What Informal Learning Programs Teach Us About Adaptation to Contactless and Remote Learning Environments

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***Abstract*—The COVID-19 pandemic forced a paradigm shift in *how* educators incorporate STEM educational activities into remote online informal experiential learning environments for high school students. While some primary and secondary institutions were "technically equipped" to seamlessly transition to an online lecture format using video conferencing platforms such as Zoom and WebEx, others were not. Instead, many instructors were not armed with the pedagogical educational infrastructure, training, and assessment tools to elucidate how concepts were presented, absorbed, and retained by students. Experiential learning programs for high school students have been uniquely impacted by this mercurial set of circumstances, where eager students and parents seek venues for engaging in meaningful learning experiences. This work-in-progress explores and compares the experiential programmatic changes in a STEM program for high school students pre- and post-COVID, with the aim of beginning the conversation and exploration of how to deliver "hands-on learning" in a contactless and remote learning environment.**

Keywords—experiential learning, high school STEM program

I. Introduction

Many careers today require a solid foundation in science, technology, engineering, and mathematics (STEM). There is a need to expand the pool of talented professionals with the skillsets necessary to fulfill these roles. One way to facilitate this educational movement is to expose children to STEM fields early in their educational preparation. Additionally, inaccessibility to rigorous curricula such as Advanced Placement and International Baccalaureate STEM courses exacerbate existing achievement and opportunity gaps that often prevent underrepresented students from advancing in STEM. Acknowledging that a significant amount of high-potential youth exists in underserved communities, there is a need for enrichment intervention programs that identify and support yet to be discovered students who have the potential to thrive in STEM. To this end, many researchers have investigated the impact of STEM intervention activities on middle and high school students, where emphasis has been placed on the examination of longitudinal academic performance and persistence, interest and engagement in STEM education and programming [1-3].

However, the COVID-19 pandemic caused a paradigm shift in the structure of many informal learning programs, where traditionally hands-on and in person exploratory learning environments were canceled or modified to allow for remote learning. Less is known about how these types of programs adapted to a remote learning infrastructure and how these forms of experiences are influenced by the type of STEM topic covered in the program. *The purpose of this study is to initiate a discussion about this transition from in-person to fully remote learning environments.* This study explores this transition from hands-on to remote differences in a high school STEM program, the W.E.B. Dubois Accelerated Learning Academy (ALA). Two different tracks in the ALA were investigated: the Artificial Intelligence (Computer Science) Track and the Bioengineering and Technology Track. The two tracks were selected because one track primarily uses computers as the form of technology, while the other uses a myriad of technologies, e.g., Arduino Boards, circuits, strain gages, 3D printers, etc. Three research questions are posed to understand the parameters that influence the effectiveness of informal STEM high school learning programs.

1. *What aspects of remote hands-on activities are effective in students' perceived learning?*
2. *How are some disciplines of STEM adaptable/or not adaptable to remote hands-on learning activities?*
3. *Are some types of STEM activities more adaptable to remote learning environments than others, i.e., computer science-based and/or engineering?*

II. THEORETICAL FRAMEWORK AND PROGRAM ASSESSMENT

Experiential learning opportunities for middle and high school students, and in particular girls and underrepresented minorities, enhance their interest, aspirations towards careers, and achievement in the STEM degrees [4-7]. The WEB Dubois Accelerated Learning Academy (ALA) provides three weekend workshops annually that employ an experiential learning process to engage high school students in STEM. Of the three models of experiential learning, the Lewinian Model of Action Research and Laboratory Training [8] is traditionally used in the ALA, where students learn via a four-stage learning cycle. For this learning theory, students are introduced to the theory fundamental concepts pertaining to a STEM topic (in this study Bioengineering or Artificial Intelligence) and engage in a concrete activity as the basis for observation and reflection. The lecture material coupled with the STEM activity are assimilated into the morning workshop to allow them to deduce STEM implications that can be used for application to a more in-depth challenging activity. This more challenging activity allows them to form more abstract concepts.

The ALA program's effectiveness is evaluated according to Kirkpatrick's 4-level training evaluation model [9] that provides a concrete framework to establish evidence-based assessments, which capture multiple facets of the educational and outreach program. The research method used for the study is an exploratory research approach, where qualitative data was obtained from elements of the Kirkpatrick evaluation model.

III. WEB DUBOIS ACCELERATED LEARNING ACADEMY

The W.E.B. Du Bois Scholars Institute is a non-profit leadership organization for high-achieving students with the primary goal of closing the gap between opportunity, access, and academic achievement. Its mission is to develop a cadre of activist-scholars and leaders who excel both academically and professionally. The Institute empowers participants with the skills and confidence to function as "change agents" in their schools, neighborhoods, and communities, so they can better serve members of under-served communities.

The ALA is a STEM program for high school students in Medical Science, Biomedical Engineering and Technology, Applied Mathematics, and Artificial Intelligence. In ALA, students explore STEM content via group activities, lectures, and hands-on demonstrations, where scholars are taught by STEM professionals. In light of COVID-19, the 2021 ALA Program took place remotely via a web conferencing platform.

IV. RESEARCH DESIGN METHOD

An Exploratory Research Approach was used to answer the research questions posed in this study. The programs of investigation for this study are two different tracks of the WEB Dubois Accelerated Learning Academy: Bioengineering and Technology, and Artificial Intelligence-Computer Science. The workshops held in 2019 and March of 2020 were held in-person on the campus of Princeton University in classrooms where laptops were provided to students. The workshops held in January 2021 and March 2021 were held remotely. An overview of the research environment, pedagogical approach for both tracks is described below, where each workshop is broken up into a morning and afternoon session. Students were given a pre-survey at the beginning of the program (prior to the first workshop) and asked to answer a post survey after each workshop. In this work, the pre-surveys were given in January of each year of the program, i.e., in January 2019, 2020, and 2021. This pre-survey was used to understand student's preliminary knowledge of the subject matter of the given workshop theme. The post-workshop questionnaire was administered at the end of each workshop. The questionnaires were administered using google surveys. Participants answered the surveys using their smart phones. Students were also invited to provide text comments to explain their ratings for the specific questions in the survey. In order to evaluate all workshops systematically and uniformly, general questions were given to the same workshops.

The questions are informed by Kirkpatrick's 4-level training evaluation model [9] and are listed in TABLE I. The questions are answered on a scale of 1 – 10, with 10 being the highest ranking. Independent t-tests were performed to observe whether significant differences occurred between workshops that were held pre-COVID-19 in 2019 and March 2020, and subsequent workshops in January 2021, and February 2021 for both tracks independently. In addition, the comparisons between the tracks themselves were compared.

TABLE I. POST WORKSHOP QUESTIONNAIRE QUESTIONS GIVEN TO THE BIOENGINEERING AND TECHNOLOGY TRACK AND THE ARTIFICIAL INTELLIGENCE COMPUTER SCIENCE TRACK.

Post Workshop Survey Questions *(Rated on a Scale of 1 to 10, with 10 being the highest)*
1. Rate the morning session.
2. How would you rate the information content of the morning session?
3. How much **new** material did you learn from the morning session?
4. How would you rate the interactive aspect of the morning session?
5. Rate the afternoon session.
6. How would you rate the information content of the afternoon session?
7. How much **new** material did you learn from the afternoon session?
8. How would you rate the interactive aspect of the morning session?
9. Rate the session overall.

In addition, to rating each session, students were asked to provide written feedback on each aspect of the program to provide a roadmap for systematic improvement of programmatic aspects of each track. Independent t-tests were performed to ascertain the differences between the means of the pre-COVID student responses in 2019 and post covid responses in 2020 and 2021 in tracks BET and AI and between tracks BET and AI. For instances where the sample sizes were not roughly equal, and the standard deviations were not comparable, Mann-Whitney tests were performed to confirm that the two data samples are likely to derive from similar types of populations, i.e., samples that have the same shape. To understand statistically different means, students' responses were reviewed and a level-1 categorial analysis was conducted to better connect quantitative with responses given by the students.

A. *Learning Environment & Pedagogy: Artificial Intelligence and Computer Science, Pre-and Post-COVID 19*

The Artificial Intelligence and Computer Science track of ALA is premised on helping students develop computer science skills. Since the focus of this track centers around computing, typical workshop practices before and after COVID focused on reducing potential areas of risk by testing and pre-staging the machines, data and other technological resources whenever possible. This included 1) ensuring that laptops had the same systems settings, configurations, updates and software installed, 2) pre-loading desktop versions of tools and provision of data and resources on the machines if internet access is unavailable, and 3) testing all activities in the lesson plan on the target machine types to address unforeseen errors.

The in-person learning environment for this track fostered a cooperative learning structure. Short segments of instructions were given immediately, followed by a knowledge check via a hands-on exercise. This allowed the instructors to garner immediate feedback on student comprehension and provided opportunities for students to help one another. The student-helper model is effective especially when there is a sizable difference in the students' programming experiences[10]. This approach solidifies student learning and presents them with the added challenge of explaining their solution to another student. In this way, the pace of the learning was set by the class as a whole.

Moving a computing workshop to a completely virtual environment might seem trivial given the nature of the subject matter. However, there were challenges when the curriculum was subject to variances in students' platforms. To accommodate variations in bandwidth, tool installation instructions and data resources were made available to students prior to the workshop for download and pre-prep. Students were also given the opportunity to schedule office hours before the workshop for tech support if they encountered issues during installation. These sessions often revealed unexpected errors that were platform specific. In addition, collaborative tools were also exploited as much as possible. For example, the workshop agenda, instructions for each activity, guidelines on how to ask for help in Zoom, and links to resources were shared in a class Google doc. Students worked in collaborative coding environments such as Repl.it and Colab and shared links to their code in the class Google doc. This approach was used so that instructors could view students' codes and aid when requested. The class also used Mural, a collaborative digital whiteboard tool, to facilitate discussions and activities.

The time spent engaging in one-way instruction (lectures) was reduced to diminish screen fatigue. Also, elements of in-person workshops were modeled, e.g., group work and presentations and submission deadlines. This fostered student independence and the ability to support their teams and manage their time wisely.

B. *Learning Environment and Pedagogy – Biomedical Engineering and Technology, Pre- and Post-COVID 19*

The WEB Dubois Biomedical Engineering and Technology Track is different from the AI Track as it covers several engineering disciplines. It introduces students to the interdisciplinary nature of the field by exposing students to traditional engineering disciplines such as Biomedical, Mechanical, Chemical, Civil, Electrical and Computer Science and Materials Science engineering. In addition, students explore biology, chemistry, neuroscience, physiology, and mathematics topics during workshop activities. Each workshop includes one or two brief lectures, group activities, and hands-on design challenges. In this way, students were exposed to new ideas, real-world applications, and relevant career paths relevant to each workshop topic. A multi-scaled mentor model informed by [10-12] was employed for each workshop where faculty, graduate student instructor served as mentors and academic advisors during the workshop. Students were also encouraged to assist and peer-mentor one another thereby leveraging their individual experiences. This approach was selected because [13, 14] found that near-peer mentoring enhances learning and understanding of core technical content and provides leadership opportunities for graduate students to mentor high school students. particular, students are encouraged to reflect and discuss each activity in teams, and then prepare short 3-minutes presentations describing what they did, how they did it and what things were expected/unexpected according to the theory covered during the lecture period. *One other critical aspect of the pre-COVID workshops was to expose students to aspects of STEM that they would not otherwise have in-depth exposure to in a traditional high school classroom due to limitations of technical resources or time for in-depth discovery required for fulfilling the cyclic nature of the engineering design cycle.* Workshop titles, activities and the number of students participating in the study are provided in TABLE II.

The same instructors for each of the tracks were maintained in order to allow for consistent data analysis between years of data. However, the length of the time of the workshops were shortened by an hour. The change in the length of time was because students generally walk to lunch and walk from their housing to the workshop location. Hence, additional time for lunch and to arrive and get settled in the morning in-person sessions were removed for the remote workshops as the additional commute times for lunch and arrival were no longer needed.

TABLE II. OVERVIEW OF THE WORKSHOP TITLES, TOPICS COVERED, AND THE ACTIVITIES COVERED IN THE WORKSHOP.

Workshop Date	Title and Activities
February / March 2019 (pre-COVID and in-person)	***Introduction to Electrical Engineering*** Topics: Electrical circuits, parallel/series, energy conversion, materials for insulators and conductors ***Morning Session: Activity 1:*** *Using Salt Water to Make Electrical Circuits,* ***Activity 2:*** *Light your way! Build a flashlight!* **Afternoon Session: Activity 3:** Design a Wind Turbine
March 2020 (pre-COVID and in-person)	***Human Bone Mechanics and Engineering of Tissue*** Topics: Human bone physiology, tissue engineering, CAD Design and Advanced Manufacturing ***Morning Session: Activity 1:*** Using TinkerCAD to design bone scaffolds to meet established standards. ***Afternoon Session: Activity 2:*** Using 3D printers to print bone scaffolds. ***Afternoon Session: Activity 3:*** Using strain gages to measure changes in bone scaffold geometry.
January 2021 (post-COVID and remote)	***Engineering Mechanics & Heart Fluid Dynamics*** Topics: Human structure, function, mechanical and electrical properties, finite element analysis ***Morning Session: Activity 1:*** Build a prototype of a human heart. ***Afternoon Session: Activity 2:*** Using SimVascular to create models of the iliac artery ***Activity 3:*** Parametric study using modeling software.
March 2021 (post-COVID and remote)	***Electricity and the Brain's Neurological Network*** Topics: Structure and function of the brain and the connection to the electricity, machine learning ***Morning Session: Activity 1:*** Trick the AI of a software ***Activity 2:*** Mathematical exercises that demonstrate machine learning principals. ***Afternoon Session: Activity 3:*** Design and test of prototype helmets designed for team specific applications.
*23 – 25 students participated in each workshop, with the exception of the workshop held in March.	

The transition of the workshops into remote learning environments occurred for the January 2021. Materials used for activities were tailored to meet a budget of $25 per student as opposed to bulk purchases for an entire class prior to COVID. In addition, to maintain safety for students, materials for workshops changed from 3D printers, circuit boards, Arduino boards, and strain gages, soldering stations, etc. to household items that could be ordered and delivered quickly and handled/operated safely without adult in-person supervision. Hence, post-COVID materials included, foam, non-toxic glue, play dough, popsicle sticks, water, etc.

C. *Data Collection and Analysis*

1) *Population Sampled*

The WEB Dubois Accelerated Learning Academy accepts applications from high school students from every state within the US. Each track typically has ~25 students, who are selected based on GPA, letters of recommendation and essay statements. The results presented for this study are based on the number of students who completed the post survey.

2) *Pre- and Post-COVID T-test Analyses*

Statistical means and standard deviations for the responses to the post questionnaire questions were captured to understand the general perceptions of students regarding morning and afternoon sessions scores, information content, opportunities for interaction and acquisition of new material. T-tests were also performed, where all workshop track scores were compared to the March 2019 values (datum). BET and AI workshops occurring on the same date were compared using t-test analyses to observe areas of similar or differing trends.

V. RESULTS AND DISCUSSION

A. *Mean and Standard Deviation Results for All Tracks, and T-test for Difference Between BET and AI Track*

The statistical means and standard deviations for each of the questions for the post-survey for both tracks and all four workshops are presented in the Appendix in Table III and Table IV. T-tests analyses were performed to determine if there were statistical differences between the AI and BET tracks for the pre-COVID workshops in 2019 and March 2020, and post-COVID workshops in January and February 2021. It was found that there were no statistically significant differences between (with a 95% confidence interval) the means of the two tracks for all four workshops. This finding illustrates that both tracks demonstrated very similar trends, where ratings for both tracks, in general, were higher during pre-COVID workshops in 2019 and March 2020, compared to lower means in post-COVID sessions. Though the workshop ratings remained high overall ($\geq$8.44 for the BET and $\geq$ 7.91 for the AI track, respectively), small reductions in ratings were observed in post-COVID workshops.

Table III STATISTICAL MEANS AND STANDARD DEVIATIONS OF BIOMEDICAL ENGINEERING AND TECHNOLOGY TRACK FOR FOUR WORKSHOPS FROM 2019 TO 2021.

Descriptive Statistics–Biomedical Engineering and Technology Track	Dec. 2019		March 2020		Jan. 2021		March 2021	
	N	Mean (std. dev.)	N	Mean (std. dev.)	N	Mean (std. dev.)	N	Mean (std. dev.)
Q1.Morning Session Score	19	9.37 (1.01)	12	9.55 (0.69)	24	8.96 (1.46)	16	8.81 (1.28)
Q2.How would you rate the informational content of the morning session?	19	9.37 (1.12)	12	9.42 (0.79)	24	9.08 (1.41)	16	9.00 (1.09)
Q3.How much new material did you learn from the morning session?	19	8.89 (1.37)	12	8.58 (2.4)	24	8.54 (1.32)	16	8.44 (1.55)
Q4. How would you rate the interactive aspect of the morning session?	19	9.37 (1.12)	12	9.25 (1.49)	24	8.46 (1.89)	16	8.75 (1.24)

Q5. Afternoon Session Score	19	9.63 (0.68)	12	9.50 (0.91)	24	8.67 (1.76)	16	9.19 (1.11)
Q6. How would you rate the informational content of the afternoon session?	19	9.58 (0.84)	12	9.50 (0.79)	24	8.58 (1.91)	16	8.88 (1.15)
Q7. How much new material did you learn from the afternoon session?	19	9.37 (0.96)	12	9.42 (0.90)	24	8.63 (2.04)	16	8.44 (1.32)
Q8. How would you rate the interactive aspect of the afternoon session?	19	9.42 (1.22)	12	9.17 (1.59)	24	8.58 (2.24)	16	9.00 (1.21)
Q9. Overall Score for the Entire Workshop	19	9.47 (0.84)	12	9.50 (0.91)	24	9.00 (1.32)	16	9.13 (1.09)

Table IV STATISTICAL MEANS AND STANDARD DEVIATIONS OF ARTIFICIAL INTELLIGENCE AND COMPUTER SCIENCE TRACK FOR FOUR WORKSHOPS FROM 2019 TO 2021.

Descriptive Statistics – Artificial Intelligence and Computer Science Track	March 2019		March 2020		Jan. 2021		March 2021	
	N	Mean (std. dev.)	N	Mean (std.dev.)	N	Mean (std.dev.)	N	Mean (std.dev.)
Q1.Morning Session Score	18	9.50 (0.79)	11	9.36 (1.29)	23	8.74 (1.66)	2	8.86 (1.13)
Q2.How would you rate the informational content of the morning session?	18	9.22 (1.31)	11	9.09 (1.38)	23	8.70 (1.99)	2	9.00 (1.20)
Q3.How much new material did you learn from the morning session?	18	8.28 (2.08)	11	8.82 (1.33)	23	7.91 (2.19)	2	8.23 (1.54)
Q4. How would you rate the interactive aspect of the morning session?	18	9.44 (0.98)	11	8.82 (1.54)	23	8.78 (1.95)	2	8.77 (1.85)
Q5. Afternoon Session Score	18	9.28 (1.07)	11	9.36 (1.03)	23	8.70 (1.40)	2	9.00 (1.35)
Q6. How would you rate the informational content of the afternoon session?	18	8.94 (1.77)	11	9.36 (1.03)	23	8.78 (1.20)	2	9.09 (1.31)
Q7. How much new material did you learn from the afternoon session?	18	8.33 (2.17)	11	9.09 (1.14)	23	8.83 (1.50)	2	8.73 (1.42)
Q8. How would you rate the interactive aspect of the afternoon session?	18	9.56 (1.09)	11	9.00 (1.55)	23	9.00 (1.13)	2	9.05 (1.33)
Q9. Overall Score for the Entire Workshop	18	9.44 (0.922)	11	9.18 (1.08)	23	8.96 (1.33)	2	8.95 (1.25)

B. T-test – Analysis for the Artificial Intelligence and Computer Science Track (Pre- and Post-COVID19)

All post survey results were for the AI workshops were compared to the pre-COVID workshop in 2019 (datum workshop). It was found that there were no significant differences in ratings between the two pre-COVID workshops held in 2019 and March 2020, and the post-COVID workshop held in January 2021. However, there was a statistically significant difference between the 2019 workshop and March 2021 workshop morning session scores ($t = 2.027$, $p = 0.05$), where the means were 9.50 ± 0.79 and 8.86 ± 1.13, respectively. The remaining ratings did not indicate any significant differences in terms of ratings between pre- and post-COVID workshops. We conjecture that these similarities in score may be due to that fact that though programming activities/lessons varied per workshop; the web-based programming and collaboration tools such as Repl.it and Colab, and google docs/slides, were maintained, and used in every workshop in both pre- and post-COVID conditions. In addition, use of web-based software and interactive tools aided the instructor and students in examining and control for computer capabilities and operation systems. Also, because the programming tools are web-based, they were accessible on all tablets, smartphones, and Chromebook, which made accessibility for low-income students somewhat normalized. Many school districts in the states where students were recruited provide students with Chromebook to complete homework and attend remote classes. Hence, in many regards, some consistency with computer tools was achievable. In addition, intermittent breaks to ward off screen fatigue are typical practices observed for in-person and remote programming courses and workshops. Thus, the ability to continue this practice perpetuated consistency between sessions. Interestingly, the standard deviation for post-COVID ratings for this track increased, which indicates that students' responses were more varied around the mean score than close to the mean.

C. T-test Results for the Biomedical Engineering and Technology (Pre- and Post-COVID 19)

The primary differences between pre- and post-COVID workshops in the BET Track were that students were not able to access more technical equipment and computers and group interaction in building and making of prototypes. T-test analyses were performed to understand if there were instances of statistical differences in the means of the pre-COVID Biomedical Engineering Technology track in workshops held in2019 and March 2020. It was found that there were no statistical differences found between the means of these two workshops that were held pre-COVID. While overall the means for the post-COVID were quite high for this track for all four workshops (9.47 ± 0.84, 9.50 ± 0.91, 9.00 ± 1.32, 9.13 ± 1.09) , statistical differences between the pre- and post-COVID were observed. The first statistical difference observed was for the 2019 and January 2021 workshop afternoon scores ($t=2.46$, $p = 0.02$), where the means were 9.63 ± 0.68 and 8.67 ± 1.76, for 2019 and January 2021, respectively. In addition, there were statistically different ratings for these two workshops for the question, "How would you rate the informational content of the afternoon session? ($t=33.05$, $p=0.028$)" Students gave a higher rating for the March 2019 than January 2021, where the means were 9.58 ± 0.84 and 8.58 ± 1.91, respectively. The differences in scores were most likely due to complications that arose from the use of a finite element analysis software (SimVascular) that required specific computer requirements, which many students' computers could not download. Though students were paired in groups with those who were able to download the software, not having to the software directly may have hampered the learning process for some students. While SimVascular is compatible with both Mac and PC platforms, it is not compatible with tables and Chromebooks. Furthermore, it requires computer memory and data storage capabilities, which could not be monitored for use for all students. In fact, of the twenty-four written responses from students in response to the question, "Do you have any suggestions about how to improve the online environment?" for the 2021 Biomedical Track, nine students indicated that they would change the software used so that it was something more accessible. In addition, three students indicated that they would have enjoyed the session more if it were in person. One student also shared, "keep groups consistent so we can build a relationship and exchange numbers so we can communicate about the project or ask each other questions." This last comment illustrated an aspect of in-person groups where students asked for contact information face-to-face and were unable to easily do this in a virtual setting.

There was also a statical significance difference found between March 2019 and March 2021 workshops ($t= 2.094$, $p= 0.044$) for the 'How would you rate the informational content of the afternoon session?'. There is also a statical significance difference found out between 2019 and 2021 workshop ($t= 2.422$, $p= 0.021$) for the 'How much new material did you learn from the afternoon session?'. Students gave higher rating during March 2019 than 2021. These differences in rating have are due to how the afternoon session was run. Specifically, after learning about the design of helmets students were asked to spend time researching helmets for different types of applications, i.e., construction, bike, etc. They were then asked to build their own helmet in groups for a specific application. Some students undertook the research component of the afternoon session more seriously than others, i.e., researched independently with their group, while others researched very little and immediately went on to build without researching with their teams in the breakout rooms as a group, while others rigorously worked together. This observation is supported by student feedback on the survey, where several students indicated that they would like more interaction with their peers. For example, out of the twelve written responses to the question, "Do you have any suggestions about how to improve the online environment?" in the 2020 Biomedical Track, three students indicated that they would have liked more student-to-student interaction. Traditionally in this track, students work in groups on prototypes, so students typically expected more interaction as some students were returning from previous years in the program. Of the twelve students that responded in this year for this track, two indicated the need for more breaks. During in-person activities, students often spend time braining together and delegating tasks between group members as one prototype is typically produced per group. However, in the remote scenario, each student is required to produce their own product, which sometimes diminishes the motivation to work together to the same degree as with in-person activities. There was, however, an increase in the ratings from January 2021 and March 2021, which is due to changes in *the way* the workshop was taught based on challenges from the January workshop. Specifically, all software that was selected for workshops were web-based and accessible on all forms of portable electronics, i.e., phones, tablets, etc. In addition, rather than having open-ended research on topics, students were given several example platforms for research discovery and were encouraged to not only use those references, but to seek out more using specific guidelines given by the instructors. The text responses from 2020 and 2021 for the assessment of the online environment are provided in the Appendix.

D. *Implications for Application to STEM Educational Programs for High School Students*

Providing digital computing devices is an important step to enhance remote learning, however, bridging the technology divide for marginalized students is more complex. Ensuring that students have access to devices extends beyond having a laptop or tablet that lacks adequate features to complete STEM-based learning activities, while it certainly presents a formidable obstacle for running and operating most engineering-applications for meaningful analysis and modeling that allow students to connect to real-life engineering challenges. Issues such as slow and unstable Wifi, hardware and software challenges, and inadequate technical supports are prevalent in marginalized and rural neighborhoods. As such, public-private partnerships committed to understanding, addressing, and investing adequate resources in marginalized communities are needed to support remote learning for vulnerable high school students. In addition, possible ways to address the digital divide, may also include assisting students with locating available free resources in their communities such as libraries with WiFi and community centers.

Activities that rely on hands-on building using systems and materials that are not typically available in contemporary classroom environments may benefit from collaborative engagement of students and instructors, peer-mentorship and in-person guidance for safety and access to shared equipment to reduce cost and optimize and enforce group work. Also, many activities that require building of prototypes leverage access of tools and equipment that can be shared among groups, that can be costly if purchased independently, such as pliers, soldering kits, X-acto knives, 3D printers, desktops that allow for engineering software, Arduino board kits, etc. Computer based activities that allow for simultaneous editing and engagement, i.e., google docs, etc. foster collaboration that is difficult to mimic in the development of physical prototypes. This is evidenced in the interactive scores for both tracks, which diminished most notably for the BET track in comparison to the AI track.

VI. Conclusions and Future Work

This results from this study indicate that activities that allow students to build prototypes and explore STEM principles can be effectively carried out in home settings. However, students' perceptions of interactivity with others may be diminished in activities that are traditionally undertaken with physical building of complex structures that require group collaborative work, division of labor and equipment that requires specialized training for safety and/or specialized equipment not readily available in homes. Students that are used to building in groups in classroom environments appear to expect a certain level of engagement even if in remote settings. The preliminary results from this study indicate that students do learn new concepts effectively in both in-person and remote environments. However, strategies for engagement in breakout rooms, or hybrid environments for aspects of hands-on activities may be meaningful endeavors to optimize remote learning programs in the future.

The interpretation of student ratings may be limited as questions posed are fairly general. For example, factors such as zoom fatigue, home environmental distractions or other factors could have led to small variations in the analysis. In the future, more content specific questions may be added to the post survey instrument to better ascertain the effectiveness of the teaching method and to gage the effectiveness of the learning activities. However, these preliminary results indicate that remote learning programs that are based on hands-on activities can be positively received and executed when opportunities for engagement are prioritized for students and software selections are limited to those that can be readily accessed through the internet. This work also illustrates the importance of student-to-student interaction and peer-to-peer feedback in engaging in STEM activities. It also elucidates the opportunities associated with being able to provide quality activities to students who may not be able to physically attend STEM workshops in person.

APPENDIX

Track	Do you have any suggestions about how to improve the online environment?
Biomedical Engineering & Technology - March 2020	More participation
	There is none, again there is not much we can do in this situation.
	no
	Maybe add more student-to-student interaction.
	na
	Include more breaks during the session or shorten the sessions, since 9-5 is very long (3 hours more than a school day) and students are already on zoom every day of the week.
	None.
	I would decrease the times of the workshop; students get "zoom fatigue" and are uninterested towards the end.
	she's doing a great job!! no complains
	N/A
	Nothing everything was perfect
	Maybe add more student-to-student interaction.
Biomedical Engineering & Technology - Jan 2021	none
	None.
	n/a
	It's perfect!
	just hope to be able to do this in person at one point
	none
	No recommendations. Since my program wasn't working for the afternoon session it was harder to enjoy.
	I have no recommendations
	being more specific when downloading software
	I think we should use software or programs that are available to everyone.
	I would have liked software that worked a little easier or was easier to understand.
	none
	Maybe trying to prepare some things earlier, for example the Paraviews/ SVsolver and along with that having videos for us to follow so we can do it ahead of time.
	There isn't. Everything is great.
	I don't have any recommendations at the time.
	none
	To choose less heavy software
	I feel like the way the activities are running are going well as they are, but it would be better in person.
	I think more hands-on activities should have been given to the students unable to download the software (which was because those students did not know the type of computer, they had to have beforehand). I think case studies on a certain aspect of the field, and then problem-solving and presentation activities afterward would be great.
	The SV project was really interesting, but the software was really confusing, and I feel like it took up some of our time.
	I liked the researching and presenting aspect of the sessions.
	To choose workshops that can work any type of computer because i have Chromebook and was not able to participate in certain parts of the workshop
	Maybe keep groups consistent so that the students in each can build a relationship and exchange numbers so that they can communicate on a project or ask questions.
	N/A
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	it was good so no recommendation
	More breaks
	None.
	None
	Maybe having two activities, so building/ prototyping two things.
	Everything looks great to me.
	It's perfect!

	None, this way works the best, could be better in person
	n/a. I think this online workshop was very good.
	I would suggest putting closed captions on for the Youtube videos that are played because sometimes the volume is really low or distorted.
	I think everything is fine the way it is.
	This workshop taught me a lot more than my school classes normally do and held my attention.
	No recommendations
	I cannot think of any :)
	So far everything was great.

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