

Development of academic projects with robotics for social support: initiatives of Mexican engineering students

Edgar Lopez-Caudana
Institute for the Future of Education
Tecnologico de Monterrey
Mexico City, Mexico
edlopez@tec.mx

Ariadna Sosa Luviano
Escuela de Ingeniería y Ciencias
Tecnologico de Monterrey
Mexico City, Mexico
A01654080@tec.mx

Joan Domínguez Lora
Escuela de Ingeniería y Ciencias
Tecnologico de Monterrey
Mexico City, Mexico
A01661548@tec.mx

Victoria Rodríguez de León
Escuela de Ingeniería y Ciencias
Tecnologico de Monterrey
Mexico City, Mexico
A01656328@tec.mx

Carina Soledad González González
Departamento de Ingeniería
Informática y Sistemas
Universidad de La Laguna
San Cristobal de la Laguna, Spain
cjgonza@ull.edu.es

Carlos Enrique George-Reyes
Institute for the Future of Education
Tecnologico de Monterrey
Mexico City, Mexico
cgeorge@tec.mx

Abstract—In today's rapidly evolving technological landscape, marked by the proliferation of artificial intelligence and robotics, the role of engineering education stands as a cornerstone of sustainable progress. Recognizing this imperative, engineering curricula are increasingly incorporating a competency-based approach that reflects the complexities of the real world, for lifelong learning, using enabling and disruptive technologies such as humanoid robotics. We present a case study from the Tecnológico de Monterrey, Mexico City Campus, where NAO robots are used in social projects with immediate impact in the fields of health and education, addressing sustainable development objectives. This research shows projects that have had a significant social impact in different communities in Mexico, in the areas of education and health with innovative solutions that motivate and engage the attention of the audience. A group of students from different engineering careers design, develop and implement application scenarios for the accompaniment and social appropriation of challenges such as: the incorporation of girls in STEM areas, support for groups with intellectual disabilities, dissemination and knowledge of sign language and dissemination of the cultural heritage of Xochimilco as a cultural heritage of humanity. Preliminary results indicate that this pedagogical approach not only inculcates students with essential skills such as problem solving, critical thinking and teamwork, but also makes them more aware of the social implications of their engineering studies. Evidence and results of the involvement of undergraduate students in social scenarios are shown, showing that, by integrating these elements, engineering programs aspire to train professionals capable of harnessing their technical knowledge for the general good of society as well as the perception of the participants and audiences reached.

Keywords—Complex thinking, competency-based education, educational innovation, higher education, data visualization, computational thinking.

I. INTRODUCTION

Recognizing the social dimension of STEM careers is not just important but imperative. As aspiring professionals, students need to grasp the potential impact and significance of their contributions, developing a sensitivity to community needs and thereby becoming worthy professionals. At Tecnológico de Monterrey, Mexico City Campus, an innovative approach to foster this awareness is through Social Service programs. These initiatives, selected voluntarily by

students, involve their exposure to pressing social issues through collaboration with more specialized institutions. The goal of the programs is to provide a valuable service to society, addressing the needs of marginalized groups with limited access to fundamental necessities like education and healthcare. Going beyond volunteerism, these programs encourage students to collaborate, forming multidisciplinary and multicultural groups. This collaborative environment not only enhances teamwork and communication skills but also promotes cultural awareness and complementation among participants, as shown by the findings of Juárez, Malik, Ayala, Nordin, and Rahim [1]. Furthermore, the integration of engineering solutions into these social service programs offers a wide range of new possibilities. Robotic tools, with their versatility and capacity to perform various tasks, become instrumental in addressing societal challenges. These tools seamlessly integrate diverse disciplines such as mechanics, electronics, and programming, while offering an empirical approach to problem-solving. The implementation of robotics solutions in social service projects represents a significant achievement for STEM students. It not only demonstrates the practical application of their skills but also serves as an exhibition of project-based learning, an innovative method that this study aims to promote. The availability of such social service programs becomes an opportunity for the convergence of engineering solutions with societal needs. A study presented by Feidakis et al. [2], shows NAO robots as a suitable solution for initiatives with social impact, serving as an assisting tool for procedures like physical therapy, and interactive education, aiding the development of communication, motor, and emo-social skills. Students at the Tecnológico de Monterrey, Mexico City Campus, have also experimented with the usage of the NAO Robot for social labor, making it an already well-settled and well-tested tool among students. Not only NAO Robots but other robotic tools can be used to enhance students' learning process; for instance, Sattar and Nawaz [3] have tested the effectiveness of engineering projects that involved drone programming to follow flight paths, improving the complex and algorithmic thinking of students.

Social service programs play a crucial role as a complementary component in the education of STEM professionals. However, the landscape of STEM education is evolving. There is an emergence and reaffirmation of

innovative methodologies, carefully designed to stimulate and improve students' performance. Among all these innovative approaches, challenge-based learning (CBL) stands out. This methodology is a breakthrough in education, and students seem immersed in the development of tangible solutions to real problems through it. This approach requires that students leverage their acquired knowledge, finding workarounds and applicable alternatives under real-world constraints. Gallagher and Savage [4] have agreed that CBL is a methodology that englobes the thinking procedures of developing a solution to a problem as a challenge to tackle, offering an innovative outcome. CBL also involves collaboration in a multidisciplinary environment. This hands-on approach stands out over traditional learning methods, serving as an incentive for students to explore their field, much beyond their current understanding, opening the possibility of making groundbreaking insights and breakthroughs, besides specializing and becoming a worthy professional. Another complementary methodology worth highlighting is competency-based education, where competencies serve as indicators, establishing a quality standard [5].

These competencies can also be further categorized into two types: technical competencies, which are specific to the student's major, and transversal competencies, encompassing more general, yet necessary skills, such as redaction or speaking [6]. Graduates who have experienced both methods as students are likely to develop confidence with the development of solutions for real-world situations, as they have experienced, and thus, familiarized themselves with the whole process, transforming them into highly valued professionals for companies they join. Hereinafter, the effects of the implementation of these methodologies with a social orientation on engineering programs in Mexico will be analyzed, in the hope to show the advantages they bring to the education process and the development of the students.

A. Social accompaniment experiences with robotics

The integration of Virtual Reality (VR) technology in various fields, such as education, therapy, and psychology, is expanding and showing favorable implications for children with autism spectrum disorder (ASD). In a study focused on children with high-functioning autism, researchers explore the use of social virtual reality robots (V2R) in the context of music education [7]. The protocol aimed to address the educational needs and poor social interactions of children with autism through real-world simulations. The intervention program lasted 20 weeks and involved five children aged 6 to 8, where they utilized virtual reality robots and virtual musical instruments. The study demonstrated the feasibility of conducting virtual music education programs with an automatic assessment system, eliminating the need for physical robots. While psychological tests indicated slight improvements in cognitive skills, a comprehensive statistical analysis of the children's performance during the music education sessions demonstrated a notable upward trend in musical abilities. This suggests potential for future studies to explore the broader impact of technology-driven interventions in enhancing social and cognitive skills in children with autism.

Expanding on the transformative potential of social robotics, left-behind children (LBCs) in rural China face challenges that impact their health-related well-being, arising from limited parental care and restricted access to educational resources. A social initiative, the Xiao En Intelligent Robots

project, developed by the Li Ensan Charity Foundation, presents a novel approach to address this problem. A study conducted by Xie, Chen, and Cheung [8] researched the effects of intelligent robots on the well-being of rural LBCs. It was found that children who engaged with the robots and expressed higher satisfaction experienced positive effects on their quality of life. This research provides empirical evidence for technology-assisted child development, demonstrating its potential to bridge the gap between left-behind and non-left-behind children. The innovative use of intelligent robots, designed to provide advanced educational and caretaking resources, offers a favorable solution to mitigate the challenges faced by rural communities in China and vulnerable populations.

B. Robotics for education and Healthcare in latin america

In a progressive approach to dementia care, an innovative conversational robot named Eva has been developed for therapeutic interventions. Verbal communication stands as a crucial element in effective non-pharmacological treatments for people with dementia (PWD). This innovative project, based in Ensenada, Mexico, focuses on refining Eva's capabilities to autonomously guide therapy sessions without human intervention. Progress includes the automatic generation of fitted therapy scripts, anticipation of participant responses, and strategies to overcome communication breakdowns. A study [9] demonstrated that, when operating autonomously, Eva's engagement with PWD in therapy was as effective as in the Wizard-of-Oz condition, showcasing the potential to enhance dementia care in the broader context of Latin America.

In the education field, the CeCi initiative (Computer Electronic Communication Interface) social robot focuses on the intersection of technology development and social impact. This research addresses common issues associated with current social robots, such as their expensive nature and a design focus on functionality rather than user preferences, which often results in users being less receptive to them [10]. The CeCi robot aims to rectify these challenges by offering a low-cost prototype built on a commercial platform with open-source code. The design prioritizes user preferences, particularly focusing on social interaction acceptability. The study provides a detailed overview of the selection process, hardware capabilities, and programming aspects, emphasizing the user-centric approach. The research not only introduces a practical solution for emerging countries like Ecuador but, also demonstrates the potential for robotics to transform the educational landscape of Latin America in the future.

C. Project-based learning in education

In addressing the shortcomings of the traditional higher education models, which tended to be heavily theoretical with deficient emphasis on practical applications, innovative techniques have emerged to rectify this lack of practical experience within the learning process. The theoretical knowledge taught was also overly generalized, lacking specialization, and thereby compromising the professional competence of students. These issues, recognized by companies, boosted the development of competency-based and project-based approaches, and have acknowledged the efficacy in delivering more robust educational outcomes [11]. These methodologies prioritize practical application, ensuring that students are not only aware of their theoretical foundations but also develop the specific skills needed in professional settings. The shift towards these dynamic

approaches represents a crucial evolution in the education of STEM subjects, which are mostly practical.

In pursuit of the application of competency-based education and project-based learning, the Tecnológico de Monterrey has brewed an innovative educational plan called "Tec21". A distinctive feature of this plan involves the seamless integration of challenges and projects into each subject, promoting collaboration among students to achieve predefined objectives. Notably, these projects are often undertaken in collaboration with external companies, which are encouraged to design projects with practical applications that are subject-specific. Within the School of Engineering and Sciences, students actively apply their theoretical knowledge acquired in the classroom through a structured and iterative process. This process encompasses the design, analysis, simulation, and construction of solutions that meet the specifications of the company, in compliance with industry standards. The projects escalate in complexity, encouraging students to build upon their foundational knowledge. This approach also encourages the application of more sophisticated methodologies and tools, closely resembling the challenges encountered in a genuine professional setting. This immersive experience enhances practical skills and aligns students with real-world professional scenarios' demands.

II. METHOD

A. *Enhancing Literacy Through NAO Robots: A Project with Special Olympics Mexico*

This project was a collaborative effort undertaken by a team of 20 students from the Tecnológico de Monterrey, studying robotics, mechatronics, and biomedical engineering, in partnership with Special Olympics Mexico. This branch of the global movement aims to provide year-round sports training and athletic competition for children and adults with intellectual disabilities, empowering them to discover their strengths and abilities. Since its foundation, the organization has assisted more than 35,986 athletes in achieving their potential and integrating more effectively into society [12].

The primary objective of this collaborative initiative was to conduct three digital workshops designed to foster reading habits among 30 individuals with Down syndrome, aged 15-30 years (female=18, male=12), within the Special Olympics community. This was achieved through various activities guided by NAO robots, which, through their interactive nature, enhanced the experience by addressing the unique learning and communication needs of the target audience by motivating and creating an engaging environment that fosters active participation among attendees. This is made possible due to their humanoid appearance and social characteristics, which allow them to convey different messages through their body language and tone of voice, aiding in understanding and retaining content. This approach is particularly beneficial for individuals with Down syndrome, who often thrive with visual and kinesthetic learning methods [13].

The three virtual sessions, each with a duration of 1 hour, began with a storytelling segment from the NAO robot, where the robot narrated a short story tailored to the audience's characteristics. This was followed by one or two activities with cognitive, creative, and interactive elements to foster literacy development.

The selected stories for the sessions were: 'Puss in Boots', 'The Little Prince', and a story created by the students themselves, titled 'Eunice's Campaign'. The first two stories were chosen for their simple and accessible language, universal themes, and positive messages. 'The Little Prince' delves into themes of friendship, love, responsibility, and the search for identity, while 'Puss in Boots' focuses on bravery and ingenuity. The third story, 'Eunice's Campaign', presented in the final session, chronicled the life of Eunice Kennedy Shriver, an exceptional woman whose devotion and love for her younger sister, Rosemary, led her to found Special Olympics. The narrative highlighted how her passion for sports and her tireless fight for the rights of people with intellectual disabilities led her to transform lives and create a global movement of inclusion and empowerment.

For all three stories, the NAO robot was programmed to narrate them in a simple yet engaging manner, using body language to kinesthetically convey the messages. This approach aimed to stimulate the audience's imagination and creativity. Following the storytelling, the NAO robot would ask questions about the story. The participants could also interact with the robot by asking questions. This dynamic served not only as a quick check to gauge their retention from the reading but also to identify their interests.

Following the storytelling segment and the Q&A with the robot in each virtual session, a different learning approach was then introduced with activities to further encourage reading among the participants.

The first session featured the 'Hangman' guessing game. The NAO Robot announced the number of letters and offered hints for guessing the word. Whenever participants guessed a letter correctly, the robot would provide encouragement. This activity aids in enhancing letter recognition, spelling, and vocabulary skills, crucial for literacy development while strengthening problem-solving abilities [14]. It is important to note that the words selected for the activity were related to the story previously narrated by the robot. In that way, the participants could apply contextual learning by recalling elements of the story, which enhances memory retention, while strengthening their vocabulary and spelling skills [15].

The second session involved solving a 'Word Search' puzzle which, like the 'Hangman' guessing game in the first session, included elements from the story narrated by the robot earlier. Together with the already mentioned benefits of contextual learning, the concentration needed to find valid words in this type of puzzle can improve overall focus, a skill that is directly transferable to reading activities [16]. This is relevant as people with Down syndrome can face challenges with attention span and concentration [17]. The puzzle was projected onto the screen and solved collaboratively. For every right answer, the robot would comment positively on it. Overall, both 'Hangman' and 'Word Search' are puzzles that can boost the audience's confidence in their language skills and comprehension of the story, serving as an effective way to motivate individuals with Down syndrome to develop confidence in themselves and engage more with reading materials.

The next activity in the second session involved the NAO robot instructing the audience to develop a short story given an object description or keyword. This was aimed to encourage abstract thinking and narrative skills, important for developing storytelling and comprehension abilities. Further,

it prompts expressive language, which can aid in social and emotional dimensions. By creating stories, individuals with Down syndrome can express their emotions and experiences, fostering emotional literacy and empathy [18].

In the final session, following the storytelling and Q&A, the robot prompted participants to paint their favorite part of the story and share their reasons with the group. This task engaged them in a reflective process as it required them to choose one single scenario and reflect on why it resonated with them.

As Zunshine [19] argues, visuals enhance comprehension by anchoring abstract concepts and simplifying complex narratives. She further notes that visual engagement can lead to deeper processing and better memory recall of stories. Therefore, by prompting participants to create visual depictions, they have a personalized learning experience, leading to a stronger connection with the material as well as a sense of ownership over their learning process by becoming the authors of their interpretations. Further, sharing their feelings about the story allows them to explore and express their emotions more deeply, which can be therapeutic and aid in emotional regulation as they feel heard and recognized through their work. This aspect of emotional engagement is crucial for individuals with Down syndrome, as emphasized by Sappok, Zepperitz, and Hudson [20].

At the end of the third session, the robot delivered a motivational speech, inspiring the audience to engage more in reading activities. It emphasized the importance of self-trust, recognizing their abilities, and understanding their potential for improvement as readers.

B. Signs of Understanding: A Digital Workshop on Sign Language Awareness

This project, led by a team of 10 students at the Tecnológico de Monterrey studying mechatronics, robotics, electronics, and biomedical engineering, consisted of a digital workshop with two live one-hour sessions conducted via Zoom to raise public awareness about hearing disabilities and the significance of sign language. It was designed to accommodate participants of all ages and contexts with no prior exposure to sign language and the deaf community. The workshop was attended by 20 people in total (female=15, male=5). A distinct aspect of this initiative was the utilization of the NAO robots, which played a key role in enhancing participant engagement by providing a unique, interactive method to demonstrate the communication barriers encountered by people with hearing disabilities. This approach not only made the workshop more immersive and memorable but also showcased the practical application of the students' technical expertise in the social robotics field to address pressing societal issues.

To ensure the effectiveness and impact of the initiative, a collaboration was carried out with 'Instituto Lagunero de la Audición y Lenguaje, A.C.', a Mexican institute that has provided an integral education to children and young people with hearing disabilities as well as carrying out awareness campaigns about sign language since 1954 [21]. This collaboration was instrumental in ensuring the workshop content was both educational and respectful of the nuances associated with sign language and the Deaf community.

The first live session focused on raising awareness about the day-by-day of individuals with hearing disabilities and the

challenges they encounter in communicating with others. For this, two educators from the collaborative institute delivered a comprehensive talk covering the various types of hearing disabilities, their classifications, and a thorough analysis of pertinent statistics, considering both the global context and the situation in Mexico. Next, they introduced LSM (Mexican Sign Language), explaining its origin, unique phonological, grammatical, and syntactical rules, and its significance within its linguistic community. The last topic covered LSM as a cultural legacy that has served as an identifier of the Deaf community in Mexico, whose language has evolved and been shaped by its users, resulting overall in a cultural heritage that has contributed to a greater societal understanding and the acceptance of the Deaf culture and sign language.

At the end of the session, a NAO robot led an activity with the participants, aimed at raising awareness about the communication challenges faced by Deaf individuals. In this interactive exercise, the NAO robot assumed the role of a person with deafness. Participants were tasked with interpreting through the robot's body language what it was trying to convey. Following this initial exercise, the robot randomly selected someone from the virtual room. This person had to assume the role of a Deaf person, while the rest of the group, as they had done with the robot, attempted to decipher these non-verbal cues. The purpose of this setup was to underscore the patience, understanding, and keen observation required to effectively communicate with people with this disability. This exercise was repeated with a total of 5 participants from the audience.

In the second session, there were two special guests from the institution: a Deaf teacher and an interpreter, who was a student of the teacher in the past. This session was dedicated to introducing the audience to someone who could share their personal story as a member of the Deaf community. The teacher discussed her experiences living with a hearing disability since birth and the challenges she has faced. Then she explained what led her to become a teacher and help those who do not speak LSM (Mexican Sign Language) to learn it and communicate with the community. Throughout, the interpreter was translating the signs.

The rest of the session focused on providing the audience with a practical learning experience in LSM. For this, all participants were encouraged to turn on their cameras, and the teacher led them through the LSM alphabet, ensuring everyone correctly imitated the signs. She then selected audience members at random to spell their names in LSM.

To conclude the session, the students prepared the NAO robot to teach basic expressions in LSM. The robot demonstrated each expression, and the audience was asked to imitate these signs. The robot constantly motivated the audience whenever they performed well. The session reached a memorable end with the NAO robot expressing gratitude in sign language, a gesture directed towards the teacher and the interpreter.

C. NAOxolotl: Preserving Xochimilco's Treasures through NAO Robots

This initiative was the final graduation project of a mechatronics student at the Tecnológico de Monterrey. It aimed to raise awareness about the recognition of Xochimilco as a World Heritage Site, particularly focusing on the conservation of the Axolotl (*Ambystoma mexicanum*). The project involved the use of innovative tools, including NAO

robots and other resources, to convey the message to a wide public.

To understand the significance of this initiative, it's important to recognize the unique historical and ecological context of Xochimilco. Located in Mexico City, Xochimilco is renowned for its ancient network of canals and floating gardens, known as 'chinampas', a significant example of Aztec agricultural innovation. The district's origins trace back to the era of Great Tenochtitlan and the surrounding villages in the Valley of Mexico. Confronted with limited land and a growing population, the inhabitants ingeniously created 'chinampas' by anchoring frames in shallow lakes and filling them with soil and plant matter, thereby creating fertile artificial islands. This resulted in sustainable farming with maximized agricultural output [22].

In 1987, UNESCO designated Xochimilco as a World Heritage Site for its historical agricultural significance, cultural value, rich biodiversity (including endemic species like the axolotl), and the unique blend of urban and rural elements that shed light on historical land use within a contemporary urban setting [23].

However, since then, Xochimilco has experienced significant deterioration. Onofre [24] highlights how Xochimilco is at risk due to a substantial decline in its agricultural-lacustrine production, the uncontrolled urban expansion of Mexico City, the conversion of communal lands into residential areas, the destruction of canals for bridge construction, pollution from household drainage, the use of fertilizers and chemical pesticides, among other issues.

Another consequence of the deterioration of Xochimilco is the endangerment of the axolotl, an endemic species that resides in its lakes. The population of this species has declined in recent years because of the destruction of their habitat as well as the introduction of exotic species like tilapia [25]. This raises significant concern, as the axolotl is naturally found only in Xochimilco's lake, and several studies have shown its unique ability to regenerate entire limbs with ease, a critical aspect of modern medical research [26].

Considering this pressing situation, this Tecnológico de Monterrey student had the initiative to develop a project to address the issue. The project consisted of a one-hour interactive show held at the Tecnológico de Monterrey, México City Campus facilities, open to all ages. The show featured staged scenes to portray the current situation in Xochimilco and the endangerment of the Axolotl through an engaging story. The primary objective of the event was to sensitize the public to this critical issue to thereafter prompt a corresponding call to action.

The story's plot unfolded with two explorers, a NAO robot, and a human, who along with the audience, pretended to be at an exploration camp near Xochimilco. They suddenly receive an emergency call from an axolotl named 'Taxo', who is asking for help as "his village is in danger from outlaws who steal their homes, pollute the water with trash, and hunt his friends and family". This leads to a call to action for the audience to join the adventure to save the species and the lake of Xochimilco. The beginning of the adventure, guided by the NAO robot and the human explorer, involved activities like solving a Xochimilco map puzzle, a crossword with keywords related to the extinction of the Axolotl, and a Kahoot! game with questions related to the show's content. Between each activity, the robot and the explorer exchange dialogues

emphasizing the importance of preserving the zone as a Cultural Heritage site and some engaging trivia. In the end, 'Taxo' reappeared with a concluding message, encouraging the audience to be more conscious of their environment and cultural richness and to share their learnings of the event with their family and friends. The event successfully attracted an audience of 100 people, including 40% children.

The execution of the project was successful due to the support of 10 Tecnológico de Monterrey students from various disciplines, including mechatronics, robotics, electronics, and biomedical engineering. These students served as staff in various roles, including managing event logistics, developing material for the activities, and promoting the event. On the day of the show they fulfilled the role of animating the crowd and ensuring everything was under control. For the technical part, the project had the support of an animator and a person with voice-over experience, who both were responsible for bringing the character of 'Taxo' to life in the interventions that happened in the show.

D. Fostering the participation of Women in STEM through NAO Robots

This project, executed by eight students (female=7, male=1) from diverse academic backgrounds including robotics, mechatronics, computer science, and biomedical engineering, was a unique initiative aimed at encouraging young women to pursue careers in STEM (Science, Technology, Engineering, Mathematics). It consisted of a one-hour presentation conducted at two high schools in Mexico: Prepa Tec Mexico City Campus, attended by 28 female students, and Prepa Tec Santa Fe Campus, with an attendance of 13 female students. The talk featured presentations of female STEM from the Tecnológico de Monterrey, nearing the completion of their bachelor's degrees. They shared personal narratives about their career paths and how these choices positively impacted their lives. The primary goal was to position these students as role models, thereby inspiring the young girls to follow in their footsteps and pursue STEM fields, contributing to the creation of a more inclusive society.

According to Eccles [27], the influences of family, school, peers, mass media, and the immediate social environment shape the expectations that girls and boys have of success, together with the self-concept of their abilities. Women are constantly affected by gender stereotypes and biases that make them feel unsuitable or incapable to perform in these fields, which can lead them to choose other careers, even though they have proven to perform well in STEM subjects during high school [28], [29]. This is a pressing issue as the absence of women from STEM education is a missed opportunity for those fields. Women bring a unique perspective that shapes and influences STEM disciplines, benefiting society. When women are not involved in the design of technological products, services, and solutions, the needs, and desires unique to women may be overlooked, and the resulting solutions are biased by not representing all users [30]. Another consideration is wages. According to Beede et al. [31], women with STEM jobs earn 33% more than comparable women in non-STEM jobs. By not pursuing careers in these fields, women may miss out on higher-paying opportunities, especially as the employment growth rate in STEM is three times faster than in non-STEM jobs [32].

There comes the importance of experienced role models to involve more women in the area. In a study conducted with

high school students in 2018, Zachmann [33] observed that exposure to female role models and gender-equitable teaching strategies improved female students' attitudes toward STEM, having an increased confidence and interest in a future STEM pathway.

This background is what made the project so significant, as the audience consisted of girls about to decide on their future careers. Following the presentation by the role models, two NAO robots were introduced to personify iconic female figures in history: Marie Curie and Katya Echazarreta. The students designed costumes for the robots, enabling them to fully embody these STEM figures, and then narrated their stories through role-playing. The NAO robot representing Marie Curie reenacted key moments in her career, discussed her discoveries, and answered questions about the challenges she faced as a woman in science. For Katya Echazarreta, the NAO robot simulated a space mission. It explained the mission stages, the role of an electrical engineer in such a mission and demonstrated some basic principles of space travel and engineering. The robot also recounted her journey as a woman in STEM and the challenges she faced in becoming a crew member on a space flight. The audience was able to interact with the robot and ask questions. At the end of the session, a space for discussion was opened, where the audience was encouraged to share their thoughts about their future careers. The event also served as a networking opportunity, as many of the girls obtained contact information from the speakers for further guidance.

III. RESULTS

A. Project I: "Enhancing Literacy Through NAO Robots: A Project with Special Olympics Mexico"

Overall, the collaborative effort between the Tecnológico de Monterrey and Special Olympics to carry out this workshop yielded positive results for the 30 participants involved. This was evident by comparing the first session with the last. In the first session, participants exhibited a lack of confidence in their reading abilities and appeared shy to participate in the activities. However, in the second and third sessions, there was a noticeable increase in engagement, reflected in their active participation and eager responses to the robot's prompts. The activities with the most engagement were the Q&A sessions after the robot's storytelling and the painting activity. Participants seemed eager to share their thoughts and reflections in both cases. Furthermore, the NAO robot proved to be a captivating tool. Its encouragement was observed to be crucial in motivating participants to share their thoughts and engage in the activities. The positive reinforcement fostered continued effort and helped them overcome frustration.

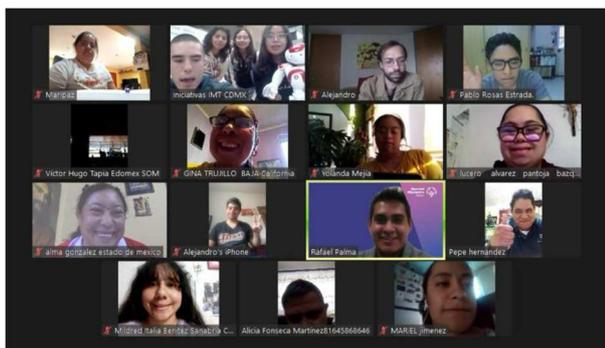


Fig. 1. Digital workshop with Special Olympics Mexico

B. Project II: Signs of Understanding: A Digital Workshop on Sign Language Awareness

This workshop, in collaboration with 'Instituto Lagunero de la Audición y Lenguaje, A.C.', successfully achieved its goal of raising awareness about hearing disabilities and Sign Language among the 20 participating individuals. Their deep engagement throughout the sessions, evidenced by insightful questions posed to the educators, served as a clear indicator of this success.

This engagement extended to the practical activities in the second session, where participants eagerly turned on their cameras to imitate the LSM signs taught by the deaf teacher. The NAO robot's teaching segment proved particularly exciting, with participants' enthusiasm prompting requests for the robot to do more.

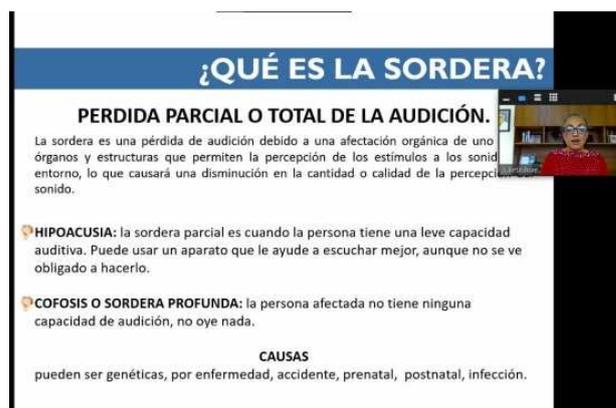


Fig. 2. Digital Workshop on Sign Language Awareness (first session).



Fig. 3. Digital Workshop on Sign Language Awareness (second session).

C. Project III: NAOxolotl: Preserving Xochimilco's Treasures through NAO Robots

This interactive show, designed to raise awareness among the 100 audience members, yielded highly positive results, particularly among the attending children. Throughout the show, participants were visibly excited to follow the plot of the story with 'Taxo', the NAO robot, and the human "explorer". The interactive nature of the show encouraged audience engagement through questions and requests for confirmation, to which they responded enthusiastically. This level of involvement extended to the activities, with the puzzle and Kahoot! game boasting the highest participation rates. The Kahoot! provided valuable insights into the audience's knowledge retention, with an impressive average accuracy rate of 85%, demonstrating effective information absorption and understanding of the situation in Xochimilco. Regarding the execution of the project, there were no setbacks, and everything was carried out according to the script.



Fig. 4. NAOxolotl educational show.



Fig. 5. NAOxolotl staff members.

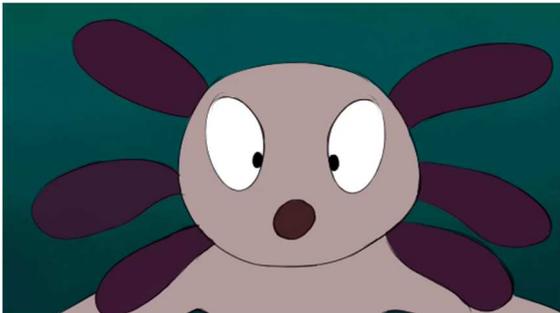


Fig. 6. 'Taxo' character animation.

D. Project IV: Fostering the Participation of Women in STEM through NAO Robots

This interactive presentation, which was held on two separate occasions at Prepa Tec Mexico City Campus and Prepa Tec Santa Fe, had an overall positive impact on a total of 41 young girls. It encouraged them to challenge stereotypes and consider new possibilities. A highlight of both events was the eagerness of many girls to obtain personal contact information from the speakers for future mentorship, as they were keen to delve deeper into STEM with the newfound confidence they acquired from the events. The NAO robots, personifying Marie Curie and Katya Echazarreta, sparked curiosity among the girls, evident in their keen interest in how the robots worked and their applications. Additionally, the participants were excited to take pictures with the robots, and some commented that they were previously unaware of the stories of the iconic women they roleplayed. The open discussions provided a safe space for them to express their fears, plans, and thoughts about their future careers. Some girls spoke openly about their initial apprehensions regarding

STEM fields. However, the encouraging words of the female speakers and practical advice on support networks and applying for STEM programs empowered some of these young women to seriously consider these career paths, suggesting a potential shift in their career aspirations.



Fig. 7. Women in STEM presentation at Prepa Tec, Santa Fe Campus



Fig. 8. Personification of Katya Echazarreta through a NAO robot.



Fig. 9. Personification of Marie Curie through a NAO robot.

IV. DISCUSSION

During the digital workshop conducted in collaboration with Special Olympics Mexico, the positive impact of

integration of robotics became evident. The organizers observed an increase in the attendees' level of confidence, and their readiness to participate in the activities. Al-Enezi [13] revealed that students with Down Syndrome incline towards kinesthetic leaning methods, which has correspondence with the reception of the workshops. The friendly look of the NAO robot, coupled with its extensive expression capabilities, eases communication, enhancing the learning experience and engagement with intellectually disabled individuals, showing off its potential as a special education and therapy tool.

Similarly, the remaining projects integrated the NAO robot to improve engagement. Its versatility allowed the raise of awareness on topics such as the importance of women in STEM fields, sign language, and the conservation of the axolotl, through dynamic activities involving storytelling and impersonation of iconic characters. Feidakis et al. [2] highlighted the pedagogical value of the NAO robot in particular, as it is capable of enhancing learning with high interactivity. The potential of robotic tools such as the NAO robot in education lies in the wide range of interactions it can provide, turning learning into an experience that stimulates students' senses.

V. CONCLUSION

A challenge-based approach in education proves to be an effective tool for involving students in projects achievable through the application of their knowledge and skills, while serving the community. Emphasizing the consolidation of understanding and the development of cooperation and communication skills is pivotal in the formation of STEM professionals. Providing students with the proper tools also boosts their capacities and serves as motivation for the competition of their initiatives.

The projects mentioned in the present document were initiated and fully maintained by students. Each project had culminated with a satisfactory outcome. Organizers of these projects are planning to further develop and improve their activities. It is important to highlight that the incorporation of robotics within these social initiatives allows the beneficiaries to have an unbiased interaction, leading to a more effective engagement, making them more likely to participate, contribute, and make the most of the initiative.

A. Project I: "Enhancing Literacy Through NAO Robots: A Project with Special Olympics Mexico"

A relevant limitation of this project was its virtual implementation. During the three sessions, we encountered setbacks due to participants' unfamiliarity with the Zoom platform. Some lacked basic knowledge of features like using chat, turning on and off cameras, and managing microphones. This required staff intervention for technical support. For future applications of this workshop, a key area of growth would be designing it for physical implementation. This would not only facilitate activity execution but also enhance the impact of human-robot interaction.

Another challenge arose from the original planning. Due to varying participant engagement speeds, some scheduled activities had to be omitted to maintain the one-hour session duration. In future implementations, including a 15-minute buffer in activity planning would be highly recommended.

Going further, future studies may involve building upon this model to create sustainable literacy programs. These programs could incorporate robot-assisted and traditional

methods for longer-term engagement and skill development. Tailoring these programs to the needs of individuals with Down syndrome would be further enhanced by partnering with educational institutions that could integrate the project into their own learning systems.

B. Project II: Signs of Understanding: A Digital Workshop on Sign Language Awareness

One of the main limitations of this project was its short duration. While the two sessions were effective in raising awareness among the audience, they did not provide enough practical skills for participants to communicate effectively with the deaf community in sign language (LSM) beyond basic expressions. Considering the NAO robots' engagement potential, a future study could explore using them as motivating agents in already existing sign language courses from recognized institutions.

Another limitation was related to the robots' three-fingered design, limiting their ability to accurately represent certain signs. This limitation orientates the robot's role to be focused more on motivational engagement than sign language teaching itself.

C. Project III: NAOxolotl: Preserving Xochimilco's Treasures through NAO Robots

While this project was impactful for a broad audience, there are limitations that could be addressed for an even greater impact. The first is the high cost of execution, due to the wide range of technological tools and materials needed, as well as the cost of gifts that were given to the public during the activities. A future study could explore ways to significantly reduce these costs without compromising engagement, allowing the project to reach a wider audience. Another challenge is the significant time and personnel commitment required. Actors need weeks of practice; the NAO robot requires extensive programming to follow the script smoothly and staff needs to be properly trained to ensure the success of the show.

D. Project IV: Fostering the Participation of Women in STEM through NAO Robots

One limitation of this project was its small sample size, involving only 41 girls. This restricts the generalizability of the results. Future studies could involve larger and more diverse groups to provide broader insights. Another limitation is the focus on immediate interest and motivation. For greater impact, future studies could be designed to track participants over time, gauging the project's long-term impact on career aspirations and STEM engagement.

Furthermore, to gather more data and better measure the project's impact, a quantitative analysis of career aspirations and choices could be conducted. This could involve surveys and observations to track changes in participants' career paths and choices over time after they participated in this interactive presentation.

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