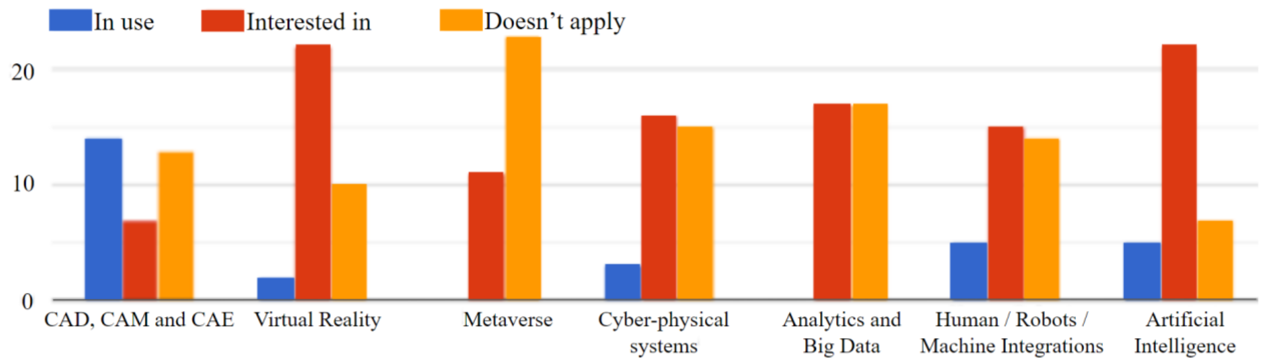


Figure 1. Responses of Professors on the Use of Technologies in the Classroom.

The survey conducted with alumni received 23 responses, with 17 of them being from alumni of the Mechanical Engineering program. More than half of the participants, 58.8%, work in the industry. Among the roles they hold, 41.2% are involved in research and product development (R&D), while another 41.2% work in management and process development. The alumni were also asked about their further educational qualifications, with 23.5% completing a master's degree and 11.7% completing a doctorate. A significant portion, 23.5% of the participants, took short-term courses. The nature of postgraduate studies varied from management, negotiation, and entrepreneurship to specific disciplines within Mechanical Engineering. Interestingly, some alumni also pursued programming courses and tools such as Six Sigma and Data Science.

One aspect of the survey was to inquire about the strengths and weaknesses of the Mechanical Engineering program. As strengths, the alumni mentioned the high quality and structure of the laboratories, numerous opportunities for scholarships and exchange programs, and a wide range of internships in various fields. They also highlighted the level of engagement, the expertise and qualifications of the professors, the balanced and challenging curriculum, and the ample number of elective courses as strengths of the program. As for weaknesses, the alumni pointed out the outdated curriculum with limited focus on practical knowledge, the lack of social sciences and programming classes, the absence of management and entrepreneurship courses, and the need for a career planning subject.

It is worth noting that one of the survey questions asked the alumni about the possibility of mini-courses on topics demanded by Society 5.0. Out of the 17 participants who were alumni of the Mechanical Engineering program, 94.1% affirmed the relevance of these mini-courses, and 64.7% expressed interest in participating. The suggested topics for the mini-courses were diverse, with multiple mentions of subjects such as Artificial Intelligence, IoT, 5G network, simulation, and Engineering in the Industry 4.0, among others.

The student survey was conducted in two versions, involving Mechanical Engineering students who had completed more than 50% of their program. The first version received responses from 65 students, including 10 (15.4%) female students. The distribution of students according to the percentage of completion of their program is shown in Figure 2. The second version received responses from 50 students, with a similar distribution by the percentage of program completion, as depicted in the same Figure.

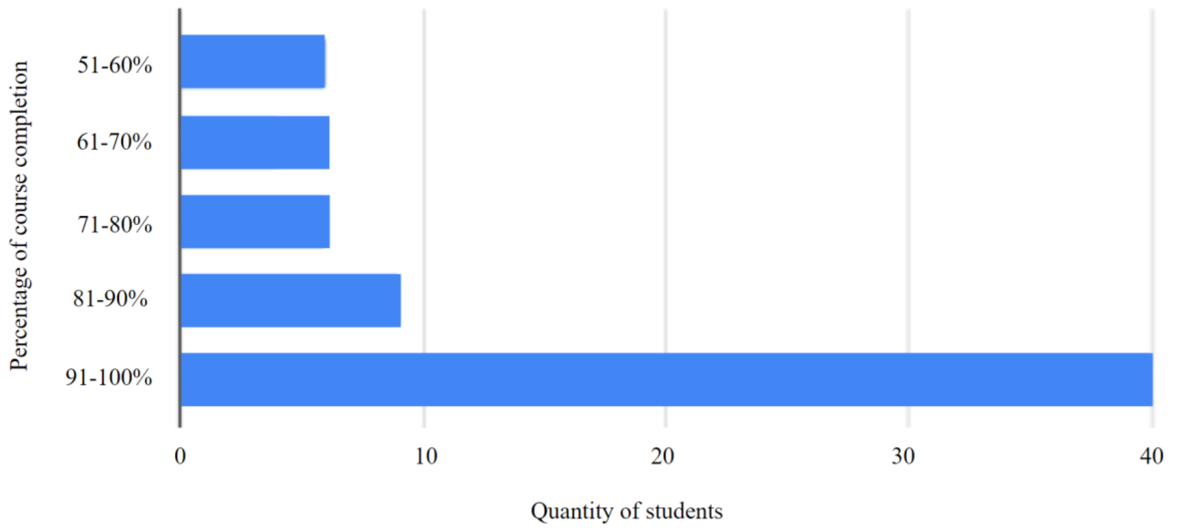


Figure 2. Distribution of student respondents by degree of course completion.

Regarding the students' perception, the majority indicated that the curriculum of the course is preparing them for an academic career. As for the aspects defined in the graduate profile, students showed satisfaction with the technical aspects (89.2%), but greater dissatisfaction with cultural and social aspects (9.2%). Additionally, the research revealed that the majority of students engaged in extracurricular activities throughout their undergraduate studies. Figure 3 provides a better illustration of student involvement in extracurricular activities.

The approach regarding the use of laboratories showed that students believe that the EMC does not fully utilize the available laboratories in the context of the offered course subjects, and students prefer practical disciplines over theoretical ones. Furthermore, interest in optional entrepreneurship disciplines was also addressed. Finally, students reported identifying extension activities throughout the course.

Thus, the research presented different perceptions of students regarding the curriculum and competencies mentioned in the National Curriculum Guidelines. Based on the information obtained from the questionnaires, the most discordant aspects among Mechanical Engineering students were: (1) Use of digital technologies in the course: students considered that the course does not make good use of digital technologies, obtaining a low final score; (2) Updating of topics presented in the course in relation to societal demands: students expressed dissatisfaction with the updating of course contents concerning current societal demands; and (3) Conducting of the Final Course Project (FCP): although most students have not yet taken this discipline, there was a general perception of partial disagreement with the way the FCP is conducted.

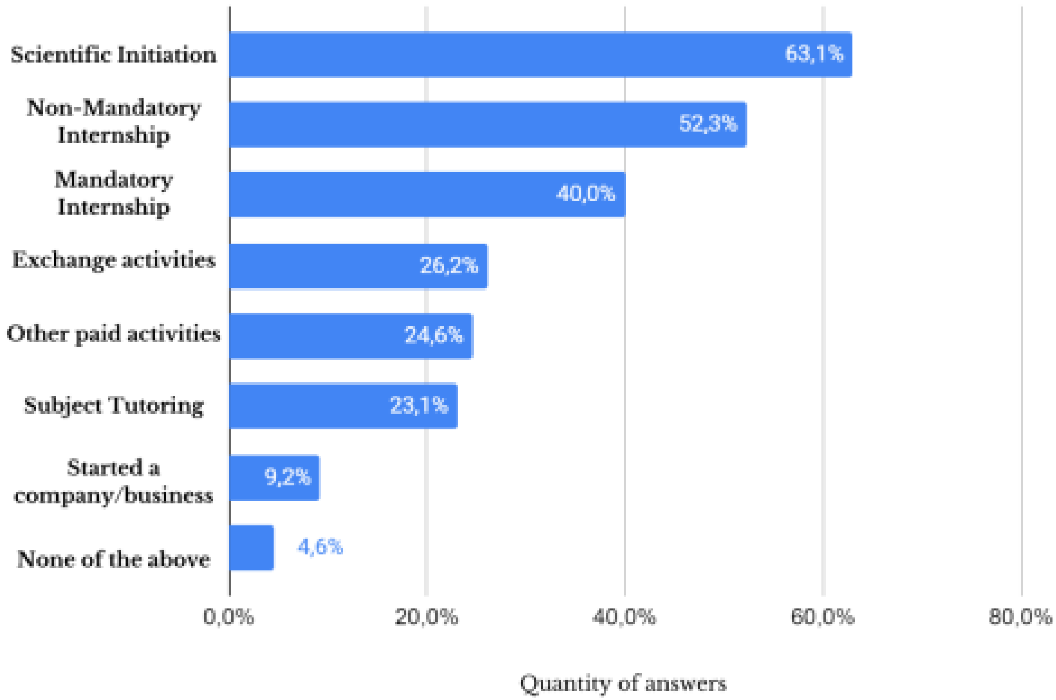


Figure 3. Out-of-class experiences conducted by each student.

On the other hand, the most agreed-upon aspects among students were: (1) Academic career as preparation: the majority of students considered that the curriculum of the course is preparing them for an academic career; (2) Technical aspects of the course: students positively evaluated the attention given to technical aspects during the course; and (3) Importance of engaging in extracurricular activities: the majority of students participated in extracurricular activities throughout their undergraduate studies, with more than two activities.

## 5. DISCUSSION

Based on the results collected from the questionnaires, there is a glaring need for the inclusion of Industry 4.0 and Society 5.0 topics in the Mechanical Engineering curriculum. The UFSC's EMC possesses a wide variety of laboratories in different areas of expertise, particularly excelling in thermal areas, which allows students to experience various activities in scientific initiation, a strong point consistently mentioned by former department alumni, as previously cited. Among the other strengths highlighted were the numerous exchange opportunities, extensive internship offerings, contact with international companies/universities, and the development of personal skills and autonomy. However, in order to reach the global state-of-the-art in engineering education (Graham, 2018), it is necessary not only to educate competent professionals but also to address the problems faced by the productive sector and the challenges encountered in society.

The Engineering Education at UFSC is nationally and internationally recognized, primarily due to the institution's history of producing highly skilled engineers for the market.

While highlighting the strengths of the EMC/UFSC, it is also important to discuss the weaknesses in order to identify existing opportunities within this environment. According to the MIT report (Graham, 2018), one of the main barriers to Engineering Education is the specialized departmental structure present in many engineering schools worldwide, including UFSC. As a result, each engineering department competes for scarce resources both among themselves and within their different laboratories and projects, while they could join forces for collaborative projects that are more robust and relevant to the productive sector and society. Based on the conducted research, it was observed that topics such as social and environmental responsibility, management, and entrepreneurship are not addressed throughout the engineering course. Another identified factor was the preference of professors for individual assignments. This hinders the development of skills such as teamwork, collaboration, and task delegation, which are key points for the engineer of the future. It was found that students feel a lack of practical applicability in what is taught by the professors.

The modernization of Engineering Education in Brazil can be achieved through the proposition of new courses or the updating of existing ones, but aligned with the demands of the Digital Transformation and even with Industry 4.0 and 5.0. According to Godwin and Potvin (2017), engineering education reform includes strengthening the engineering mathematics foundation along with increasing the focus on project work and laboratory experiences, emphasizing communication and social skills. It is necessary to integrate the social sciences, continuous curriculum development and encourage students in lifelong learning. The EMC/UFSC already offers optional social science courses for engineering students. These courses are taught by faculty members from social science areas, providing students with a worldview beyond the scope brought by traditional engineering education. According to Freire Junior et al. (in Oliveira et al., 2013), contemporary educational processes should aim to develop professionals who are always ready to learn, seeking and managing information, deriving the necessary knowledge to interact in their environment and propose solutions to new challenges. In this context, the CDIO Initiative (Crawley *et al.*, 2007) can be explored. CDIO stands for Conceive, Design, Implement, and Operate.

This methodology has been successfully applied in various engineering courses, both nationally and internationally, and could prove useful for Mechanical Engineering at UFSC. In a reality where industrial processes have transformed with the evolution of big data systems, the Internet of Things, artificial intelligence, and machine learning, the engineer's profile must develop new competencies to succeed in the job market. In this regard, the use of CDIO, which employs active and cooperative methodologies such as project-based learning, flipped classrooms, and blended learning, should be discussed and implemented to enhance the scope and quality of the engineering course. The focus is to empower students in "learning by doing," that is, studying, researching, and building "something," as opposed to traditional teaching methodologies that place much more emphasis on "how to teach" rather than "how to learn" (Oliveira, 2004). It is evident that several subjects in the curriculum are not easily understood by students due to a lack of physical/mechanical insight into real-world situations under study. This lack of competence often creates a disconnect between students and the subjects, compromising their technical and scientific education and, likely, their performance when entering the job market. In the engineering course, the challenge lies in combining active methodologies with laboratory activities and practical experience, highlighting the importance of utilizing resources and technologies that, when combined with quality education, bridge the gap between theory and practice, providing engineering students with practical experience alongside theoretical classes.

## 6. FINAL REMARKS

The data and analysis presented here are not entirely definitive or comprehensive. They specifically pertain to the case of Mechanical Engineering at UFSC. However, it is likely that this scenario is quite relevant in other universities as well. Technological advancements, especially those based on digital foundations, are not synchronized just-in-time with educational advancements due to the natural inertia of the process, especially when dealing with highly regulated and traditional public entities. The fact that things have worked well so far, with high demand and satisfactory employability, does not imply complacency. On the contrary, change should be implemented while the outcomes are still favorable. Therefore, continuous studies and performance evaluations of educational institutions that produce engineering professionals, involvement of all stakeholders, observation of the competition, and especially those considered avant-garde, should occur consistently and with great intensity. This is precisely what the protagonists of the Department of Mechanical and Materials Engineering are determined to accomplish.

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## 8. RESPONSIBILITY NOTICES

The authors are the only responsible for the printed material included in this paper.