Global STEM Education through e-Service Learning in the Time of COVID-19: A Case Study

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***Abstract*—COVID-19 has brought about a lot of disruption, and education was one of the areas that was very significantly impacted. In many places in the world, students and teachers were forced to learn or teach online, oftentimes with very little preparation, in other places, schools shut down altogether and students' learning was interrupted. In this paper, we describe a case study that attempts to alleviate some of these challenges through an online STEM workshop series. Focus group studies were used to inform the design of the workshops, which were run as part of a service-learning program, incorporated student-directed, tangible learning, virtual experiential learning alongside theoretical content delivery to complement the formal curriculum. We present evaluation information as well as lessons learned for future similar endeavours.**

Keywords—STEM Education, Service-Learning,

I. INTRODUCTION

STEM education has become a global trend that an increasing amount of educators have viewed as foundational to student learning, especially for undergraduate and K-12 students [1]. It is considered a transdisciplinary pedagogical approach for teaching and learning where all teachers guide the students on applying knowledge and skills from science, technology, engineering, and mathematics to solve real-world problems [2,3]. Studies from the United States show that the research in STEM is expanding, and the most common themes addressed were integrative STEM, program implementation, and impact on students [3,4]. Studies have shown that the benefits of STEM education include making students better problem solvers, innovators, inventors, self-reliant, logical thinkers, and technologically literate [5]. Also, integrated STEM pedagogy has a positive impact on student attitudes and interest in school [6], their motivation to learn [7], and achievement [8]. For example, the University of Washington designed and implemented an afterschool STEAM program for underrepresented students in grades 4 and 5, aiming to develop their confidence and interest in STEM fields [9]. Also, Kintsakis [10] developed and conducted a pure remote programming-based STEM project for grade 5 primary school students. Results showed that feasibility and efficiency of the eLearning approach could be maintained, compared with the traditional face-to-face strategy.

However, by the end of 2019, Coronavirus (COVID-19) started to be seen for the first time and gradually turned into a pandemic. It has required the cessation of activities in many areas, suspension and change of functioning. Social contact was limited, and educational institutions have been forced to move the teaching and learning to virtual platforms [11]. Distance teaching was introduced to replace traditional face-to-face teaching in a physical classroom [12]. The sudden transition to distance teaching raises concerns about its educational quality, especially the area requiring intensive practice and hands-on experience. Also, most STEM implementations are carried out in face-to-face setting [13,14]. Under this sudden transition, numbers of STEM activities in school were cancelled and only small proportion of them moved online [15,16].

While integrating distance learning into STEM education, several studies examined the practices and effectiveness. For example, Evagorou [15] shared their experience and practices on delivering a virtual STEM fair. Due to lack of experience with online teaching and learning, the researchers found that the major challenge was how the teachers could transform the STEM activities to help them interact with the audience. Ozdemir [16] analyzed the opinions of science teachers who conducted online STEM courses during the transition to distance education during the COVID-19 pandemic. The teachers reported that online STEM implementations were challenging, and the process was complicated. They have to spend extra time and effort to prepare the lesson. Also, they had difficulties in time management and suggested the lesson time could be reduced to 30 minutes. Regarding the students, teachers stated that the learners did not take distance education classes seriously, attendance was not sufficient. Also, connectivity and infrastructure problems had a negative impact. Coleman et al. [17] studied the effectiveness of parent communication and engagement in an online STEM activity. This research showed that educators should deploy a multi-layered communication approach to engage families and maintain parent connection which this was not required in face-to-face setting.

In summary, on one hand, online STEM implementation can contribute to developing students' 21st-century skills, such as problem-solving, accessing and analyzing data, and critical thinking [16]; on the other hand, educators, students, or parents are facing different difficulties and challenges.

This paper shares a case study of implementing a global STEM education program for grade 1 to grade 3 learners in Hong Kong, Vietnam, and Cambodia. The program was conducted through an e-Service-Learning course which is available to all undergraduate students. Followed by the outline of the project design and course model, challenges and lesson learnt are discussed. To understand the impact of online STEM education programs on the community, course coordinator, and university students, quantitative feedback was collected and examined. Finally, we conclude this paper with the best practices of conducting distance STEM learning programs.

II. Project Background and Design

The University has a long tradition of organizing STEM-related service learning projects in local and offshore communities. Since 2005, our students have contributed over 70,000 man-hours of services to underprivileged communities, serving in Hong Kong, China, Cambodia, Vietnam, Rwanda, and Myanmar. Starting from 2012, service learning is a mandatory graduation requirement for all full-time undergraduate students. The courses are open-to-all general education type courses, and students have choices over when and which subject to take to meet the requirement. All of the subjects carried three credits with approximately 130 hours of students' work, including 60 hours of teaching and project preparation, 40 hours of direct services closely linked to the academic focus of the subject, and 30 hours of structured reflective activities.

Our case study is a 2-semester service-learning subject offered by the Department of Computing named "Socially Responsible Global Leadership in a Digital World", which is open to all undergraduate students and enrolled 40 students in the spring semester in 2019/20 cohort. The objectives of this course are:

1. To introduce the concepts of socially responsible leadership and global leadership, and to facilitate students to practice and demonstrate these competencies in practice;
2. To acquaint students with significant issues of social needs, justice, and ethics related to the information age, such as the concept of the information divide and how technology may be used to meet these needs; and
3. To nurture a sense of civic responsibility and engagement through engineering or STEM-related services.

The service project, which is required of all students enrolled in the class, involves conducting a series of STEM workshops for groups of primary schoolchildren, aged between 7-10, in Hong Kong, Vietnam, Cambodia and Rwanda.

Due to the COVID-19 pandemic, the services had to be arranged online. Our community partners were a primary school (Hong Kong), and three grassroots non-government organizations (Vietnam, Cambodia and Rwanda.)

To ensure that our services would best serve the community, we conducted a semi-structured community assessment with the community partners to assess the impact of the pandemic upon our target primary students. As expected, the situations varied quite significantly between locations due to differing COVID-19 situations and the pandemic control measures taken by the local authorities, as well as the infrastructure level. For example, while all classes had been suspended for the Rwanda and Cambodia schoolchildren that we were working with, the Hong Kong schoolchildren had continued to attend class, albeit in online form. Hong Kong primary school teachers thus mainly struggled with trying to duplicate the hands-on, kinesthetic learning from labs and exercises online, while our other community partners struggled with trying to supplement their community's children's learning in the face of the digital divide and poor infrastructure.

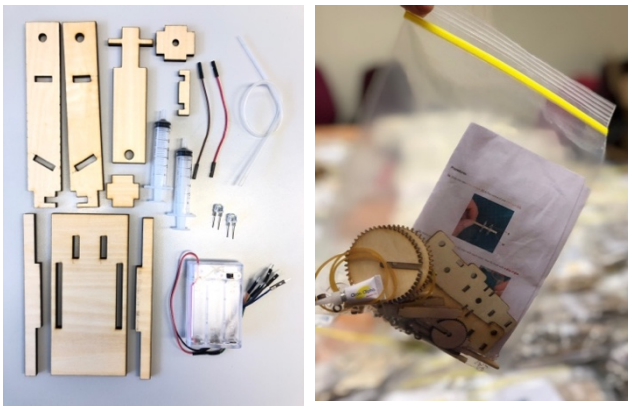

Figure 1: Tangible kits for teaching STEM. (Left) hydraulic arm, (right) rubber-band powered car

Given our findings, the following design principles were established for setting up the STEM projects:

1. Compensate for tangible and self-directed learning experiences that were missing with online teaching. STEM is traditionally a "high-touch" learning activity, with labs and other similar learning activities allowing students some self-agency [18]. However, many of the tangible experiences are lost with online learning, with online simulation replacing hands-on laboratory experiences; and student self-directed learning replaced by one-way teacher-driven teaching. Many of the primary school teachers that we talked to felt that this decreased the effectiveness of the STEM classes.
2. Engage students and ensure individual attention and encourage real-time feedback. One of the casualties of online teaching is the loss of proximal and spatial information, which then translates into loss of real-time feedback from students and individual attention from teachers. The teachers that we spoke to observed that children with special educational needs and less self-

confidence did not feel comfortable and rarely voiced out during Zoom lessons.

III. Project Implementation

Given the aforementioned principles, our STEM workshops were designed to have the following features:

1. Tangible building kits and hands-on equipment was incorporated into the lessons. For example, a lesson on forces was complemented with two kits: one for building a hydraulic arm, and another for building rubber-band-controlled cars (Figure 1). Some other activities incorporated equipment with materials that students were expected to find at home. For example, a lesson on botany was supplemented with USB microscopes that children could use to view leaf samples and make observations. This allowed us to incorporate self-directed learning into the activities and allow the children some self-agency.

2. In addition to hands-on learning, experiential learning was incorporated into the lessons. Since the children had been cooped up at home because of social distancing, it was felt that it would be beneficial to include field trips, conducted virtually. Google Cardboard virtual reality headsets, which were cheaply acquired, were used for these learning activities. The university students shot some of the VR content themselves, negotiating with sites that the schoolchildren would normally get to visit on field trips to allow special visits to create content. Other VR content was found from YouTube.

Figure 2: 360 video of Ocean Park Conservation Center, a popular field trip locale for primary students before the pandemic.

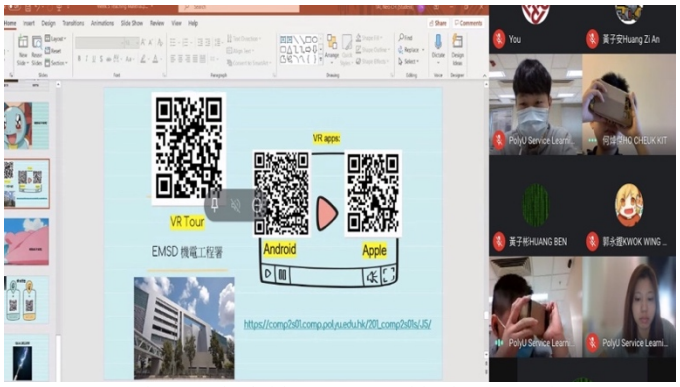

Figure 3: Working with children to assemble their Google Cardboard VR headsets

3. The incorporation of self-directed activities meant that there would be discrepancy in the progress of the children, which would be further exacerbated in a large-class, online format. Therefore, we departed from the usual mode of hosting workshops that resembled normal lessons, with a class of students being simultaneously taught by one teacher. Instead, we adopted a small group teaching mode, where the children would be divided into groups of no more than 5 or 6, and each group taught by two or three university students. This ensured that even if some learners fell back in their progress, a teacher could always help them separately while not holding the rest of the class back (using breakout rooms if necessary); it also encouraged rapport and relationship-building between the university students and the children, which we hoped in turn would help to engage the children and ensure enough individualized attention. It also ensured that the university students, who were responsible for actually delivering the workshops, would have support and backup from their peers.

4. Different online platforms were also used to improve the interaction, encourage real-time feedback, and facilitate keeping track of the children's learning progress. These included co-creation platforms such as whiteboards or bulletin boards, and gamification elements such as voting systems. Similarly, hardware equipment such as visualizers were used to better support the hands-on activities, such as building the STEM kits or conducting experiments.

The STEM workshops were held between August to October 2020 and involved 275 children in Hong Kong (160), Vietnam (51), Cambodia (56) and Rwanda (8). The majority of the sessions were hosted by two university students and involved 3-5 primary school children. However, there were some exceptions. Due to logistical challenges with recruiting translators, the Vietnam and Cambodia workshops involved 8-10 children. The Rwanda workshop, on the other hand, had challenges with poor IT infrastructure, and ultimately only around 8 primary school children could participate. They were taught by 4 university students. Due to social distancing regulations, the Hong Kong and Rwanda workshops were held in the children's homes; the COVID-19 situation in Vietnam and

Cambodia was less severe at that point and the workshops were held in community centers.

Each workshop consisted of 5-10 sessions, lasting between 2-3 hours each. To accommodate the attention span of the children, the content delivery sessions were interspersed with hands-on activities, which were timed such that the maximum time spent on one-way learning activities at any one stretch would be no more than 30 minutes.

The majority of the sessions went smoothly, though there were a number of commonly-encountered challenges that occurred throughout the workshops. Chief among this was the digital divide, which manifested itself in poor connectivity and frequently-interrupted sessions with the groups in Vietnam and Rwanda.

Even without the connectivity issue, the digital divide still manifested itself in the form of a skills divide. For example, many of the children in Hong Kong were supervised by grandparents to connect the children to the sessions while parents were working. A group of students who used <redacted> (the name of our university) as the password for the Zoom class, found that the grandparent who was supervising the child that day could not type and did not read English, and thus had to be helped to log into the Zoom session by the teacher!

Figure 4: Student conducting a session. The visualizer is used when working with the tangible STEM kits.

IV. Community Feedback

Since our participants were children, feedback was invited from the community partners and parents in lieu of directly evaluating the children. Much of their feedback was very positive. For example, our community partner in Cambodia wrote:

"The children really enjoyed the sessions. They got to experience virtual video through Google cardboard kit. They said 'Wow, they feel like they are in the ocean and the whale and shark are so close to them'. The kids said 'I can't wait to show this to my parents in the village.'"

Figure 5: STEM session in Cambodia. Due to translation logistics, the number of children being taught at the same time had to be increased.

A Rwanda parent wrote:

"Very thankful to you all the great job done teaching our children, supplying the required demonstration materials and everything you did. The kids have surely enjoyed the sessions!"

And Hong Kong parents wrote (translated):

"Fantastic! In addition to learning STEM, there was also conservation, and language learning! Very constructive! Thank you!"
"Even as parents, sitting there we learned a lot."

Figure 6: Hong Kong parents' testimonials (on WhatsApp)

V. Student Reflection

Since this was a service-learning class, the learning of our own university students is also important and also forms part of the evaluation of this project. From our students' reflections, most of their learning gains centered around the digital divide, and the challenges that arose from it:

During the workshop … the connection kept on getting disrupted. After an hour of trying to connect with them, we decided to end the call and think of various solutions to make them have access to our workshops. One solution proposed was to provide the internet. This became a discussion topic whether the parents would feel weird and embarrassed if we gave them better internet access, or if that providing them the internet

would mean looking down at them and the facilities they had by providing better equipment. Even though it may seem fine for us, we never know what they would feel, if they feel grateful that their children are having access to education after months of not going to school or embarrassed. Oftentimes, we are so used to having some privileges we take them for granted. Having internet access became so normal, especially when we are having online learning. To us, having internet access is a necessity in our daily life. However, to the Rwandan children, having access to the internet is a privilege for better education.

- *Year 2 student from Design*

Some students spoke about adapting to uncertainty:

"The most significant skills I learnt is problem-solving, flexibility and adaptation in a short time. The nature of the service was changed from solar system installation in Cambodia to STEM classes in Hong Kong. Also, I need to modify the service from face-to-face to online lessons. All issues that happened were required to resolve immediately. Therefore, 21st-century skills are acquired, which will be helpful in further contribution to the community. We must face obstacles every day; we need to solve them or adapt to them."

- *Year 1 student from Industrial Engineering*

And some students spoke about the impact on the participating children:

"Personally, I mostly want to bring caring and connection to the kids. Being lockdown is a double-edged sword. Some children are able to have a better connection with their parents, while some might be stressed. For those happy kids, I wish my class would have offered them space where the family can work together to finish the STEM kits. For those lonely kids, I wish it was a place for them to communicate with the university mentors as a new friend. COVID-19 took away the chance of meeting friends with the kids. Some of them might not be able to talk to their friends if their parents did not help them. Therefore, this STEM workshop can not only bring knowledge to them but also caring and happiness."

- *Year 4 student from Nursing*

VI. Lessons Learned

Tangible Teaching Kit: Incorporation of the tangible learning into the STEM workshops appeared to significantly increase the children's motivation and improve the learning atmosphere. Even though our kits could have been replaced with simulations, a simulation would not have afforded the children the hands-on learning in terms of putting the parts together, and problem-solving when certain parts did not fit properly. Completing the task was therefore a lot more rewarding and the children felt a bigger sense of achievement as a result.

Parental Involvement: In the workshop sessions that were held in the children's homes, parental (or guardian) involvement was observed in ~42% of the Hong Kong sessions, and in 100% of the Rwanda sessions. Although this was intimidating for the university students conducting the sessions at first, the parents/guardians were able to help out by providing troubleshooting when necessary, for example, when internet interruptions happened or when the child had trouble with the tangible kit. Our partner primary school also suggested that this improved the relationship between children and parents, as the parents could have a better understanding of how or what their child was learning.

Technical Training to NGO: Designing and offering the workshop sessions afforded us an insight into the difficulties that primary school teachers encountered during the pandemic and online learning. The teachers that we talked with had low confidence in their ability to transform their usual face-to-face teaching to online mode [19], and as such, they tended to spend a larger proportion of their own online classes on teacher-directed content delivery rather than student-directed learning. Towards the end of the workshop series, our primary school partner arranged for some of their teachers to observe the workshop sessions as a form of observational learning.

Our NGO partners in developing countries faced a different set of issues. They had less experience with computer equipment and online communications, and their infrastructure was also less developed. It was critical during the design of the workshops to help them to bring their infrastructure up to speed – for example, we helped one of our partners to identify a solution to their slow internet (by substituting cellular data) which they had not been aware of before. In addition, it was also necessary to provide feedback even in the setup of the room where the workshops would be conducted, such as ensuring the distance between the children to the computers, the placement of the microphones and the cameras, and the positioning of the translators.

Provide a Connection to the World: The COVID-19 pandemic enforced social distancing in most regions, and many places even had to endure a hard lockdown. In the case of our primary students from Hong Kong and Rwanda, many of them had not been outside of their home for several months by the time the workshops started. We observed that teaching content that was relatable to the outside world, such as our virtual field visits and discussion about botany and conservation, helped to increase the motivation of the children, as opposed to simply teaching about theoretical concepts.

Provide extra preparation & training to the university students: Classroom management in an online setting is quite significantly different from classroom management in a physical setting, and our university students who were teaching the sessions also needed additional preparation and training on top of the usual classroom management skills. These include appearance-based topics such as how to appear in front of the camera and how to speak through a microphone, as well as training on available virtual tools and platforms.

VII. Conclusion and Future Work

In this paper, we have thus presented a case study of using service-learning – a common teaching pedagogy in many universities and even high schools – to solve a very pressing problem for the community. Even though the university students who were conducting these sessions were not trained teachers, they were still able to deliver a much needed service to the community, alleviate the workload faced by the primary teachers, and supplement lessons with hands-on activities.

Going forward, we see the massive development and expansion in online communications platforms that was catalysed by COVID-19 as an opportunity. Online communications does offer possibilities that are not possible with face-to-face interaction, and we plan to expand our online teaching services to investigate some of these opportunities.

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