

International Journal of Human Sciences Research

PROMOTING STEM EDUCATION IN HIGH SCHOOL STUDENTS IN QUERÉTARO: EXPERIENCE AND RESULTS OF THE STEM CLUB

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Abstract: The STEM Club in the State of Querétaro is an interinstitutional initiative aimed at fostering interest in science and technology among high school students. Through virtual and in-person sessions, the program provides participants with practical and educational experiences that stimulate scientific thinking, engineering, and innovation. Evaluation results demonstrate a positive impact on participants' STEM knowledge and skills, as well as their perception of careers in these areas. High satisfaction ratings and the intention to recommend the program highlight its effectiveness and acceptance among students. According to the findings, the STEM Club showcases the potential of interinstitutional interventions to promote STEM education and regional socioeconomic development. However, challenges persist regarding equity in access and long-term interest maintenance. These findings have significant implications for educational policy formulation and the implementation of similar programs in other regions.

Keywords: STEM, interinstitutional education, socio-economic development, scientific thinking, innovation.

INTRODUCTION

The growing importance of STEM careers in the current and future job market is undeniable. According to the World Economic Forum report (2020), there is a significant projected increase in demand for STEM-related jobs in the coming years, surpassing many other fields. Additionally, technological advancement and digitalization are rapidly transforming entire industries, creating an even greater demand for professionals with skills in science, technology, engineering, and mathematics. This is corroborated by studies such as the Organization for Economic Cooperation and Development (OECD, 2023) report, which highlights the

importance of STEM education for a country's competitiveness and economic innovation. Therefore, preparing students with STEM skills has become a priority in many regions of the world, as it not only ensures job opportunities for young people but also drives economic growth and innovation at a national and global level.

The STEM Club initiative in the State of Querétaro arises in response to the need to foster interest in science and technology among high school students. This interinstitutional program aligns with the United Nations Sustainable Development Goals of the 2030 Agenda, specifically with Goal 4 (Quality Education) and Goal 9 (Industry, Innovation, and Infrastructure). By promoting STEM education, the STEM Club aims to contribute to the sustainable socio-economic development of the region, as well as to democratize access to emerging technologies. This initiative is based on evidence that a strong STEM education can open up job opportunities and contribute to societal progress (UNESCO, 2017).

The STEM Club in the State of Querétaro implements short workshops with hands-on activities focused on the STEM approach for high school students. These activities include building models and solving practical problems related to science, technology, engineering, and mathematics. According to research conducted by Bell, Lewenstein, Shouse, & Feder (2009), this type of hands-on, project-based approach can be highly effective in engaging students in STEM learning, fostering their curiosity, and promoting critical thinking and problem-solving. Additionally, activities such as model building and hands-on experimentation can help students visualize abstract concepts and better understand the underlying scientific and mathematical principles (Linn, Clark, & Slotta, 2003).

The intervention of the STEM Club was carried out in collaboration with high schools and universities in the state of Querétaro, constituting a statewide program. This inter-institutional collaboration is essential to achieve greater impact and reach within the educational community. Research conducted by Bryson, de Waal Malefyt, and Srivastava (2020) has shown that partnerships between educational institutions can strengthen STEM education programs by providing shared resources, complementary expertise, and collaboration opportunities between students and teachers. Additionally, interinstitutional partnerships can contribute to greater coherence and coordination in the implementation of educational interventions, ensuring that the needs of students are effectively and sustainably met.

At the end of the STEM Club intervention, a comprehensive evaluation was conducted to measure its impact and effectiveness. This evaluation included an online survey designed specifically to collect data on participants' perception of the intervention. According to research by Means, Toyama, Murphy, Bakia, and Jones (2010), online surveys are an effective tool for collecting data in educational settings, as they offer a convenient and accessible way for participants to provide feedback on their experience. Additionally, online surveys allow for efficient data collection and analysis, facilitating the evaluation of the impact of educational programs such as the STEM Club in the State of Querétaro.

The implementation of the STEM Club in the State of Querétaro represents an innovative approach to addressing the STEM skills gap and fostering interest in science and technology among high school students. By aligning with the United Nations Sustainable Development Goals of the 2030 Agenda, this program seeks to contribute to the sustainable socio-economic development of the region,

as well as to the democratization of access to emerging technologies. Previous studies, such as that conducted by Bybee (2013), suggest that STEM-focused educational interventions can have a positive impact on critical skills development, employment readiness, and societal advancement as a whole. Therefore, the STEM Club represents a significant opportunity to inspire students and promote innovation and competitiveness in the State of Querétaro and beyond.

The implementation of the STEM Club in the State of Querétaro reflects a grounded optimism in the results obtained and the future potential of the intervention. By examining the positive impact on interest in STEM areas among participating youth and alignment with sustainable development goals, the relevance and effectiveness of the program are evident. This sense of hope is supported by research such as that of Cakmakci, Bas, and Isbasaran (2018), which highlight the importance of STEM interventions in preparing students for the future workforce and promoting sustainable development. Additionally, positive feedback from participants and collaborating educational institutions support the continuation and expansion of the STEM Club as a key initiative for educational and socio-economic development in the State of Querétaro.

CONTEXT AND MOTIVATION

The need to foster interest in science and technology among high school students in the State of Querétaro is a relevant challenge in the current educational context. As society moves towards a knowledge- and technology-based economy, it is crucial to equip students with the skills and competencies necessary to face the challenges of the future. However, numerous studies indicate a lack of interest and participation in STEM areas among youth, raising concerns about the workforce

readiness for the 21st-century job market. In this regard, the STEM Club emerges as a strategic response to engage high school students in stimulating and motivating activities that ignite their curiosity and passion for science and technology, preparing them for careers in STEM fields and promoting the socio-economic development of the region (Bybee, 2013).

The alignment of the STEM Club with the United Nations Sustainable Development Goals (SDGs) of the 2030 Agenda reflects its commitment to the sustainable socio-economic development of the Querétaro region. These global goals set a comprehensive roadmap for addressing urgent challenges such as poverty, inequality, climate change, and lack of access to education and technology. By specifically contributing to Goal 4 (Quality Education) and Goal 9 (Industry, Innovation, and Infrastructure), the STEM Club seeks not only to promote interest in science and technology among youth but also to provide them with the skills and competencies necessary to address the challenges of the 21st century and contribute to the sustainable development of society (UNESCO, 2019).

The recognition of STEM education as a key driver for innovation and competitiveness in the global context underscores the strategic importance of the STEM Club in the State of Querétaro. In an increasingly technology- and innovation-driven world, skills in science, technology, engineering, and mathematics are crucial for economic and social advancement. Research such as that of Carnevale, Smith, and Melton (2011) has shown that STEM careers have a significant impact on the economy, as they not only offer higher wages and greater employment opportunities but also drive innovation and business growth. Therefore, the STEM Club seeks not only to prepare youth for successful careers in STEM fields but also to cultivate a culture of innovation

and excellence that contributes to sustainable development and regional competitiveness.

The importance of democratizing access to emerging technologies and promoting equity in STEM education in the State of Querétaro is crucial to ensuring equitable opportunities for all students. The digital divide and socio-economic disparities can hinder some youth's access to resources and opportunities in STEM, which in turn can limit their potential for academic and professional success. Therefore, the inclusive approach of the STEM Club in the State of Querétaro, by providing access to high-quality STEM activities and resources through interinstitutional collaborations, is essential to address these inequalities and promote diversity and inclusion in STEM education.

Interinstitutional collaboration as an effective approach to addressing educational challenges and promoting socio-economic development in the Querétaro region is fundamental to the success of the STEM Club. By joining forces with educational institutions, governmental organizations, and private sector companies, the STEM Club can leverage a wide range of resources, expertise, and knowledge to enrich its programs and activities. Through strategic collaboration, the STEM Club can maximize its impact and more effectively contribute to the advancement of STEM education and the socio-economic development of the Querétaro region.

STEM CLUB

The STEM Club is an interinstitutional initiative in the State of Querétaro aimed at expanding the STEM educational approach among high school students. Additionally, it seeks to foster interest in science and technology, bridge the gap between upper secondary and higher education, and promote 21st-century skills within the framework of the Sustainable Development Goals of the 2030

Agenda. Since its inception in 2022, the STEM Club has experienced significant growth, serving more than 200 students across two cohorts. This intervention has been carried out in collaboration with teachers from both upper secondary and higher education, involving 12 educational institutions, including the University Tecnológica de Corregidora. Due to the positive results and impact achieved in its initial implementation, the STEM Club was scaled up to a statewide level in 2023, reaching over 800 high school students from 20 educational institutions, 14 of which were upper secondary and 6 were higher education institutions. This growth demonstrates the commitment and effectiveness of the STEM Club in its mission to promote STEM education and socio-economic development in the State of Querétaro.

INTERVENTION METHODOLOGY

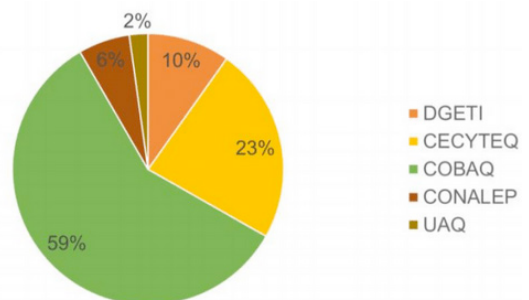
The intervention methodology of the STEM Club was designed with the aim of providing a comprehensive and enriching experience for participating students. This intervention was structured into three virtual sessions and one in-person session, each with specific focuses and activities. In the first virtual session, a talk on future jobs was offered, highlighting the importance of digital transformation in the industry and its impact on future job opportunities. Additionally, a practical activity aimed at stimulating students' scientific thinking was conducted. The second virtual session focused on the development of engineering-oriented thinking, using tools such as Tinkercad and MIT App Inventor to explore embedded systems and mobile applications. Finally, the third virtual session centered on fostering innovation-oriented thinking, where tools such as design thinking were shared to encourage creativity in the development of new products. The culmination of the intervention took place in the in-person

session, where students had the opportunity to visit higher education institutions and participate in hands-on activities related to the academic offerings in STEM areas. This holistic and progressive methodology allowed students to explore different aspects of STEM education and make informed decisions about their future academic trajectory.

RESULTS AND EVALUATION

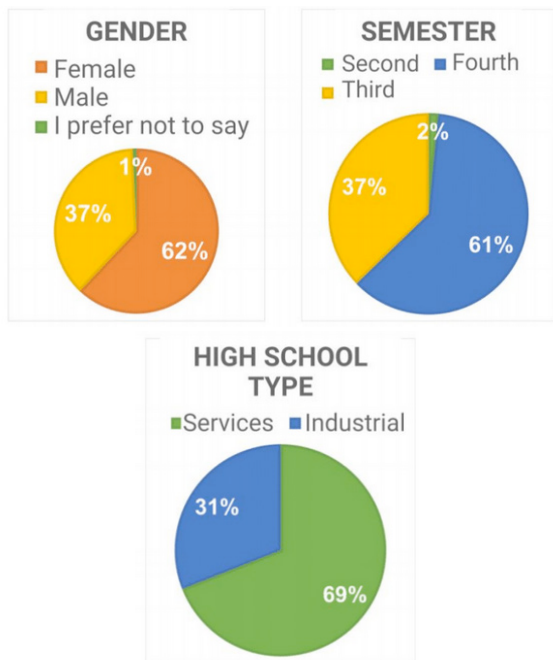
In order to measure the impact of the STEM Club, online forms were randomly implemented at various intervention points in all participating institutions in 2023. On average, 260 students were surveyed in each activity, within a universe of 813 students who participated in the program in the State of Querétaro.

The surveyed high school students belong to 6 educational subsystems in the State of Querétaro, which are: the General Directorate of Industrial and Service Technological Education (DGETI), the College of Scientific and Technological Studies of the State of Querétaro (CECYTEQ), the College of Bachelors of the State of Querétaro (COBAQ), the National College of Technical Professional Education (CONALEP), and the high school departments of the Autonomous University of Querétaro (UAQ). The participation percentage of the surveyed students can be seen in Graph 1.



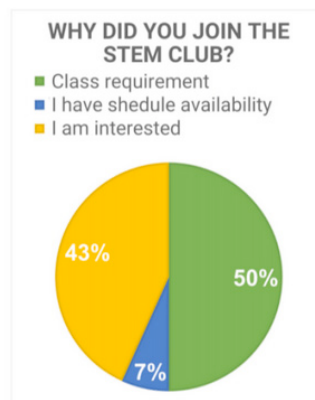
Graph 1. Students by educational subsystem participating in the STEM Club 2023.

The results showed a broad representation of students from various educational subsystems, with women comprising 62% of the sample. The participating students were primarily in the fourth semester (61%). Additionally, students from service (31%) and industrial (69%) high school programs participated.



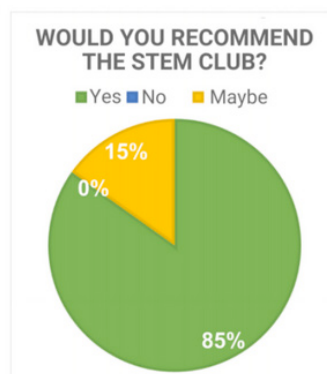
Graph 2. Sample Characteristics.

During the Club STEM intervention, three key moments were identified. The first moment corresponds to session 1, focusing on future jobs and activities to develop scientific thinking. During this initial stage, students were asked to rate their level of curiosity on a scale of 1 to 10. On average, surveyed students assigned a rating of 7.6, which is noteworthy as it is an important characteristic for scientific thinking development. Additionally, 8.3% of the sample had not yet defined their career choice at this stage. Furthermore, surveyed students were asked about the reasons for joining the Club STEM program, with 50% stating it was a requirement for a class, 43% expressing genuine interest, and 7% joining because they had free time (see Graph 3).



Graph 3. Reasons for Students' Participation in the Club STEM Program.

During the second phase of the Club STEM educational intervention, sessions 2 (engineering-oriented thinking development) and 3 (innovation-oriented thinking development), regarding student satisfaction, an average rating of 8.7 (on a scale of 1 to 10) was obtained for Club STEM activities, with 85% of students expressing their intention to recommend the program to their peers, while 15% may consider recommending their peers to participate in similar activities (see Graph 4).



Graph 4. Satisfaction of participating students in the Club STEM.

During the third and final stage of the intervention, which concluded with the in-person session at participating university campuses (such as the Technological University of the State of Querétaro, Technological University of Corregidora,

Technological University of San Juan del Río, Polytechnic University of Querétaro, Polytechnic University of Santa Rosa Jauregui, and Aeronautical University of Querétaro), students were asked again about their career choices. The results indicated that only 0.6% of the sample remained undecided, showcasing a decrease from the initial 8.3% at the beginning of the intervention in Session 1. Moreover, there was an overall improvement in the level of STEM knowledge and skills during the intervention, leading to a significant impact on career decision-making. These findings affirm the effectiveness of the Club STEM in its mission to promote interest and competence in STEM among high school students in the state of Querétaro.

CONCLUSIONS AND DISCUSSION

Based on the results and evaluation of the Club STEM intervention in Querétaro, several significant conclusions can be drawn. Firstly, the successful implementation and scalability of Club STEM demonstrate the feasibility of interinstitutional interventions to promote STEM education and socio-economic development in a specific region. The widespread acceptance of the program by students from different educational subsystems and genders highlights its ability to reach a diverse range of young people and foster interest in science and technology across the student community.

Moreover, the evaluation results show a positive impact on participants' STEM knowledge and skills, as well as their perception of careers in these areas. The high satisfaction rating and intent to recommend the program to other students reinforce the importance and effectiveness of the approach used in Club STEM.

More broadly, these findings suggest that interinstitutional educational interventions can play a crucial role in preparing the workforce of the future and promoting sustainable development at the regional level. By providing enriching learning experiences and practical opportunities, such as visits to higher education institutions, Club STEM is not only preparing young people for successful careers in STEM but also inspiring them to contribute to technological advancement and economic growth in their community.

However, it is important to note that challenges still exist, such as the need to ensure equity in access to STEM opportunities and to maintain students' interest over time. Additionally, it would be beneficial to conduct long-term follow-up of participants to assess the ongoing impact of Club STEM on their educational and professional trajectories.

In summary, the Club STEM intervention in Querétaro has proven to be an effective model for promoting STEM education, developing 21st-century skills, and preparing young people to face the challenges of the future. These findings have important implications for the formulation of educational policies and the implementation of similar programs in other regions.

Knowledge acquired during the **STEM Club** (online and in-person sessions)



Graph 5. Knowledge Acquisition during the Club STEM.

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