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STRATEGIES FOR STRENGTHENING STEM PROGRAMS IN UPPER SECONDARY EDUCATION AS A LINK TO HIGHER EDUCATION

STRATEGIES TO REINFORCE STEM PROGRAMS IN HIGHER SECONDARY EDUCATION AS A LINK TO HIGHER EDUCATION

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Abstract-- The COVID-19 pandemic caused significant disruptions in high school education, particularly affecting the development of mathematical, scientific, and technological skills essential for academic continuity in STEM fields. This study analyzes the impact of an academic enrichment program implemented for high school students in Ciudad Juárez, Chihuahua, to assess their STEM competencies and their influence on career choices. The study, which employed a qualitative approach, included a literature review and a pilot program based on micro-credentials, tutoring in basic sciences, and introductory courses to degree programs at the Technological Institute of Ciudad Juárez. The results show that, of the 182 students served, 57 entered higher education, with a marked preference for engineering programs. Additionally, factors such as self-efficacy, family support, and gender stereotypes were identified as influential in career decisions. It is concluded that strengthening STEM skills contributes to improving the educational transition and career guidance of young people.
Keywords-- STEM, Micro-credentials, Upper Secondary Education.

Abstract-- The COVID-19 pandemic caused significant disruptions in upper secondary education, particularly affecting the development of mathematical, scientific, and technological skills essential for academic progression in STEM fields. This study analyzes the impact of an academic enrichment program implemented with high school students in Ciudad Juárez, Chihuahua, aiming to assess their STEM competencies and the program's influence on career decision-making. Using a qualitative approach, the research combined a literature review with a pilot program based on micro-credentials, tutoring sessions in basic sciences, and introductory courses to engineering-related majors at the Instituto Tecnológico de Ciudad Juárez. Results indicate that out of 182 participants, 57 enrolled in higher education, showing a strong preference for engineering programs. Additionally, factors such as self-efficacy, family support, and gender stereotypes were identified as influential in students' vocational choices. The study concludes that strengthening STEM skills enhances educational transitions and supports more informed and solid professional pathways for young learners. **Keywords**: STEM, High School Education, Microcredentials.

INTRODUCTION

Currently, the teaching-learning process in upper secondary education has undergone transformations marked by tensions and challenges in the classroom. The skills that students were supposed to gradually develop were suddenly interrupted as a result of the COVID-19 pandemic, a disease caused by the SARS-CoV-2 virus. What was initially classified as a public health emergency in late January 2020 ended, within a matter of weeks, leading to a massive and prolonged lockdown, which, as Villamizar and Constanza (2020) point out, not only altered social dynamics but also profoundly disrupted the foundations of education, exposing structural vulnerabilities and new demands for the education of young people.

The prolonged isolation and near-total suspension of physical activity experienced by millions of students led to an increase in sedentary lifestyles, accompanied by intensive—and in many cases excessive—use of technological devices. These conditions, rather than merely representing changes in daily routines, created an environment profoundly different from what students were accustomed to, with visible repercussions on their habits, behaviors, and learning processes.

Based on the above, it is clear that a considerable number of high school students currently face difficulties in acquiring basic mathematical skills, fundamental scientific knowledge, and applied concepts specific to the fields of engineering. These shortcomings directly impact their academic performance and limit their smooth transition to higher levels of education, where such competencies are an essential requirement.

In this context, STEM education has taken on increasing importance as a key approach to preparing young people for an increasingly interconnected and innovation-driven world. The early integration of science, technology, engineering, and mathematics not only strengthens essential cognitive skills but also influences career choice processes. Various studies have shown that educational and career decisions related to STEM fields do not depend solely on academic performance, but also on social, emotional, and contextual factors that shape young people's aspirations. Thus, understanding how these decisions are formed is essential for promoting more inclusive and equitable educational pathways.

Recent research indicates that many students experience stress when choosing a STEM career due to perceptions of difficulty, a lack of self-efficacy, or low motivation linked to previous learning experiences (Pérez, 2025). These dynamics are further influenced by gender inequalities, as women often face stereotypes that undermine their confidence and reduce their retention in science or technology programs, even when they possess skills equal to or superior to those of their male peers. In this

In this regard, it has been found that the presence of female role models and educational environments that foster positive identification with science contribute significantly to narrowing these gaps (Hernández Herrera, 2022).

Teacher training also plays a crucial role in this process. Various studies indicate that limitations in teacher training, particularly regarding active methodologies and the use of educational technologies, reduce the scope of truly interdisciplinary teaching, as required by this approach (Malusay et al., 2025). In contrast, when teachers consolidate their technological, pedagogical, and disciplinary knowledge, they are able to create learning environments that spark curiosity, foster critical thinking, and link content to real-world situations—key factors in guiding students toward scientific fields.

Systematic reviews, meanwhile, show that the integration of teaching strategies such as project-based learning, guided inquiry, and problem-solving significantly increases student motivation and fosters the development of highly valued competencies in STEM fields, including creativity, digital literacy, and analytical skills, as noted in Ortega-Macías et al., 2025, and in Ramos Doria & Núñez, 2024. These methodologies allow young people to explore personal interests, understand practical applications of scientific knowledge, and develop the confidence necessary to consider career paths related to engineering, technology, or the natural sciences.

However, career choices are also influenced by factors outside the classroom. These include emotional and academic support from family and friends, the availability of educational resources, and the expectations that the social environment places on certain professions. A recent review of upper secondary education identifies self-efficacy, family support, and the perception of job opportunities as decisive factors in the choice of STEM careers, as noted in Díaz Avalos et al., 2025. When this support is insufficient or gender biases are present, the likelihood that students will choose these fields decreases, especially among those from socioeconomically disadvantaged backgrounds.

At the same time, an analysis of educational trends reveals that career preferences are closely linked to labor market dynamics and perceptions of employability. In some contexts, the limited visibility of career opportunities or a lack of clarity regarding the benefits of STEM disciplines limits their appeal to young people (Biel-Maeso et al., 2022). Despite this, specialized initiatives designed to provide hands-on experiences—such as labs, tech clubs, or extracurricular programs—have shown encouraging results, particularly when targeted at high school students who are at a crucial stage of career exploration (Pantoja Amaro et al., 2020).

At the same time, strengthening digital skills and computational thinking—even in fields not traditionally considered scientific—expands students' opportunities to pursue careers in technology or engineering. The growing importance of these competencies in academia and the workforce encourages students from various disciplines to develop skills related to logic, programming, and algorithmic problem-solving—elements that can positively influence career orientation toward STEM fields (Aguilera Rueda et al., 2025; Ramírez Martinell & Casillas Alvarado, 2022).

Finally, various documents focused on education policy emphasize that STEM education should be conceived as an inclusive and transformative approach, capable of narrowing access gaps, promoting diversity, and opening up equitable opportunities so that a greater number of students can envision science and technology as viable and meaningful career options (Gras & Alí, 2023). The integration of innovative pedagogical perspectives with adequate emotional support and well-defined institutional strategies enables the creation of educational environments that foster the development of career paths that are more autonomous, informed, and aligned with the demands of the 21st century. Such conditions enhance not only interest in STEM disciplines but also the holistic development of young people in a context that demands creativity, critical thinking, and adaptability.

General Objective

To assess the development of skills and knowledge among high school students in STEM fields through a capacity-building program.

Specific Objectives

Conduct a literature review focused on STEM skills.

Identify the impact of the SARS-CoV-2 pandemic on the development of mathematical and scientific skills.

Implement a pilot academic enrichment program for high school students.

To assess the impact of implementing these strategies on high school students and their transition to higher education.

Rationale

This research examines the impact of STEM skills enhancement strategies on high school students, using Ciudad Juárez, Chihuahua, as a case study. Its overall objective is to analyze the development of students' skills and knowledge in STEM fields following the implementation of an enhancement program designed specifically for this educational level.

The relevance of this research lies in the growing need to recognize the fundamental role that STEM skills play in students' career guidance, particularly in a context where academic and professional decision-making requires a solid scientific foundation. Furthermore, the

research is grounded in the urgency of identifying the effects of the pandemic on learning in mathematics, science, and technology—areas that were particularly vulnerable to the disruption of traditional school dynamics.

- Based on this research, we expect to obtain specific evidence regarding the effectiveness of the STEM enrichment program in developing scientific, technological, and mathematical competencies among high school students. Furthermore, we aim to identify areas for improvement that will enable better future interventions and guide more relevant pedagogical strategies.
- This situation has an impact on various spheres, including social, cultural, environmental, and technological ones, as strengthening STEM skills not only affects academic performance but also young people's ability to analyze their environment, participate in problem-solving, and engage with a society that demands critical thinking and innovation. In this regard, it can be said that promoting these skills constitutes a strategic approach to fostering individual and collective development.
- For this reason, this article will have an impact on the field of education by providing elements that strengthen students' STEM skills, helping to improve their career guidance, recover learning lost due to the pandemic, and foster more solid academic trajectories in scientific and technological fields. Its contribution focuses on offering a well-founded analysis that can guide institutional decisions and teaching practices.

DEVELOPMENT

The research conducted was qualitative in nature, given the literature review and the pilot program implemented to strengthen the academic performance of upper-secondary students, which made it possible to verify adherence to and fulfillment of the research objectives. The pilot research project, titled "Academic Strengthening of Upper Secondary Education Students in Chihuahua," was carried out with the participation of students from institutions such as CBTIS, CECYTECH, CONALEP, and COBACH.

This academic enrichment initiative was structured around micro-credentials based on the STEM approach, which made it possible to assess the level of proficiency that upper-secondary students possess in mathematics, science, technology, and engineering. Its primary purpose was to identify the degree of vocational orientation toward engineering fields at the time of entering higher education. In this regard, the literature review was essential for defining the theoretical framework and, together with the evaluation of the strengthening process, lent greater rigor and credibility to the conclusions reached.

The strategy was based on the recognition that mastery of the basic sciences is a crucial element for academic success at the higher education level, especially in technology and engineering programs. A significant proportion

of high school students faces difficulties in subjects such as mathematics, physics, and chemistry, which can affect their future performance and increase the risk of dropping out.

Aware of this reality, the Ciudad Juárez Institute of Technology (ITCJ) is promoting the "Designing Your Future" initiative, which has a twofold purpose: on the one hand, to provide solid academic support in the basic sciences; and second, to foster early exposure to the participants' fields of interest, so that they can identify their strengths, recognize areas for growth, and make more informed career decisions. This initiative aligns with the ITCJ's institutional mission, which is focused on contributing to the region's academic, scientific, and social development.

The structure of the initiative is based on the following components, designed to ensure comprehensive academic support and relevant career guidance:

- Phase 1: Basic Science Tutoring (8 weeks, 4 hours per Saturday)
  - Mathematics: 6 weeks of tutoring focusing on algebra, trigonometry, analytic geometry, and basic differential calculus.
  - Physics: 1 week of tutoring in kinematics, dynamics, and fundamental concepts of mechanics.
  - Chemistry: 1 week of tutoring on the structure of matter, chemical reactions, and basic applications.
- Phase 2: Introductory course in the field of interest (8 weeks, 4 hours per week)
  - Each student will select an introductory course in their preferred field of study within the ITCJ.
  - The course will include hands-on activities, lab visits, and simple projects related to the chosen discipline.

The goals to be achieved are:

- Provide instruction to high school students for 16 consecutive weeks.
- Ensure that at least 80% of participants strengthen their skills in basic sciences.
- Encourage at least 70% of students to define or solidify their interest in a university degree program at ITCJ.
- Establish an annual outreach plan between ITCJ and the participating high schools.

Therefore, the expected impact is:

- A reduction in academic gaps in basic sciences among students who subsequently enroll at ITCJ.
- A greater number of applicants with a clear sense of purpose and the motivation to continue their professional training.
- Increased enrollment in strategic programs in the region.

- Recognition of ITCJ as an institution that is accessible and committed to the education of young people starting in high school.

DISCUSSION AND ANALYSIS OF RESULTS

During the January–June 2025 semester, a total of 182 high school students were served, of whom 57 were admitted to the ITCJ, representing a conversion rate of 31.32%, as shown in Figure 1. This data is significant, as it indicates that approximately one in three students served decided to continue their academic journey at the institute, reflecting the positive impact of the guidance and support initiatives implemented.

Figure 1. *Students served by the program*.

Source: *Prepared by the author* (2025).

An analysis of enrollment by program shows that the program with the highest enrollment was Mechatronics Engineering (IMCT) with 22 students, accounting for 38.5% of total enrollment. This was followed by Industrial Engineering (II) with 12 students and, to a lesser extent, Computer Systems Engineering (ISC) with 4 students. These three programs account for more than half of the total enrollment, indicating a marked preference for programs related to manufacturing, production, and information technology—areas aligned with the needs of the regional productive sector, as shown in Figure 2.

Figure 2. *Newly enrolled students by program*.

Source: Author's *own work* (2025).

Figure 3 shows the programs with the lowest enrollment figures, ranging from 1 to 3 students per program, with Logistics Engineering (IL) leading the way with 3 students, followed by Business Management Engineering, Electrical Engineering, Electronics Engineering, and other disciplines, each with 2 students. Although these figures are lower, they reflect students' diverse interest in different areas of knowledge, which strengthens the multidisciplinary nature of the ITCJ.

Figure 3. *Educational programs at the ITCJ*.

Source: Author's *own work* (2025).

The outreach project, developed in collaboration with the COBACH, CBTIS, and CECyTECH subsystems, has proven to be an effective strategy for strengthening the connection between the Ciudad Juárez Institute of Technology and high school students. Its implementation made it possible to reach a broad audience and ensure

a considerable percentage of successful admissions, demonstrating the importance of maintaining and expanding academic support and career guidance initiatives. This joint effort contributes not only to the promotion of technology programs but also to better alignment between high school and higher education, in response to the educational and employment needs of the socioeconomic context of Ciudad Juárez.

During the January–June 2025 semester, the project served a total of 182 students from various institutions with active agreements with the ITCJ. The highest participation came from CECyTECH 14, with 92 students served, followed by CBTIS 114 with 22, COBACH 5 with 9, and CBTIS 128 with 4, while 55 students did not report their school of origin. Of the 57 students who ultimately enrolled at the ITCJ, 19 came from CECyTECH 14, 9 from CBTIS 114, 4 from COBACH 5, 3 from CBTIS 128, and 22 did not specify their school of origin, as shown in Fig. 4.

Figure 4. *High schools served.*

Source: Author's *own work* (2025).

Figure 5 shows the results, which indicate that CECyTECH 14 was the subsystem with the greatest reach and impact, accounting for nearly half of the total students served and a significant proportion of those who successfully enrolled in the institute. In contrast, the CBTIS and COBACH campuses showed more limited participation, which calls for strengthening ties with these subsystems through sustained promotional strategies, demonstration workshops, and more personalized guidance activities.

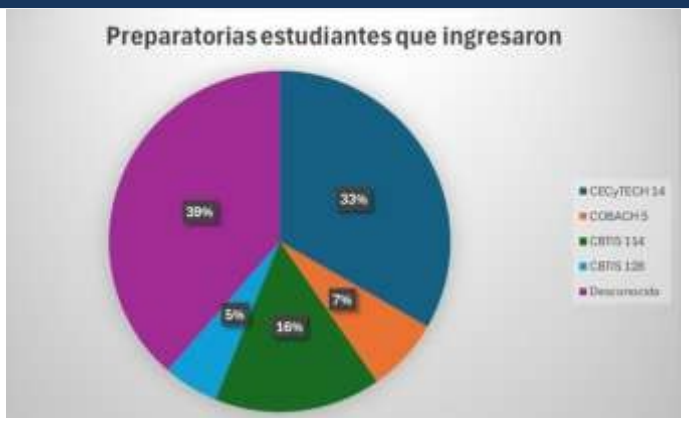

Figure 5. *High schools with students who enrolled at the ITCJ.*

Source: Author's *own work* (2025).

Overall, the results confirm that "ITCJ Designing Your Future" is an initiative with high potential for growth and educational impact. Consolidating this project as a permanent initiative will allow the ITCJ not only to attract better-prepared and vocationally oriented students but also to reaffirm its social commitment to training competent, critical-thinking young people who are committed to the region's scientific and technological development, as shown in Figure 6.

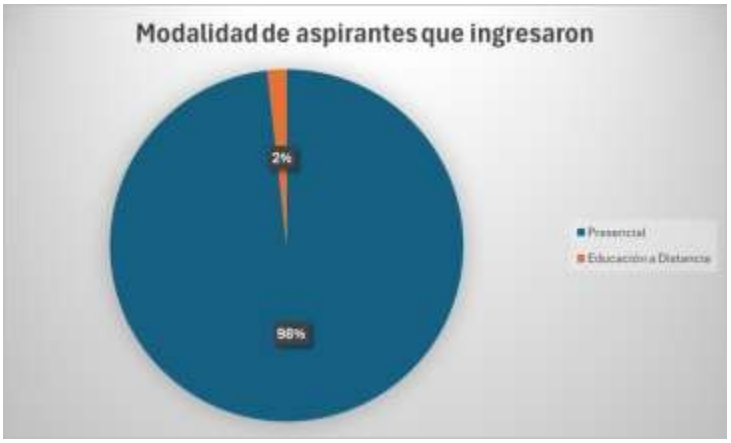

Figure 6. *Types of applicants who enrolled at ITCJ.*

Source: Author's *own work* (2023).

Areas of Opportunity

- Strengthening the promotion of programs with low enrollment: Although most new students are concentrated in Mechatronics Engineering (IMCT) and Industrial Engineering (II), there are programs with only one or two students, such as Public Accounting (CP), Business Systems Engineering (ISEM),

Biochemical Engineering (ICIB), and Mechanical Engineering (IM). *It is necessary to design differentiated promotional strategies to highlight the advantages and job prospects of these less-in-demand programs.*

- Targeted academic support: The high preference for IMCT and II may be linked to the perception that these majors offer a more solid foundation in basic sciences. *It is recommended to strengthen counseling in specific areas of physics and chemistry to spark greater interest in related programs that require these skills.*

- More personalized career guidance: The 31.32% conversion rate shows positive results, but it also reflects that more than two-thirds of the students served did not enroll. *A key opportunity is to implement vocational assessments and personalized counseling to help young people better identify their interests and connect them with ITCJ's academic offerings.*

- Linking with the productive sector to attract students: Many young people choose majors perceived as "secure" in terms of employability. *Programs with lower enrollment can boost their appeal through partnerships with local companies, short-term internships, or demonstration projects that highlight professional opportunities in those fields.*

- Strategies for continuity with high school subsystems: Given that the agreement with COBACH, CBTIS and CECYTECH already exists, it can *be leveraged to implement ongoing mentoring programs, regular visits, and joint projects that maintain constant contact with students, ensuring that the ITCJ remains a factor in their career decision-making process.*

- Strengthening administrative processes: The high number of students without a record of origin reflects the need to *improve data control and monitoring mechanisms, ensuring complete and reliable information for the program's institutional evaluation.*

CONCLUSIONS

According to the study on the topic, "Strengthening STEM Skills and Career Guidance Among High School Students," and considering both the results obtained through the micro-credentials used and the reviewed literature, it can be concluded that the educational consequences of the lockdown significantly affected the development of knowledge in mathematics, science, technology, and engineering. The interruption of in-person academic activities, coupled with increased sedentary behavior and excessive use of electronic devices, created learning gaps that directly impact students' readiness to advance to the next level of education.

Given these findings, it is recognized that a lack of these skills not only hinders academic performance but also influences career decisions, particularly in the fields of engineering and technology. Furthermore, the literature shows that factors such as self-efficacy, family support,

, the presence of female role models in science, and access to meaningful educational experiences are key determinants in young people's consideration of a career path in scientific disciplines. For this reason, it is essential to implement educational strategies in high schools that reinforce essential competencies, as well as to foster educational environments that spark interest, curiosity, and confidence in students.

Similarly, there is a consensus that STEM learning requires structure, freedom to explore, and appropriate conditions that allow students to build knowledge both independently and collaboratively, which is crucial for strengthening their career orientation. Consequently, it is necessary to continue promoting educational initiatives and institutional actions that foster the comprehensive development of young people, bridging gaps and encouraging more equitable and robust participation in the fields of science, technology, engineering, and mathematics.

FUTURE WORK

Based on this research, it is expected that in the near future this area will be strengthened through the implementation of more precise strategies to reinforce STEM skills and provide career guidance to high school students. It will be necessary to expand the evaluation of micro-credentials, explore new teaching methodologies, and monitor the impact of these actions on academic performance and the choice of scientific and technological careers.

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