A novel Collaborative Online Robotics Platform to address engagement and social emotional challenges in remote learning environment

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***Abstract*—In this WIP-Innovation Practice, the authors present a shared Collaborative Online Robotics platform embedded in Google Slides application for students from primary grades to University to enhance the learning and teaching process in online and blended/hybrid environments. This Computer Supported Cooperative Work (CSCW) system is intended to facilitate an immersive experience in a collaborative virtual environment by combining physical digital artifacts with remote STEM-based instruction. Particularly relevant during COVID-19, it also helps connect students potentially isolated by other factors (geographic, economic, environmental, health limitations, etc.). In this paper we present a first approach to the performance, acceptance, and adherence to a novel remote collaborative platform that facilitates STEM and Social Emotional Learning (SEL) enhanced by the interaction of a multiple-users with a LEGO MINDSTORM EV3 Robotic platform based on the Positive Technological Development (PTD) framework.**

***Index Terms*—robotics, education, e-learning, online STEM, Social Emotional Learning**

I. Introduction

Online learning, mostly associated with students at the university level before the COVID-19 pandemic, is now a closer reality to lower education levels. This shift on the learning and delivery teaching requires adjustments to address the differences from learning and teaching in face-to-face environments to remote learning, preserving child development and maintaining motivation and engagement in learning.

Advances on the internet and emerging technologies have favored developing a wide range of educational robotic technologies. They aim to support robotics learning, from web-based platforms that allow connectivity with multiple robotic devices (e.g., MakeCode [1], OpenRoberta [2]) to simulated robotics environments (e.g., CoderZ [3]). Nevertheless, physicality with the robotic platform is a commonality in using those approaches that combine software and robotic devices limiting their use for affordable in cost, space and time to use them, bringing disadvantages for distance instruction when experimenting with robotic platforms. Robotic simulation software has proven to be a solution for the limitations of the physicality using robotics devices. However, some studies reported that interacting with real devices, specifically in distance learning environments, add the opportunity to work in real scenarios and constraints that nurture the learning process [4] [5]. Besides, another common limitation of previous approaches is that group interaction and collaboration in real-time is not supported. Both interaction and collaboration are desirable in distance learning for avoiding learning isolation and lack of social presence affecting student motivation [6].

Social Constructionist Learning theory supports that interaction and collaboration, which includes the engagement of learners to solve challenges together, affect the learning and knowledge construction because learners are motivated to study together to assist each other in developing their understanding of content [7].

Some different strategies can be adopted to overcome the distance barrier in hands-on activities, such as providing a home kit to students or reducing the experimentation to teacher demonstration. Still, sometimes it is not always possible and depends on the goals of the learning outcomes [8]. Other approaches at the university level have been the development of remote laboratories. Although these solutions demonstrated their potentiality and start to provide secondary students' service, some considerations have to take into account when using them at earlier levels [9].

Based on the previous aspects, educational advantages could be achieved from combining remote access with robotics-based activities in synchronous collaborative learning, especially for practical experiences in robotics and STEM subjects

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and development of social-emotional learning skills beyond skills related to those fields.

This web-based platform is based on the collaborative online framework that Google cloud offers with a synchronized communication in real-time with conference technologies like Google Meet, where teachers and students will be enabled to share practical experiences. In addition, the system allows for tracking the student's learning progress, integrating and combining different educational tools and applications to support teaching to enrich the student's learning process. Besides, the system's distributed nature can be used and applied for facilitating flexible layouts that allow in-person, remote, blended and hybrid learning and teaching modalities.

II. Work Context

To understand the context where we consider that CORP contributes positively, we need to map it with the context of robotics in education, distance learning, and remote laboratory.

A. Robotics in Education

It's not new that robots have been used to enhance education. Theorists of education, like Papert, promoted robot-based activities to improve classroom teaching [10]. Educational Robotics (ER) provides an immersive context for understanding mathematical, technological and mechanical language and systems (STEM Education); accepting and adapting to constant changes driven by complex environments; and utilizing knowledge in real situations or across time, space, and contexts [11]. In additional benefits added by ER, we see that they make possible the development of teamwork, problem-solving, and creativity [12]. In [13], authors show that robots, user manuals and instructions included in problem-solving activities could help learners link the experience to STEM concepts. LEGO ® Robotics has demonstrated one of the best results considering some evaluated criteria (modularity level, hardware, curriculum, price, etc.) [12].

These pieces of evidence support the use of Google Slides with guides prepared by the facilitator, and LEGO-based activities, as an optimization process to learn better. And to overcome the lack of standardization of teaching practices or methodologies for evaluating results described in [11], we have proposed the theoretical framework of Positive Technological Development (PTD) as an alternative to assess and track students' engagement during the activity.

B. Distance Learning, Online Learning, and Blended Learning

After the consolidation of the internet as a general communication media, acquiring skills and knowledge has been disrupted in different ways. One of the most relevant is the channel of knowledge transfer between the real world and the digital world. Based on these channel characteristics, we can identify distance learning, online learning, and blended learning. Distance learning occurs when the teaching and the learning process occurs in a different location. Online learning is a type of distance learning where everything is delivered using the internet. In some cases, there is a combination of both factors, physical presence and online educational tools. In such cases is when we refer to a blended educational system [14].

Nowadays, blended learning has become the most effective instruction adopted because it enhances efficiency, flexibility, timely and continuous learning [15]. One of the conclusions of the study presented in [15], is that the biggest challenge to adopting an efficiently blended learning process is the teacher's reluctance, illiteracy and incompetency level to use such technologies, augmented by the fact that students are more proficient and technologically competent in using those tools. Because the success of educational technology relies on the capacity of educators to adopt it, we need to make these tools as seamless as possible. Following this strategy, we consider that using a Google-based technology, with over 60% of the educational market [16], increases the already mentioned adoption factor.

CORP can be used online or in-person, and combining the CORP sidebar with the educational material attached to the Google Slides ensures the principals for an effective learning experience in internet-based tools: simplified material, clear step guidelines, and real-time support of the classmates and facilitator [17].

C. Remote laboratories in K-12

Remote laboratories (RL) or web labs are software applications that allow students to control and interact with real devices and experiments over the internet remotely. In the past decades, RL have been developed in different fields [18] by universities for fulfilling the gap of experimental learning and educational objectives of conventional classroom education. Recently, RL started to approach schools (e.g., [19], [20], [21]) and as an European projects like [22]. Sustained by resources based on information and communication technologies, these systems present benefits that overcome limitations in costly hardware, accessibility, maintenance and so on [23]. Beyond the technological features, findings in the literature suggest their potentiality and positive impact on students' skills (e.g., data processing skills [24]), attitudes and conceptual understanding [25].

Nevertheless, some drawbacks appear on the move of using RL: the dependency of the university and labs' developers, time availability of the experiment and lifetime, limited scalability and multi-user access, scarce real-time collaborative learning and feedback during the learning processes, difficult to follow the student's learning path, learning by trial and error and flexibility in terms of varying the experience.

The approach presented in this paper tries to sustain the limitations and needs mentioned above, based on an alternative remote lab infrastructure based on the Google cloud platform and LEGO Mindstorm EV3 robot.

III. The CORP environment

We present this work as an alternative architecture based on an existing environment, Google Cloud, to accelerate the solution's adoption and scalability based on the already existing users within the K-12 education. CORP is a cloud web-based environment that provides a flexible and collaborative space for promoting collaboration, interaction, and active learning [26]. The system combines physical robots with remote STEM-based instruction where students in the K-12 range experiment with robots, improve their knowledge and STEM and SEL skills and engage with peers in the learning process. Additionally, the platform is intended to facilitate teaching work and processes by integrating robotics for instructional purposes and addressing the needs of virtual robotics instruction.

A. Architecture

CORP is accessible from a computer, tablet and iPad connected to the Internet by means of an internet browser and a free Gmail account not requiring installing additional software. CORP is based on an application developed in Google Slides (one of the educational packages for online presentations inside of Google accounts). From a conceptual point of view, CORP architecture can present two topological configuration depending on where students are located as we can see on Fig. 1.

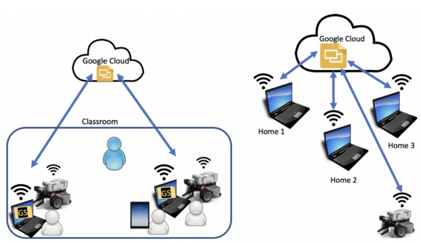

Fig. 1. CORP System. Left side, students working in the same space. Right side, students working from remote locations.

The overview of the software elements is shown in Fig. 2. They are built on Google Slides, Google Meet, and LEGO Mindstorms EV3 software using several programming languages and applications.

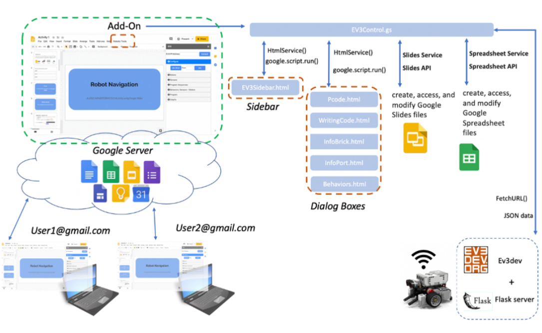

Fig. 2. Overview of CORP Architecture.

B. User Interface

The environment has been developed leveraging the Google Slides application's potentialities: (1) it is a free web-based environment for presenting; (2) is a working space that offers an easy way for delivering the content and the teaching materials of the learning sessions as well as the students' workbook; and (3) its functionalities can be extended by implementing customized applications to interconnect directly with many other G Suite and third-party services and systems over the Internet.

In this case, a custom application has been developed integrated in Google Slides to interact with the LEGO Mindstorms EV3 robot. Furthermore, it empowers the connection between the robotic system (Flask Server at the LEGO Robot) and the Google cloud services (slides, spreadsheet, etc.) through a sidebar (Fig.3) composed of multiple dialog boxes. This structure allows real-time coding, sharing, and reporting through a merging of existing Google Slides functionality with a web-enabled sidebar additional for directly connecting to the physical robots (locally or remotely located).

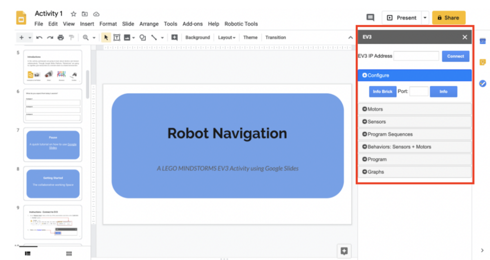

Fig. 3. CORP User Interface: the Slides (left side) and a custom Sidebar application (right side) to interact with the robotic device

IV. Positive Development Framework

The theoretical framework of Positive Technological Development was introduced in [27]. Its mission is to evaluate how technology educational settings help to develop children's skills and behaviors positively. It can be used to consider and iterate the design of new technological tools for education. The six behaviors, which can be related to Social Emotional Learning (SEL) skills and that improve engagement with technologies in the classroom identified in PTD are: communication, collaboration, community building, content creation, creativity, and choices of conduct.

The PTD tool is organized in six sections related to the six behaviors mentioned before. Each section includes a description and an evaluation scale from 0 "Never" to 5 "Always". It is designed to be used once or several times during the activity. Its objective is to get quantitative information regarding the observable behavior. Suppose the observer repeats the measure with a group of participants. In that case, the tool provides group-behavior understanding, and if it is applied several times over time with the same individual, we can extract trajectories of her/his behavior [28]. In [28], we can also see a case study where the most significant data obtained is related to fostering content creation, communication, and collaboration, all of them associated with the SEL process.

The PTD checklists used in this portion of the study are based on existing checklists proposed in [29], but refined for clarity and to reflect the affordances of the study. The measures are categorized into six sections according to the behaviors in the PTD framework where all items are rated on a 5 Likert-type scale. We used two PTD checklists; one for the environment and the facilitator [30], and the second one for each student [31].

V. CORP Study

The study consisted of four two-hour long sessions, once per week, for four weeks. Nine participants located in the United States of America and their primary language was English, with ages between 10 to 17 years old (mean=13.78, SD=2.77) were recruited (before testing) for the study.They were randomly assigned in groups of 2-3 participants maintaining similarity in age. All were new users of this platform and participated in the study remotely. The sessions consisted in activities and challenges: the mechanics of motion, sensors, sensor data logging and programming. "Roboticists Learners", using CORP, gave instructions collaboratively to the robotic system and documented their processes developing their STEM and SEL skills: Self Management (goal setting and following instructions), Relationship Building (communication and cooperation), Social Awareness (turn-taking and appreciating diversity), Self Awareness (confidence and efficacy), and Responsible Decision-Making (problem-solving).

The data collected were: 1) Notes of direct observation on user's performance with the platform; 2) Video recordings to analyzed users' behavior and problems. During the sessions, users were invited to think aloud, verbalizing their thoughts when interacting with the platform to identify the significant misconceptions and 3) the results of the modified PTD observational checklists mentioned in the previous section.

Next, we present the results of the four sessions to validate the approach of using the PTD framework to evaluate the hypothesis of the learning space's benefits (performance, acceptance, and adherence) where robotics in education, online and blended learning, and remote labs are combined.

VI. Results

The PTD results of evaluating CORP from the point of view of the environment and the facilitator are: Communication (4.33), Collaboration (4), Community Building (4), Content Creation (4.33), Creativity (4.33), and Choice of Conduct (4). We have identified that it empowers a lot the communication because of the attributes of Google Cloud services, already designed for such purpose and allow students to express themselves and customize the environment.

The results of the PTD Engagement for Tasks and behaviors for the average of all nine students are represented in Fig. 4. For every general behavior, the mean, the Standard Deviation, and the confidence interval considering a confidential error of 1.96 are: Communication (mean=0.78 and SD=0.3), Collaboration (mean=0.87 and SD=0.16), Community Building (mean=0.48 and SD=0.17), Content Creation (mean=0.88 and SD=0.14), Creativity (mean=0.86 and SD=0.23), and Choice of Conduct (mean=0.96 and SD=0.08). We can appreciate a very good engagement in communication, collaboration, content creation, creativity, and Choice of Conduct. The only challenge detected is the Community Building, mainly because the slides' content was very much oriented to focus on the activity and non-being distracted. In addition to that, one of the subjects was completely driven and over-controlled by one of the parent guardians. This situation prevents the student from participating more.

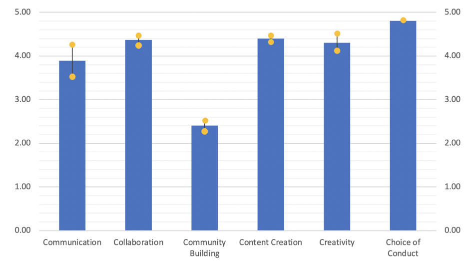

Fig. 4. PTD Engagement Checklist Task/Behaviors

VII. Conclusions and Future Directions

The initiative presented in this document aims to provide a learning environment to support and enrich the teaching and learning process by taking advantage of the accessibility, scalability, and integration with existing tools already familiar to users provided by cloud technologies like Google Cloud Platform and the G Suite of services. The system offers new ways to expand educational opportunities by facilitating access for students and teachers to robotic technologies to foster STEM learning and programming skills, improving the quality of learning experiences, and extending learning beyond the school environment.Using LEGO Robotics as the robotic platform, we have validated that we cover all challenges of Educational Robotics, Online and Blended Learning, and Remote Laboratories presented in Section II by using the PTD framework introduced in section IV. We have learned that by customizing the activities' content with the participants' contextual environment, we can increase community building. In addition, we experienced the interference of a parent guardian who overtook the participant's role, avoiding the SEL experience of the other participant. This experience was extended in all four sessions. However, more experiments are needed to consolidate this finding. COVID-19 restrictions are driving drastic changes to the educational landscape, there exists a great need for running high-quality online workshops that help remote participants to develop their STEM abilities in tandem with SEL skills.

In future directions, we plan to combine the results presented in this paper with the usability study (SUS) and related data collected. Also, we are planning to conduct more studies with more participants, consolidate information related to participants' gender and age, and involve more the teachers' community to get their feedback and needs when interacting with the platform.

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