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Research Article

Enhancing STEM Student Learning: Exploring the Impact of International Science Competitions

[1]Professor, Ricardo Ipiña Sifuentes*, [2]Professor, Guillermo M. Chans, [3]Professor, Vianney Lara-Prieto

[1]School of Engineering and Sciences, Tecnologico de Monterrey, Mexico
[2] School of Engineering and Sciences, Tecnologico de Monterrey, Mexico
[3]School of Engineering and Sciences, Tecnologico de Monterrey, Mexico
[1]ricardo.ipina@tec.mx, [2]guillermo.chans@tec.mx, [3]vianney.lara@tec.mx
[1] https://orcid.org/0009-0008-3458-4733, [2] https://orcid.org/0000-0002-7373-3710, [3] https://orcid.org/0000-0002-6119-3657

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ABSTRACT

Students exhibit distinct learning patterns when immersed in demanding environments, particularly within competitive settings, which offer an active, hands-on approach. Rather than passively absorbing theoretical concepts, students are prompted to apply their knowledge in time-sensitive competitions, catalyzing more agile, profound, and substantive learning experiences. These competitions cultivate essential competencies such as critical thinking, problem-solving, collaboration, and preparedness, effectively equipping students to confront diverse real-world challenges. The amalgamation of knowledge application, intrinsic motivation, and skill enhancement leads to more impactful, enduring learning outcomes for students. To address this need, we established the International Science Competition, designed for exceptional high school students worldwide to receive recognition for their endeavors in STEM fields (Science, Technology, Engineering, and Mathematics). Participants compete in the Computing, Physics, Mathematics, Chemistry, and Biology categories, complemented by conferences, STEM-related activities, and university tours. Held concurrently in over 30 locations across Mexico and Latin America and online for select international participants, the 2023 competition attracted over 1,900 students in its in-person format and nearly 700 online. Of these, 100 students reached the final phase, and 25 were awarded for exceptional performance. The study population was analyzed considering the exam STEM domain, exam modality (in-person or online), and the winners' origin for the different subject areas. A perception survey was conducted to evaluate the participants' learning experience and their satisfaction level with the event organization, the exam, and the activities provided. Most of the participants enjoyed the competition and would recommend other students to participate in it.

Keywords: Challenge-based learning, educational innovation, engagement, higher education, STEM, science competition.

I. INTRODUCTION

The global demand for engineers has surged in recent years as the world faces various complex challenges, including climate change, technological advancement, and infrastructure development. Engineers are at the forefront of devising solutions that will shape the future of our societies. However, despite this increasing need, there has been a noticeable decline in the number of students opting to pursue engineering or STEM-related fields in their higher education [1]. This trend raises concerns about the potential shortfall in skilled professionals required to address and solve critical issues. Understanding and addressing the factors contributing to this decline is crucial for ensuring a robust pipeline of talent capable of meeting the world's pressing demands.

STEM education embodies an interdisciplinary approach that integrates the four foundational areas: Science, Technology, Engineering, and Mathematics [2]. This approach emphasizes bridging academic knowledge with

real-world challenges and is the cornerstone for incorporating these disciplines into education [3].

STEM plays a critical role in cultivating a skilled workforce, driving technological advancements, robust infrastructures, and innovative solutions to global challenges, thereby creating a more advanced and sustainable world. It furnishes top-tier science and technology education, equipping learners with the requisite knowledge to grasp the interconnectedness of science, technology, and culture [4]. Moreover, STEM education nurtures essential digital competencies among students [5], fostering interpersonal skills like problem-solving, creativity, and critical thinking. Consequently, higher education institutions must attract many capable and motivated students to their STEM programs to produce proficient STEM graduates [6].

However, STEM-focused programs encounter significant attrition rates during the shift from secondary to the initial stages of higher education [7]. Furthermore, there has been a decline in student interest in STEM fields in recent years [1]. Therefore, it is becoming increasingly imperative to develop activities to raise students' awareness of the significance and impact of STEM disciplines in shaping the progress of their communities, nations, and the world. To achieve this, teachers and professionals in the industry have proposed new learning methods for students.

Engaging high school students in scientific competitions is an effective method to attract them to STEM fields. An example of this is a robotics design contest where high school students design a practical solution to solve a real-world challenge faced in industry [8]. Students are motivated to apply their basic science knowledge to practical applications and are competitive and excited to be able to win such a competition. Another study in Indonesia [9] presents a science creativity competition where high school students improve their critical thinking competency by analyzing problems and finding the right solutions by creating scientific, creative works.

A study considering a large high school student population in the United States has determined that competitions effectively foster career interest in STEM fields. The research revealed that students engaging in STEM contests are more inclined to pursue a STEM-related undergraduate program upon high school graduation than their non-participating peers. Additionally, the study highlighted that the correlation between participating in competitions and developing an interest in a STEM career varies across different fields. Finally, it was found that engaging in multiple competitions significantly increases the impact on students' pursuit of a STEM career. [10]

In recent years, hands-on activities and Makerspaces have become increasingly popular, recognized for their capacity to spark interest and foster identity development in STEM fields. Science and technology contests in Taiwan have shown effectiveness in raising students' interest in STEM careers and developing student's soft skills. [11]

This paper presents findings from a basic science contest hosted at a Latin American university. The contest was strategically designed to enhance high school student's interest in STEM fields and encourage them to pursue further studies at the undergraduate level.

II. METHOD

In March 2023, Tecnológico de Monterrey organized the "International Science Competition" [12] to foster learning within STEM domains. This contest allowed participants to select a single area of focus from Computer Science, Physics, Mathematics, Chemistry, or Biology. Tailored for high school students, nationally and internationally, eligibility criteria encompassed current enrollment in a high school, maintaining a cumulative GPA above 80, and being under 20.

The competition took place concurrently in over 30 distinct locations. In Mexico, the event adopted a face-to-face format, while for participants residing outside the country, the examination was conducted online via the Zoom platform. Throughout the elimination phase, over 2,600 students underwent testing simultaneously.

Comprising two phases, the competition entailed an elimination round and a showdown, with each exam lasting one hour. During the initial stage, the top 20 students in each discipline were selected, advancing to the final phase, where the top five in each category were declared winners.

Canvas was selected as the technological platform [13] to ensure stability and promptness in delivering scores for each exam. This tool enabled the immediate generation of a report containing the grades of all students, allowing for the swift compilation of a list of those who progressed to the next phase within minutes.

Before launching the call to invite students, an initial committee was assembled, comprising a project leader and five professors, each specializing in a distinct area: Computer Science, Physics, Mathematics, Chemistry, and Biology. This committee designed the exams for both the preliminary and final stages.

Considering the specialized knowledge needed for exam development and the distinct academic frameworks of the five subjects, the competition grants flexibility to the faculty on the exam development committee. They determine the number of items per exam, the type of questions (open-ended or multiple choice), and the difficulty level of each question. Notably, the difficulty level of the questions significantly escalated in the final phase. However, it is essential to ensure that the exam's difficulty level is appropriate for high school students and adheres to the maximum duration of one hour. It's noteworthy that all exams were conducted in Spanish.

Additionally, the faculty team created an exercise guide and a sample exam to assist students in their preparation beforehand.

To enroll, students navigated to the event's website [12] and furnished personal information, including name, school of origin, cumulative GPA, age, and contact details, alongside choosing their preferred STEM specialization. Supplementary documentation was mandatory, like an official ID and a certified document verifying academic qualifications. A panel of 12 evaluators meticulously reviewed the documentation submitted by each student to ensure compliance with the requirements outlined in the call for applications, with responses issued within 48 hours of registration. Based on this evaluation, students were admitted to participate in the competition.

Upon admission, students were provided with the following materials to aid in their preparation and optimize their performance during the event:

1. Exercise guide.

2. Sample exam.

3. An event schedule detailing the precise time and location of the exam administration.

Another committee was tasked with setting up individual accounts for each student on the Canvas platform and enrolling them in the corresponding exam area.

The study population (contest participants) was analyzed considering the STEM domain chosen for the exam, exam modality (in-person or online), and the origin of the winners of the different subject areas.

At the end of the event, a four-question survey was conducted to assess the impact of the International Science Competition on students' learning experience and their satisfaction level with the event organization, the exam, and the activities provided.

III. ACTIVITIES

To ensure the success of the event, the following measures were implemented:

1. Each student must bring their laptop to the event in Mexico. For students located outside the country, it was mandatory to have a computer equipped with a camera, enabling them to connect to a designated Zoom link at the specified time. Students were recommended to use laptop batteries during in-person sessions and ensure a stable internet connection for online participation. In the event of disconnection, students could reconnect; however, the clock continued to run without pause.

2. Each student was instructed to bring a pencil and two sheets of paper for calculations. Additionally, a printed periodic table was necessary for the Chemistry exam. Students were not permitted to utilize any other materials, such as calculators.

3. The exam was accessed using a unique password provided to students before the start time. In the in-person format, this password was distributed upon entry to the examination room, while in the online format, it was communicated through Zoom. This protocol ensured that only authorized individuals could access the exam, thus maintaining the integrity and security of the assessment process.

The elimination stage, the final stage, and the awards ceremony took place on the same day. Additionally, various workshops and lectures featuring academic and educational content were offered to students and the

accompanying teachers throughout the day. A committee was responsible for designing and overseeing these activities, ensuring students benefited from a day filled with learning and information that fueled their curiosity and interest in STEM fields.

The tour of the university's engineering labs provided students with a firsthand glimpse into STEM-related careers and the processes involved in developing projects that positively impact our environment. Moreover, they had the opportunity to observe the equipment they would utilize in their future endeavors if they decided to pursue a career in STEM.

In our efforts to bolster the knowledge of students engaged in this competition, we curate and deliver workshops on STEM subjects, concentrating on contemporary issues affecting both industries and global landscapes. Among the workshops provided are "Additive Manufacturing and Prosthesis Printing" (Fig. 1), "Cloning and Nourishment of Carnivorous Plants" (Fig. 2), and "Utilization of Technology and Digital Transformation in Formula 1" (Fig. 3), among others. These workshops are facilitated by proficient faculty instructing at the Tecnologico de Monterrey undergraduate level.

Fig. 1: Additive Manufacturing and Prosthesis Printing

Fig. 2: Cloning and nourishment of carnivorous plants

Fig. 3: Utilization of Technology and Digital Transformation in Formula 1

Table 1 illustrates the overall agenda, encompassing the examination and supplementary activities designed to enhance students' experience and learning during the event.

Table 1. General agenda of the event

Time	Activities
9:00 -10:00	Reception and delivery of commemorative badges and T-shirts for the events
10:00 - 11:00	Welcome and Keynote on STEM
11:00 - 12:00	**Elimitation Stage**
12:00 - 12:30	
12:30 - 13:00	Guided tour of the university´s engineering labs
13:00 - 13:30	
13:30 - 14:00	Mealtime
14:00 - 14:30	
14:30 - 15:00	Live stream: Announcement of finalists
15:00 - 15:30	Instructions for finalists
15:30 - 16:00	
16:00 - 16:30	Break
16:30 - 17:00	**Final Stage**
17:00 - 17:30	
17:30 - 18:00	STEM workshops and recreational activities
18:00 - 18:30	
18:30 - 19:00	
19:00 - 20:00	Live stream: Announcement of winners and award ceremony

Awarding ceremonies concluded the event with the following prizes:

- 1st place: Laptop computer
- 2nd place: iPad
- 3rd place: Video game console
- 4th place: Speaker
- 5th place: Headphones

IV. RESULTS AND DISCUSSION

2,946 students registered and submitted their information and documentation to be considered for the International Science Competition. However, only 2,662 students passed all the filters and requirements previously established on the competition's official website. Among these admitted students, 1,975 opted to attend the event in person, constituting 74%. Participants came from 22 states in Mexico, as well as Colombia, Guatemala, Ecuador, El Salvador, Honduras, Peru, and the United States. The percentage of participation of foreign students was 5%.

Table 2 depicts the distribution of students according to their chosen field of competency. Mathematics garnered the highest interest, followed by Biology and Chemistry, while Physics and Computer Science recorded the lowest

participation rates in the contest.

Table 2. Dispersion of students by field

Field	Students accepted	In-person format students
Math	902	629
Biology	664	517
Chemistry	506	389
Physics	402	299
Computer Science	188	141
Total Student	2,662	1,975

Given the international scope of the competition, winning students could hail from diverse regions across Mexico or any other participating country. However, in this edition, all the winners were from Mexico. Table 3 provides a visual depiction of the geographical distribution of the winners.

Table 3. Dispersion of the winners by location

Field	Mexico (Southern Region)	Mexico (Central Region)	Mexico (Northern Region)	Mexico (Western Region)	Total
Math	1	1	2	1	5
Biology	1	1	1	2	5
Chemistry	0	0	3	2	5
Physics	1	0	2	2	5
Computer Science	1	0	3	1	5
Total Student	**4**	**2**	**11**	**8**	**25**

The survey results regarding the participation process in the International Scientific Competition are outlined below.

In response to the first question, “How would you rate the following aspects of your participation process in the International Scientific Competition?” it is evident that the clarity of the registration process and the overall experience during the event were predominantly rated as excellent (Fig. 4).

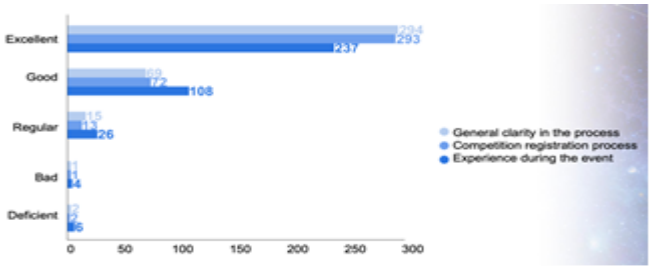

Fig. 4: Satisfaction in the participation process

In the second question, "How did you learn about the International Science Competition?" the primary source was invitations from their respective schools, followed far behind by invitations from friends or family or via email (Fig. 5). Despite considerable efforts invested in social media outreach, direct invitations from students' high schools remain the most impactful channel. This underscores the importance of incorporating this insight into communication strategies for inviting students to various activities, including contests, conferences, workshops, and campus tours.

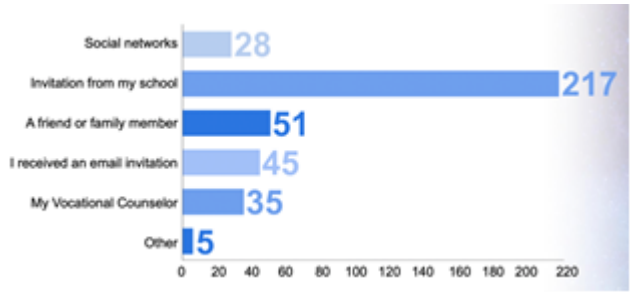

Fig. 5: How did you learn about the International Science Competition?

In response to the third question, "How difficult did you find the exam you took in the International Science Competition?" the findings reveal that a significant portion of participants found the exam to be highly complex, followed closely by those who perceived it as moderately difficult and aligned with their level of knowledge (Fig. 6). Since the participants come from different high schools and even different countries, their academic background is also quite different. Crafting the contest exam requires a delicate balance: it should be intentionally challenging to stimulate students and foster growth, yet not overly difficult to deter them or instill doubt regarding their suitability and potential for a career in engineering or STEM.

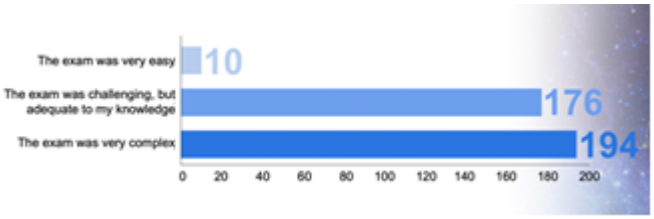

Fig. 6: How did you find out about the International Science Competition?

Regarding the final question, "How likely would you be to recommend participating in the International Scientific Competition?" most respondents indicated that they would be "Very likely" to recommend it, comprising 77% (275 individuals). This was followed by 18% (69 individuals) who responded "likely," while only 4% (17 individuals) responded "unlikely." Overall, participants are satisfied with the experience, which is very relevant since one of the main objectives of this competition is to attract students to STEM-related undergraduate programs.

Finally, students were invited to share their general comments about the event's benefits. Here are some of their remarks:

- *This competition allowed me to enhance my resume and gain recognition and knowledge in science.*
- *It helped me improve personally and test my knowledge about Computer Science.*
- *Engaging in these activities pushes you beyond your comfort zone.*
- *I had the opportunity to meet new people, build connections, and expand my network.*
- *I gained a deeper understanding of STEM fields, helping me to choose my career path better.*
- *I had fun and found fulfillment in the competitive aspect.*

Overall, the survey responses indicate that students are content with the event's organization and the positive outcomes they experienced from participating in the competition. Fig. 7 shows part of the student's experience during the event.

Fig. 7: Students' experience

While the exam was supervised in both the on-site and online formats, a limitation of the contest was that, due to the large number of attending students, monitoring individual screens was not feasible. Looking ahead, we aim to facilitate the participation of international students in Mexico. This will not only ensure that the exams are conducted under optimal conditions but also provide students with the opportunity to partake in additional experiences, such as university tours and workshops.

V. CONCLUSIONS

The International Science Competition was executed successfully, receiving excellent feedback from participating students. This initiative provided a platform for students to showcase their scientific abilities and knowledge and played a pivotal role in engaging them more deeply with STEM disciplines. This contest immersed participants in both practical and theoretical problems, fostering a more profound and meaningful relationship with science. The academic and cultural exchange among students from various countries enriched their learning experience, enhancing their interest and engagement in Science, Technology, Engineering, and Mathematics. This event highlighted the young individuals' capacity to tackle complex scientific challenges and proved to be an effective tool in inspiring a future generation of leaders in STEM fields. The exams proved to be challenging, meeting the standards of an international competition. Moreover, students gained a comprehensive experience through workshops and familiarization with university facilities, aiming to inspire them to pursue careers in STEM fields.

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