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# Evaluating Declared Laboratories in Industrial Engineering with minor in Systems: A Comparative Analysis at Tec de Monterrey

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***Abstract*– This study thoroughly analyzes the potential impact of laboratory practices outlined in the structural curriculum of the Industrial Engineering with minor in Systems Degree at the Tecnologico de Monterrey (Tec de Monterrey), San Luis Potosí campus, Mexico. It examines how these practices affect the outcomes of graduates, who are evaluated through the standardized EGEL test by the CENEVAL evaluation center, which is nationally recognized in Mexico for its educational assessment rigor.**

***The research underscores the critical importance of assessing university programs' vitality and relevance through national and international accrediting bodies. It emphasizes the significance of academic laboratories as essential components in the comprehensive training of Industrial Engineers with minor in Systems, optimally preparing them to tackle the complex challenges of the contemporary workplace.***

***The qualitative and quantitative results and analyses presented in this study offer a valuable contribution to higher education by providing detailed and critical insight into the effectiveness of laboratory practices in student academic training based on the results of EGEL´s test, a survey of business or educational partners and the opinion of eight graduated candidates of Industrial Engineering with minor in Systems at Tec de Monterrey in San Luis Potosí. These findings are pivotal in promoting the updating and continuous improvement of university curricula, ensuring their alignment with the labor market's and society's demands and expectations.***

***Keywords- Industrial Engineering with minor in Systems, curricula Analysis, Standardized Evaluation of Academic Programs, Higher Education, Educational Innovation, Innovation.***

## I. Introduction

The certification bestowed upon an engineering program by the Accreditation Board for Engineering and Technology (ABET) holds paramount importance on a global scale. It guarantees educational excellence, international recognition, professional mobility, requisite qualifications for employment and career progression, and adherence to ethical standards and professional responsibilities within the engineering domain [1]. ABET is the foremost authority in accrediting engineering programs worldwide, owing to its extensive history, rich experience, active engagement with industry stakeholders, rigorous standards, and widespread acknowledgment [2]. Through its meticulous evaluation process and stringent criteria, ABET ensures accredited programs consistently meet the highest benchmarks in engineering education.

Nevertheless, it's crucial to acknowledge that engineering educational programs may also obtain national certifications tailored to specific local requirements and contexts. For instance, in Mexico, the Accreditation Council for Engineering Education, Civil Association (CACEI) evaluates engineering programs by considering aspects pertinent to the Mexican educational framework, governmental regulations, and local industry demands. Despite this, both ABET and CACEI share common ground in their commitment to upholding the fundamental tenets of quality engineering education. Both entities assess curriculum rigor, faculty competence, resource availability, and student outcomes. However, it's worth noting that the evaluation of student outcomes by certifying bodies like CACEI and ABET may differ depending on contextual nuances and the distinct standards set forth by each accreditor.

In Mexico, the National Evaluation Center for Higher Education (CENEVAL in spanish) is pivotal in administering standardized evaluation exams across various educational levels, including higher education [8]. One of the most pertinent assessments conducted by CENEVAL is the General Examination for the Graduation of the Bachelor's Degree (EGEL in spanish). Tailored to evaluate the knowledge and competencies students acquire upon university studies, the EGEL holds particular significance for engineering programs in Mexico. Some educational institutions and engineering programs mandate the EGEL as a prerequisite for obtaining an engineering degree. The examination employs a grading scale of *Outstanding*, *Satisfactory*, and *Not Satisfactory*, aiming to gauge the professional readiness of graduates.

The relationship between CENEVAL's EGEL and accrediting bodies such as CACEI and ABET lies in considering EGEL results as a component of the evaluation process for engineering programs. Accreditation by CACEI or ABET may incorporate students' EGEL performance as an indicator of a program's quality and efficacy in preparing

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graduates for professional practice. Furthermore, the EGEL assesses various facets of the specific engineering discipline pursued by the student, encompassing technical proficiency, analytical insight, communication abilities, and ethical awareness.

While the content and structure of the exam may vary depending on the engineering specialization and educational objectives, it typically covers areas such as applied mathematics, physics, materials science, thermodynamics, mechanics, and electronics. It evaluates students' capacity to analyze intricate problems, apply engineering principles to devise practical solutions and make sound decisions within engineering contexts. The ability to make informed decisions in practical settings is closely tied to the specific disciplines students address, mainly through the laboratory components embedded in a program's curriculum.

Laboratories and hands-on coursework facilitate the application of theoretical concepts acquired in the classroom to real-world scenarios, fostering a deeper and more practical comprehension of engineering principles. Engaging in laboratory experiments, projects, and practical activities enables students to cultivate indispensable practical and technical skills for tackling genuine engineering challenges. Substantial laboratory exposure can enhance students' performance on the EGEL by showcasing their adeptness in mastering concepts and their adeptness in applying them to practical scenarios.

Moreover, laboratories and practical coursework are pivotal in honing students' analytical and problem-solving proficiencies. Confronted with practical dilemmas and projects, students must employ analytical reasoning to comprehend and address complex issues, identify pertinent variables, gather and analyze data, and make well-founded decisions to resolve technical difficulties. Laboratory experiences foster critical thinking and problem-solving within a controlled, applied setting, equipping students with the skills necessary to tackle the questions and predicaments they may encounter on the EGEL. Proficiency gained through rigorous laboratory training can significantly bolster performance on the EGEL, demonstrating students' adeptness in applying analytical and problem-solving competencies in practical contexts.

Amid rapid technological advancements, including the advent of Industry 4.0 and 5.0, as well as generative artificial intelligence, engineering education and industrial practices are undergoing profound transformations. Despite these digital strides, practical laboratories retain their significance and relevance within this evolving landscape for several compelling reasons:

1. *Real-world practical experience:* Laboratories offer invaluable opportunities for students to grasp complex concepts, cultivate technical competencies, and bolster their confidence in applying knowledge within a controlled setting.

2. *Experiential learning:* Students can internalize and apply learned concepts with greater depth and meaning through hands-on experimentation and problem-solving in laboratory settings.

3. *Development of technical and analytical skills:* Laboratories foster the honing of critical competencies such as teamwork, problem-solving, decision-making, and technical communication, which are crucial for success in engineering fields.

4. *Industry readiness:* Despite technological strides, many engineering disciplines necessitate direct interaction with physical equipment and systems in authentic industrial settings, underscoring the enduring relevance of practical laboratory experience.

5. *Adaptation to emerging technology:* Laboratories are adaptable environments capable of integrating and incorporating emerging technologies such as virtual reality, 3D printing, the Internet of Things (IoT), and artificial intelligence, ensuring alignment with evolving industry demands.

In essence, laboratories retain their relevance by evolving alongside industry demands and technological advancements, making them indispensable components of contemporary engineering education rather than relics of the past.

This report presents a longitudinal analysis of data extracted from EGEL evaluations spanning from 2016 to 2023, focusing on a cohort of students who graduated with a degree in Industrial Engineering with minor in Systems (IIS) from Tec de Monterrey, San Luis Potosí, Mexico. In 2019, Tec de Monterrey, hereafter referred to as Tec de Monterrey, implemented its new educational paradigm, the Tec21 Model. The omission of laboratory courses or approved academic laboratory practices within the domain of manufacturing and supply chain in Tec's Tec21 educational framework, particularly within the IIS program, and its adverse impact on graduates' EGEL scores from CENEVAL constitute the primary subject of inquiry in this study.

Firstly, we acknowledge that the reduction or elimination of laboratories in the Tec21 Model may indicate shifts in pedagogical approaches, possibly prioritizing alternative methods such as active learning, collaborative teamwork, and case-based projects—a paradigm shift worth exploring. Understanding the pedagogical rationale underpinning this decision is imperative.

Secondly, the curtailment of laboratory exposure may impede the preparedness of IIS students to tackle practical challenges within the industrial realm. Thirdly, this truncation could potentially impinge upon students' performance in standardized assessments like CENEVAL's EGEL. Since laboratories have historically constituted a pivotal component of the curriculum, contributing to students' readiness for such evaluations, their removal could undermine graduates' performance on these crucial tests. This encapsulates the core hypothesis of our research.

Armed with data to validate or refute this hypothesis, the authors emphasize the necessity of conducting a comprehensive evaluation of the Tec21 educational model, inclusive of the eradication of laboratories within the IIS program, to ascertain

its impact on student learning, industrial preparedness, and performance in standardized assessments such as CENEVAL's EGEL.

To achieve this aim, this report offers a descriptive historical analysis spanning from 2016, aiming to furnish a holistic overview of IIS program students' performance in the test above while considering the minimal or non-existent utilization of laboratories within the domains of manufacturing, operating systems, supply chain management, strategic and project management, and work-study, as classified by CENEVAL [9], as delineated in Table 1. The analytical procedures outlined herein are executed using Python, leveraging prevalent programming tools within the data science domain.

In a complementary way, this study presents the findings derived from analyzing a focus group of key industry partners who have collaborated closely with students of different academic levels in the IIS career at Tec de Monterrey. This discussion group analyzes and evaluates the competencies, both specific to the area and those of a transversal nature, that IIS students possess to face the challenges presented to them in real industry environments. Furthermore, in reciprocity to the contributions obtained in the focus group, the results of an in-depth semi-structured interview conducted with eight recent graduates of the IIS program at the Tec de Monterrey, San Luis Potosí campus are included, although not exhaustive. This interview explores the experiences of graduates in facing industrial challenges, as well as the development of their disciplinary and transversal skills during their professional training.

TABLE I
CENEVAL STUDY AREAS OF THE INDUSTRIAL ENGINEERING PROGRAM RELATED TO DECLARED LABORATORIES.

| Study Area | Study Area Related with Laboratories Courses |
|---|---|
| Manufacturing And Service Operating Systems | YES |
| Supply Chain Management | YES |
| Strategic and Project Management | NO |
| Work Study | NO |

## II. APPROACH

The assessment and accreditation of the Industrial Engineering with minor in Systems (IIS) program at Tec de Monterrey in San Luis Potosí by two esteemed institutions exemplify the university's steadfast commitment to educational excellence. Accreditation from both the Accreditation Board for Engineering and Technology (ABET) on an international scale and the Council of Accreditation for Engineering Education, Civil Association (CACEI) nationally underscore the program's rigor and relevance, positioning it as a standard-bearer in the cultivation of highly skilled and proficient engineers.

ABET, established in 1932 in the United States, enjoys global recognition for its stringent accreditation procedures. These procedures assess program quality in natural sciences, computer science, engineering, and engineering technology across associate, bachelor's, and master's levels. With the involvement of 35 member societies in setting standards, ABET ensures that accredited programs adhere to rigorous criteria, equipping graduates to confront the challenges of an increasingly globalized workforce.

Conversely, CACEI is a pivotal national accrediting body tasked with evaluating and enhancing the quality of engineering programs in Mexico. By focusing on standards and requisites tailored to the national context, CACEI ensures that accredited programs align with the needs of local industries and labor markets, thereby fostering the country's economic and technological advancement.

ABET's reevaluation and subsequent accreditation of the IIS program in 2021 marked a significant milestone for Tec de Monterrey in San Luis Potosí. This exhaustive process scrutinized various facets of the program, including curriculum, teaching quality, resources, and infrastructure. The favorable outcome of this evaluation reaffirmed the program's excellence while identifying areas for enhancement, thus fortifying the preparation of future Industrial Engineers with minor in Systems.

Accreditation has profound reverberations on the program and its graduates. Graduates of the IIS program at Tec de Monterrey in San Luis Potosí possess robust and contemporary academic training, affording them domestic and international employment opportunities. Accreditation assures employers of the caliber and relevance of the education received by these professionals, translating into heightened employability and professional esteem for program alumni.

Looking to the future, Tec de Monterrey in San Luis Potosí is committed to maintaining and continually improving the quality of the IIS program. This includes constantly updating the curriculum to reflect technological advances and market demands, as well as investing in resources and teacher training to ensure an excellent educational experience. In addition, the institution will continue to collaborate closely with ABET and CACEI to ensure compliance with quality standards and promote continuous improvement of the program.

In summary, the evaluation and accreditation of the IIS program at Tec de Monterrey in San Luis Potosí by ABET and CACEI not only confirms the quality and relevance of the program but also promotes its positioning at a national and international level as a reference in the training of highly trained and competent engineers. The evaluation criteria for ABET and CACEI used for the Industrial Engineering program is showed at Table 2.

TABLE 2
Evaluation Criteria Considered by the International Accreditation Body ABET and the National Accreditation Entity CACEI for the Industrial Engineering Program.

| ACCREDITATION CRITERIA FOR EVALUATION | |
|---|---|
| **ABET [3] International Entity** | **CACEI [6] Nacional Entity** |
| Criterion 1. Students | Criterion 1. Faculty |
| Criterion 2. Program Educational Objectives | Criterion 2. Students |
| Criterion 3. Student Outcomes | Criterion 3. Curriculum |
| Criterion 4. Continuous Improvement | Criterion 4. Assessment and Continuous Improvement |
| Criterion 5. Curriculum | Criterion 5. Facilities and Equipment |
| Criterion 6. Faculty | Criterion 6. Institutional Support |
| Criterion 7. Facilities | |
| Criterion 8. Institutional Support | |

Incorporating modern tools and laboratories within the IIS program is pivotal in fostering students' comprehensive development, both domestically and globally. At an international level, integrating virtual and physical laboratories has emerged as a cornerstone in cultivating proficient and contemporary engineers. These resources complement theoretical instruction, offering students invaluable practical experiences and equipping them with technical competencies for navigating real-world challenges.

On a national scale, the continual evaluation of the IIS program by esteemed institutions like CACEI is paramount in upholding its quality and relevance. Established in 1994, CACEI occupies a prominent position within Mexico's engineering education landscape, continually elevating educational benchmarks and championing academic distinction.

As a signatory member of the Washington Accord (WA), a pivotal initiative within the International Engineering Alliance (IEA), CACEI underscores its dedication to fostering quality and continuous enhancement in engineering education. Moreover, its active involvement in the Iberoamerican Network for Quality Assurance in Higher Education (RIACES) and adherence to the Lima Agreement underscore its commitment to upholding best practices and quality benchmarks across accredited educational programs throughout Iberoamerica.

The symbiotic partnership between the IIS program at Tec de Monterrey in San Luis Potosí and CACEI ensures adherence to stringent national and international quality standards, fostering a culture of perpetual improvement and academic distinction. The program endeavors to dynamically adapt to evolving labor market demands through meticulous assessment processes and close collaboration with industry stakeholders, ensuring graduates are adeptly equipped to tackle real-world challenges.

This collaboration with CACEI ensures conformity with exacting quality standards and fosters a culture of perpetual improvement and academic distinction, benefiting students, the institution, and society at large.

The Accreditation Council for Engineering Education, Civil Association (CACEI) mandates that the industrial engineering curriculum encompass specific industrial engineering and fundamental sciences subjects. This holistic approach aims to give students the knowledge and skills to conceive, develop, implement, and refine integrated systems spanning people, materials, information, infrastructure, equipment, and energy [7].

A comparative table (see Table 3) has been included to facilitate a clearer understanding of the alignment between evaluation criteria. This visual aid enables a precise assessment of the unity and disparities in evaluation standards set forth by both institutions. Furthermore, it elucidates how the evaluation criteria of the IIS program at Tec de Monterrey in San Luis Potosí align with the standards delineated by ABET on the international stage and CACEI on the national front.

TABLA 3
This Table Delineates The Evaluation Criteria For Accreditation Institutions, Drawing A Comparison Between The International Body ABET And The National Entity CACEI.

| Criterion | International Evaluator (ABET) | National Evaluator (CACEI) |
|---|---|---|
| 1. Students | Included | Included |
| 2. Program Educational Objectives | Included | Inside Criterion 5 |
| 3. Student Outcomes | Included | Inside Criterion 5 |
| 4. Continuous Improvement | Included | Included |
| 5. Curriculum | Included | Included |
| 6. Faculty | Included | Included |
| 7. Facilities | Included | Included |
| 8. Institutional Support | Included | Included |

The second institution, the National Evaluation Center for Higher Education, A.C. (CENEVAL), has been offering evaluation services to a spectrum of entities since 1994, including higher education institutions, corporations, educational authorities, professional organizations, and public and private entities [8].

The General Examination for Bachelor's Degree Graduation (EGEL) is a nationally recognized evaluation instrument to assess graduates' performance and mastery of evaluated content [8]. The EGEL Plus industrial engineering assessment comprises a disciplinary section segmented into four distinct disciplinary areas:

*Work Study:* Encompasses methodologies for design, analysis, ergonomics, engineering methods, and work measurement. It also incorporates relevant knowledge to enhance team coordination, task optimization, and tool alignment with individual needs and capabilities, ensuring safety and minimizing occupational risks and environmental impact.

*Supply Chain Management:* Oversees the main components of the supply chain, including procurement, customer service, logistics, product generation, and the market's distribution network. Embracing a systemic approach, it utilizes

data analysis, tools, and optimization methodologies to efficiently manage the flow of products, services, and information within the value chain.

*Investment, Strategic, and Operational Projects*: This area encompasses market, technical, and financial studies to evaluate the viability of operational projects aligned with organizational strategic objectives, employing project management tools for decision-making.

*Manufacturing and Service Operations Systems:* Introduces concepts and methodologies for managing operations or integrated manufacturing systems using optimization models, data science, and analytics. It also incorporates quality tools and standards to effectively govern production and service operating systems, thereby generating value and conferring competitive advantage [9].

Aligning with the criteria of accreditation institutions, both national and international, and CACEI evaluators, it is opportune to elucidate the career profile at Tec de Monterrey. The initial phase involves delineating the profile of graduates from the Industrial Engineering program with a specialization in Systems at Tec de Monterrey. The primary objective is to nurture professionals adept at resolving complex problems across various organizational contexts and innovating, optimizing, and ensuring the sustainability of processes and systems. These individuals are characterized by their capacity to spearhead transformative initiatives in a globalized and dynamic milieu, seamlessly integrating methodological tools to bolster productivity and competitiveness. This entails adept application of project management, mathematical modeling, analytical tools, statistical methods, and information technologies [10].

Currently, two program models are under scrutiny to evaluate their efficacy: students following the 2011 curriculum and those enrolled in the Tec21 or 2019 curriculum. Through a comprehensive analysis spanning several years, courses can be categorized by study area, as illustrated in Figure 1.

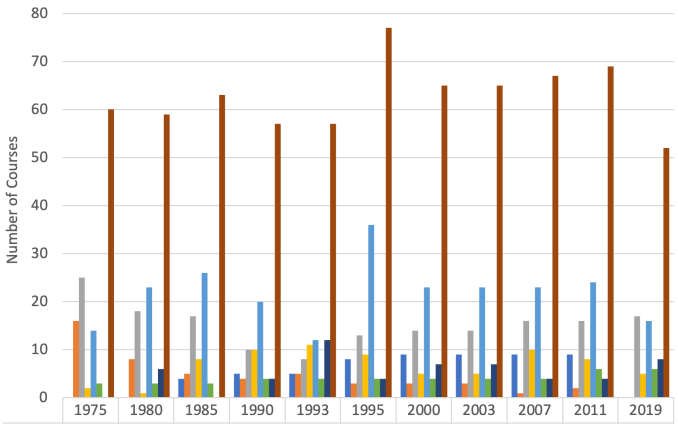


Fig. 1 Categories of courses in the Industrial Engineering with minor in Systems at Tec de Monterrey by study plan from 1975 to 2019. The color code consists of: blue for preparatory courses, orange for general education, gray for basic sciences, yellow for humanities and entrepreneurship, light blue for industrial engineering, green for statistics, dark blue for selective courses and brown for all courses.

Since the 1980 curriculum, most courses have centered around industrial engineering domains, with a discernible uptick in the significance of statistics over time. Nevertheless, introductory science courses exhibit a sustained and stagnant trajectory.

In particular, the conventional academic laboratory courses from the 1975 curriculum have remained steadfast and endured up to the 2011 curriculum. To delve deeper into this phenomenon, these laboratories have been meticulously classified by CENEVAL criteria, furnishing the insights delineated in Figure 2 for further analysis.

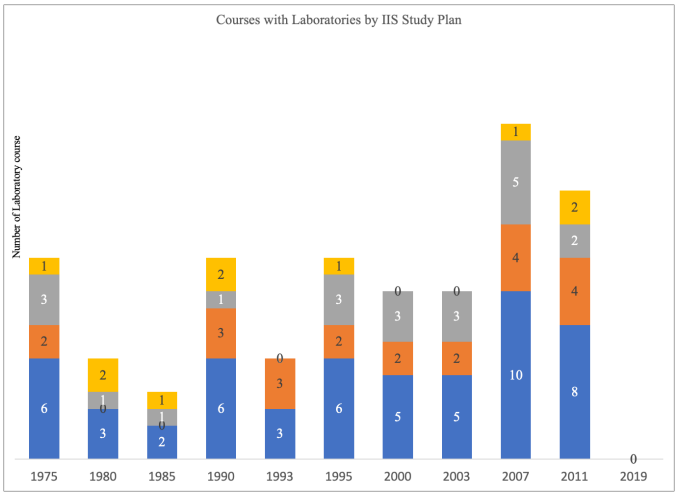


Fig. 2 Declared laboratories of the Industrial Engineering with minor in Systems by study plan from 1975 to 2019. The color code consists of yellow for laboratories with supply chain area, gray for manufacturing and operating systems laboratories, orange for basic science laboratories and blue for total courses with laboratories.

Within the integrated exit exam assessed by CENEVAL across four key areas, a discernible concentration of laboratory or consolidated courses emerges prominently in two vital domains: supply chain management and operations and manufacturing systems. An in-depth analysis of these laboratories or designated academic practices is conducted to discern their impact on graduates, with the CENEVAL exam serving as a benchmark.

A palpable distinction between the 2011 and 2019 curricula is evident across most facets of Tec de Monterrey's IIS degree. The revised curriculum addresses intricate challenges within diverse organizational contexts, prioritizing process and system enhancement, optimization, and innovation to ensure sustainability. This objective is realized through project management, mathematical models, analytical tools, statistical methods, and information technologies. While the emphasis on manufacturing undergoes a reduction in the new curriculum, this analysis is visually articulated in the ensuing graph. It juxtaposes Tec de Monterrey's mission across curriculum iterations and illustrates the correlation of student outcomes for each curriculum with the CACEI evaluation criteria, as depicted in Figure 3.

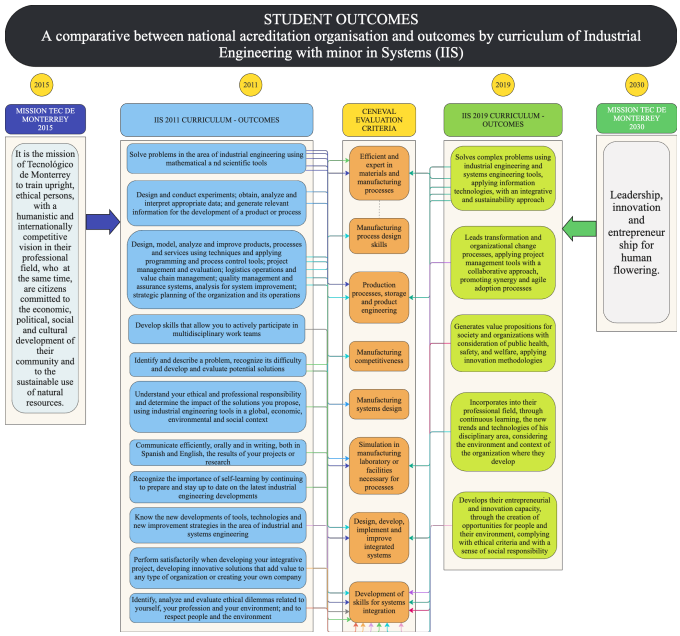


Fig. 3 Comparison between the evaluation criteria of the national accreditor CACEI and the graduation competencies of the 2011 and 2019 curriculum of the Industrial Engineering with minor in Systems degree at the Tec de Monterrey.

This visualization holds significance as it highlights a noteworthy contrast between the 2019 curriculum and its predecessor, particularly in the manufacturing domain, where laboratory simulation receives less emphasis than the 2011 curriculum. This subtle discrepancy potentially contributes to a decline in the evaluation outcomes for supply chain management and operational and manufacturing systems within the CACEI assessment.

Considering this analysis, coupled with the official data from the CENEVAL exam results, it is conceivable to posit that the absence of laboratory courses, whether utilizing real or virtual tools, as declared in a study plan, may correlate with the performance of students in the IIS program under the evaluation criteria stipulated by CENEVAL.

## III. Methodology And Results

We opted to conduct our statistical analysis in two phases. Initially, we undertook a historical, descriptive examination dating back to 2016 to gain insights into the performance trends of Industrial Engineering with minor in Systems (IIS) degree students at Tec de Monterrey's San Luis Potosí campus.

Subsequently, we embarked on a comprehensive study of scores obtained at the national level across all campuses in Mexico. This approach was necessitated by limited access to information; while individual scores were accessible locally, this was not the case nationally, with only statistical summaries available by campus.

The analyses delineated below were executed using Python, leveraging standard data science libraries.

According to the CENEVAL criteria, understanding how this instrument presents information is crucial for a comprehensive visualization of the analyses conducted:

The Ceneval Index ranges from 700 (lowest score) to 1,300 points (highest score).

It serves as a scale for classifying students into performance levels: Not satisfactory, Satisfactory, or Outstanding, based on their results by area, section (Disciplinary and Transversal), and overall.

Irrespective of the section or area, a score:

- Between 700 and 999 corresponds to a Not-satisfactory performance level.
- Between 1,000 and 1,149 indicates a Satisfactory performance level.
- Greater than or equal to 1,150 corresponds to an Outstanding level.

Commencing our descriptive analysis, we present the historical score trends of locally-based IIS students at Tec de Monterrey's San Luis Potosí campus since 2016. In Figure 4, box plots depict these scores, categorized by area and grouped by year.

Our primary statistical analysis reveals an average score of 1080.9 points, falling within the "Satisfactory" category as per CENEVAL standards. However, the data exhibit significant variability, with standard deviations ranging between 82.6 and 95.8 points across different areas. Notably, the presence of atypical values, evident in Figure 4, prompts discussion on the rising (or declining) trend in the proportion of students falling into the most extreme categories, namely "Not satisfactory" or "Outstanding."

On a national scale, when considering the scores of IIS students across all Tec de Monterrey campuses in Mexico, our analysis focuses on the proportion of students in each category in 2016. A marked decrease in the proportion of students qualifying for the outstanding category is noteworthy, juxtaposed with a corresponding increase in those falling under the "Not-satisfactory" category.

Amidst this uncertainty, our analysis indicates a significant decrease, approximately seven percentage points, in area 2, related to Supply Chain Management topics. Conversely, area 4, related to Manufacturing and Service Operations Systems topics, exhibits a downward trend, experiencing a reduction of 4 percentage points in recent years, as depicted in Figure 4.

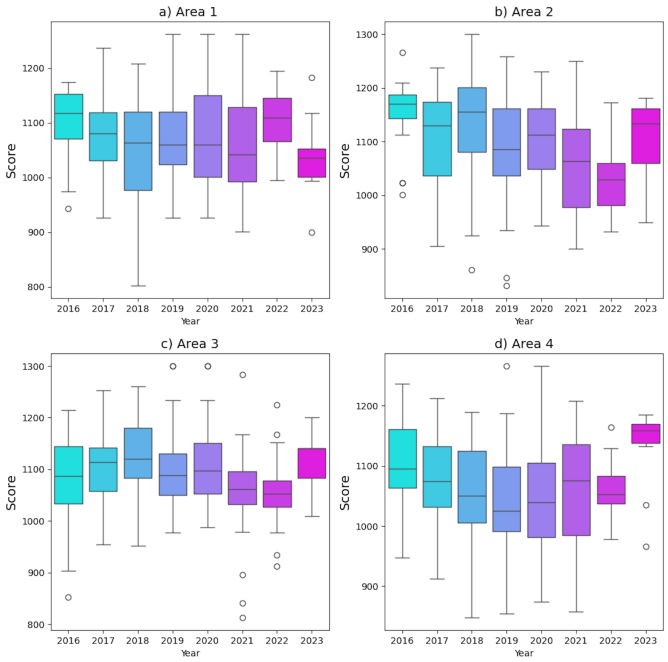


Fig. 4 Box plots for scores obtained since 2016 for students at Tec de Monterrey in San Luis Potosí. Area 1: Work study, area 2: Supply Chain Management, area 3: Investment, Strategic and Operational Projects and area 4: Manufacturing and Service Operations Systems.

In conclusion, it is worth emphasizing the notable difference observed, which aligns with the apparent decline in laboratory practices, as noted earlier. The correlation between this observation and the predominantly affected areas leads us to infer that the impact stems from the modifications made to the 2019 curriculum.

*Focus group.*

The role of interaction between students and future employers (training partners under the Monterrey Tec model) is crucial in the study we are carrying out. With the aim of knowing the perception that business or educational partners have in the training of both transversal and disciplinary competencies, we focused on a group of training partners to whom a survey was applied on the ten competencies that are currently being trained. The responses, on a Likert scale, range from 1 (not relevant) to 5 (very relevant) and the results of this interview can be seen in Figure 5.

The disciplinary competencies range from A to F and these focus on the skills that directly impact the training of students as Industrial Engineers with minor in Systems. The competencies labeled G to J correspond to the disciplinary ones, that is, those that impact both training as an engineer, as well as in various fields such as ethics, communication and teamwork. It is noteworthy that the perception of the business or educational partners in this aspect is positive, which is reflected in the high percentage of responses 4 and 5.

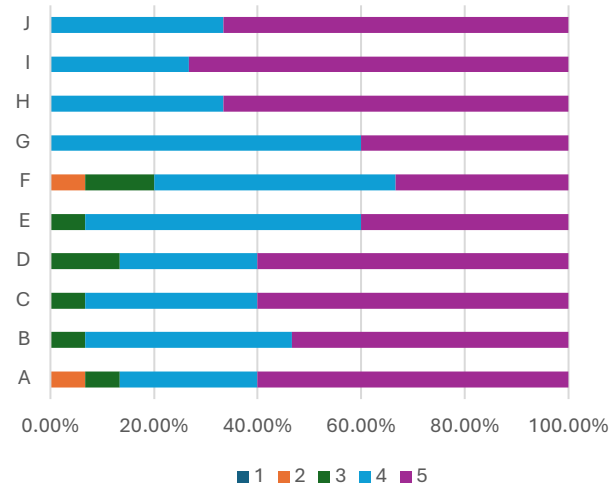


Fig. 5 Results of the survey of business or educational partners. Disciplinary competencies A-F, transversal competencies G-J. Scale for responses 1 (not very relevant)-5 (very relevant).

*In-depth semi-structured interview.*

The role of the Industrial Engineer with minor in Systems (IIS) in the contemporary business environment is increasingly crucial, given the accelerated pace of technology and globalization. The following interview explores the perceptions and experiences of recent IIS program graduates regarding current business challenges and the competencies needed to address them.

The semi-structured interview was conducted with eight students of the IIS program, focusing on two main areas: (i) analysis of the IIS program and business context and (ii) competencies of the Industrial Engineer with minor in Systems. The interview is detailed below:

1. *Analysis of the IIS Program and Business Context:*
   a. From your experience as a student about to graduate, what do you think are the main changes or challenges the business context is currently experiencing?
   b. You are considering your experience working with business partners during your training; what areas of the Industrial Engineering with minor in Systems (IIS) program could be improved in the short, medium, and long term to adapt to these challenges?

2. *Competencies of the Industrial Engineer with minor in Systems:*
   a. Based on your experience as an exchange student abroad or on your professional stays, what do you think are the disciplinary skills necessary for an Industrial Engineer with minor in Systems (IIS) to face the current challenges of the business world?

b. In addition to disciplinary competencies, what transversal skills have you found most helpful in your experience as a student abroad or in your professional stays, and how do you think they could be incorporated into a new study plan for IIS?

## IV. Results And Discussion

Based on the preceding information, the hypothesis posited regarding the correlation between courses or standardized laboratory practices centered on supply chain and manufacturing processes and their impact on the outcomes of Industrial Engineering with minor in Systems students (IIS) upon graduation, as per the results of the CENEVAL exam, appears substantiated. Notably, upon comparing the data presented in Figure 4, a decline is evident in the proportion of students achieving an outstanding grade when juxtaposing students from the 2011 curriculum with those from the 2019 curriculum.

A pertinent consideration is that the other two areas assessed by CENEVAL, namely work-study and projects, which are not directly associated with laboratory practices, as evidenced in Figure 2, exhibit a similar trend across the 2011 and 2019 study plans. This suggests that the presence of laboratories as integrated practices within the IIS degree curriculum, based on the presented data, emerges as the influencing factor on graduates' outcomes in the CENEVAL evaluation exam.

However, for a more comprehensive comprehension of this relationship, a detailed analysis considering other potential influencing factors on student outcomes, such as quality of teaching, laboratory infrastructure, academic support, and student motivation, would be beneficial. Subsequent studies could delve into these aspects to garner a more holistic and precise understanding of how laboratory practices and other curricular components impact the performance of IIS students on the CENEVAL assessment exam.

*Focus group results*

As previously mentioned, the interview with business or educational partners reveals the importance of competencies, both disciplinary and transversal, in the future Industrial Engineer with minor in Systems, and this can be seen in that at least 80% of the responses constitute values 4 and 5 for all competencies, however, it is noteworthy that in the transversal category (competences G-J) 100% of the responses consist of values 4 and 5 of the scale. The latter indicates to us that the value that this category has in the future field of work of our students according to the perception of business or educational partners.

In turn, we can observe that for the training partners, the competencies declared in the IIS curriculum are aligned with the needs of the current market and respond to the future needs of employers. With this information we can conclude that conducting focus groups and carrying out a periodic review of the Tec de Monterrey study plans allows us to have updated graduates in their focus discipline, covering the point of continuous improvement that accreditors such as ABET and CACEI evaluate by certify study plans.

*In-depth semi-structured interview results.*

The interview revealed the complexity of today's business environment and the need for comprehensive training that addresses both technical competencies and soft skills. Below, we present the categories that result from the participants' voices regarding the improvement of the IIS program and the preparation of students for business challenges.

*Analysis of the IIS Program and Business Context:*

*Main changes and challenges in the business context:*

Categories:

A. Technological advance and critical thinking.
B. Market competition and international job search.
C. Transition towards industry 4.0.
D. Generational change and digitalization in companies.
E. Regulatory and labor uncertainty.

*Areas for improvement of the IIS program:*

Categories:

A. Strengthening interpersonal skills.
B. Inclusion of emerging technologies and technical skills.
C. Improvement in project management and adaptability.
D. Adaptation of the program to the needs of the labor market.

*Competencies of the Industrial Engineer with minor in Systems:*

*Required disciplinary competencies:*

Categories:

- Knowledge of systems and approach to processes.
- Comprehensive understanding of context and technology.
- Organization and logical thinking skills.
- Systemic vision and informed decision-making based on data.

*Most useful transversal skills:*

Categories:

A. Critical, analytical, and systemic thinking.
B. Effective communication and self-confidence.
C. Negotiation skills and adaptability.
D. Commitment to long-term projects.

As you can see, it is essential to continually adapt the IIS program to stay relevant in an ever-evolving business environment. The need to develop a balanced combination of technical competencies and transversal skills is emphasized to prepare future Industrial Engineers with minor in Systems for the challenges of the contemporary business world. This implies that the effective use of laboratories in IIS training complements and reinforces the technical competencies and soft skills necessary to face modern business challenges, as identified in the quantitative study. Strategically integrating labs into the IIS curriculum can significantly improve students' preparation for the world of work and contribute to success in business.

## V. Conclusions, Assessments And Limitations

This study serves as an initial step towards discussing enhancements to the Industrial Engineering with minor in Systems (IIS) curriculum at Tec de Monterrey for 2026 plan. The insights gleaned from the implementation of laboratory practices furnish substantial evidence to affirm their beneficial impact on students. Although the IIS program at Tec de Monterrey has shifted its focus away from the manufacturing domain, the opportunity for external evaluation affords us a critical and objective assessment of our graduates, thereby catalyzing continuous self-improvement. The data and analysis presented provide foundational elements advocating for the inclusion of laboratory practices that enrich student learning experiences.

The process of external assessment validates the quality of our training and offers invaluable guidance to continuously adapt and enhance our academic programs. External validation ensures that the IIS curriculum remains pertinent, updated, and capable of meeting the evolving needs of the contemporary world.

However, it is essential to acknowledge certain limitations within this study. For instance, while the CENEVAL test data provides an external evaluation of graduates, it lacks insights into the evolution of students and the effectiveness of laboratory practices within the program. Furthermore, this analysis primarily focuses on a singular aspect of academic preparation, highlighting the necessity to complement these findings with further research that considers additional influential factors, such as employer feedback on graduates' skills.

Regarding the results of the focus group the study carried out highlights the importance that competencies have within the work field and this is in line with the current study plan of the Tec de Monterrey, specifically for the Industrial Engineer with minor in Systems, however, the fact that some business or educational partners consider some of them to be of little relevance, forcing us to look for areas of opportunity such as courses with laboratories.

Including standardized laboratory courses in the IIS curriculum will allow for generating a homogenized experience in students and future graduates, although the Tec21 model poses real challenges and is practical or real-life laboratories, because the challenges are different from campus to campus and the business or educational partners are not the same, the experience for students differs from place to place and from semester to semester. Having laboratories as part of the curriculum will allow students to be part of a common experience that allows them to develop the competencies declared in the IIS curriculum.

The present study, in its qualitative component, suggests that recent graduates of the IIS program clearly perceive the challenges facing the current business context and the skills necessary to address them effectively since they recognize the importance of comprehensive training that addresses both technical competencies and soft skills. Suggestions for improvement in the program and identified competencies provide valuable guidance for adapting IIS training to the constantly evolving labor market demands. The interview with recently graduated students from the IIS program allows us to identify categories of analysis on the relationship between the world of work and the engineer's professional training in an increasingly digitalized world. This could transform the notion and pedagogical use of the laboratories that students take during their studies to redirect them to the impact on the development of their specific competencies that allow them to overcome the challenges of the world of work.

In summary, this paper lays a robust foundation for deliberation and evaluation in refining the IIS curriculum. It underscores the importance of adapting to the changing demands of the professional landscape and establishing external assessment mechanisms to ensure the quality and relevance of the education imparted.

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