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Abstract

The move to virtual schooling and other measures to reduce the spread of SARS-CoV-2 infection dramatically changed the educational experience for grades K–12 populations during the years 2020 and 2021. STEM teaching and learning, and community partnerships focused on STEM education, were not exempt from the changes. Universities and other community partners had to adapt their STEM partnership programming to address new needs and assist students, teachers, families, and schools throughout periods of at-home learning and the re-reintroduction of in-person classes. Some of the changes included developing new programs, providing health-related guidance to school leaders, and converting student-focused programs to virtual formats. Through these experiences, new approaches emerged and lessons were learned that can be applied to partnership activities during normal times. These lessons included recognizing the importance of addressing inequities in students' access to technology; development of strategies to redesign enrichment programs and classroom instruction for effective online delivery; and identifying and adapting to the range of technologies available to support virtual teaching in differing schools. The increased familiarity by all partners with virtual formats has opened the door to greater participation by students in STEM enrichment programs, online partnerships with STEM professionals and mentoring opportunities.

Keywords

STEM partnership; COVID-19; coronavirus; STEM outreach; COVID curriculum

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Author Contributions

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INTRODUCTION

The COVID-19 pandemic highlighted strengths and shortcomings in how we provide education at all levels in the United States. Implementing measures to reduce the spread of disease was the only option last year. The school and business shutdowns of 2020 prevented healthcare facilities from being overwhelmed by patients severely ill with SARS-CoV-2 coronavirus infections. And, stay-at-home guidelines reduced community spread of the virus at a time when scientists were still learning about its transmission. However, the complex impacts of the pandemic on educational systems and outcomes for learners are just emerging.

In our location (Houston, Texas region), the pandemic forced dramatic changes to all aspects of everyday life beginning in March 2020 (Limon, 2020). After the annual spring break, students and teachers were asked to remain at home and prepare for virtual learning, which began in April in most schools (Swaby, 2020). Local education leaders worked with city and county health officials to “flatten the curve” and contain the spread of SARS-CoV-2 in schools by eliminating or reducing in-person attendance by students and personnel. As the 2019-2020 school year came to an end, students, teachers and staff stayed at home and followed health precautions communicated by state and local agencies and the Centers for Disease Control and Prevention.

During the fall 2020 start of school, most grades K–12 schools and school districts allowed families and caregivers to choose between in-school or distance (mostly online) learning modalities. These experiments resulted in new kinds of technology mediated education, with some students participating remotely and others attending school in person. All strategies were further complicated by social distancing practices that were implemented inside school buildings. Schedules frequently were upended, because teachers, school staff or students needed to self-isolate due to SARS-CoV-2 infection or quarantine at home after exposure. Almost all extra-curricular activities, such as sports, theatre arts, music and afterschool enrichment programs were placed on hold, while students and teachers struggled to meet the demands of their regular courses. Many large-scale science, technology, engineering and mathematics (STEM) activities, such as robotics and science fairs, were conducted virtually or cancelled (University of Houston STEM Center, 2021; FIRST in Texas, 2021).

In response to the substantive changes in K–12 education, universities and other community partners had to adapt their programming to address new needs and assist students, teachers, families and schools throughout periods of at-home learning and the re-reintroduction of in-person classes. For our Center for Educational Outreach, these adjustments included developing new programs and curricula, providing direct guidance to area school leaders and classroom teachers, providing logistical support and health-related resources or guidance, and converting afterschool and summer student programs to virtual formats.

One Institution’s Response in the Context of STEM Education.

Under normal circumstances, Baylor’s Center for Educational Outreach works closely with local teachers and schools to support STEM teaching and learning across grades K–12 with a particular focus on biomedical sciences. We develop curriculum materials, disseminate

teaching resources, provide teacher professional development, support afterschool STEM programs and have close partnerships with individual schools. Three Houston Independent School District (Houston ISD) schools formally are affiliated with Baylor. The schools are: Michael E. DeBakey High School for Health Professions (established in 1972); Baylor College of Medicine Academy at James D. Ryan Middle School (established 2013); and Baylor College of Medicine Biotech Academy at Rusk Middle School (established 2016). Each of these three schools is supported by a Baylor science and health educator who is present full-time on the campus to guide specialized health sciences curricula, work directly with teachers and coordinate unique opportunities for students.

Prior to the outbreak of COVID-19, our Center offered, facilitated and promoted as many first-hand science experiences as possible to students and teachers in the three affiliated schools, to elementary students in afterschool STEM clubs, and when providing teacher professional development. Following recommendations of the *Next Generation Science Standards*, the *Framework for K–12 Science Education* and the *Texas Essential Knowledge and Skills for Science* (NGSS Lead States, 2013; National Research Council, 2012; State of Texas, 2017), we aimed to immerse students in authentic scientific and engineering practices, such as planning and carrying out investigations or analyzing and interpreting data. We designed and disseminated STEM lessons and curriculum modules that enable teachers to facilitate inquiry-based learning by teams of two to four students with an emphasis on hands-on engagement with actual phenomena, tools and systems (Moreno and Erdmann, 2010; Michaels et al., 2008). Purposefully, we promoted in-person engagement of STEM professionals with students and teachers, rather than utilizing videoconferencing platforms, even though necessary software subscriptions and some equipment, such as smartboards, webcams and computer video projectors, already were in place in our institution and some schools. Overall, we aimed to increase students' interest in and preparedness for a range of educational pathways and even careers in STEM by providing them with a range of authentic experiences with science activities and science professionals (Tai et al., 2006).

Our Center activities evolved rapidly during the pandemic. Baylor educators in each of our three affiliated schools became important conduits of health information within their own schools and the school district as a whole, helped teachers convert lab-based courses to online delivery and developed virtual programs to connect students with science and clinical faculty, trainees and students. When some students returned to campuses to resume in-person learning, they no longer were allowed to share materials or work together in small groups. This created additional challenges related to the redesign of hands-on experiences and students collaborative work to maintain social distancing among students and reduce or eliminate students' contact with shared supplies or equipment.

Simultaneously, our STEM curriculum development team expanded its efforts to create new resources related to the science of viruses and SARS-CoV-2, infectious diseases, and even safe school operations to reduce the spread of COVID-19. Beginning in June 2020, Baylor faculty members and educators began participating in weekly meetings with local school superintendents, other institutions of the Texas Medical Center and business leaders. These discussions along with direct feedback and requests from partnering teachers and schools led

to numerous project changes and new programs, which are listed below to provide context to our discussion of lessons learned.

- Development of a guide to healthy school operations during the COVID-19 pandemic in the form of a PowerPoint® slide deck for use by school leaders, which was posted in multiple locations, including the Greater Houston Partnership, Baylor's main website and BioEd Online.
- Dissemination of easy STEM-based lessons (called STEM @Home) for teachers and care givers to use with homebound students of all grade levels early in the pandemic—before local schools had resumed classes and converted to online teaching (https://www.bioedonline.org/stem-home-activities/). The lessons were selected from existing hands-on lessons on the BioEd Online website and curated as a single resource collection on the site. The index pages for these lessons were accessed 4,310 times from April through December, 2020.
- Creation and dissemination of the COVID HACKS (Healthy Actions, Community, Knowledge, and Science) curriculum with more than 20 standards-aligned lessons for four grade bands (K-2, 3-5, 6-8, 9-12) on infectious diseases, COVID-19 transmission and prevention and public health (https://www.bioedonline.org/lessons-and-more/resource-collections/covid-19-pandemic/). With support from local philanthropists, the existing curriculum development team enlisted the assistance of two science curriculum writers to develop and disseminate new pandemic-related lessons online. From August 1, 2020 through May 10, 2021, COVID-19-related pages and lessons were accessed more than 6,700 times, with more than 1,170 downloads of slides and lesson documents. We also logged 22,200 additional views of related resources on infectious diseases, the immune system and microorganisms.
- Conversion and delivery through virtual online formats of summer bridge camps at two affiliated STEM middle schools, and a summer health professions camp, called DocPrep, for rising high school seniors. The DocPrep program, supported by the Texas Joint Admission Medical Program, involved students from several high schools located in South Texas and Houston. These students normally would participate in a one-week residential program at Baylor College of Medicine. In total, the virtual programs involved more than 260 students.
- Development and implementation of new formats for piloting and evaluating STEM curriculum programs using videoconferencing for teacher professional development and online data collection from teachers and students. Existing curriculum development activities aimed at elementary school audiences were postponed until spring 2021, so that lessons and assessments could be reconfigured for in-person, online or blended delivery.
- Conversion of an existing grades 4–5 STEM afterschool program to a virtual experience ("Community STEM") to sustain students' interest in and readiness for STEM educational pathways through engagement in active learning and

open-ended engineering challenges. Materials required to complete the activities were items available in the home or provided online by teachers. The activities included hands-on components for students to do in their own yard or community to alleviate screen fatigue, incorporate hands-on science, and help students see the relevance of science in the world around them. Seven schools and more than 200 students participated in afterschool STEM activities using live videoconferencing for teacher development and student engagement.

These experiences, and those of other Houston-area colleges and universities, demonstrated that STEM organizations have important community roles as communicators, advisors and advocates. In an evolving health crisis, scientific and biomedical institutions have access to up-to-date and accurate information—and in-house experts who can help interpret and apply this information. In Houston, university partners across the region contributed medical and public health advice, collaborated with city and county public health officials, and helped interpret evolving guidance that came from local or state sources.

Existing challenges, such as inequitable access by students to technology resources, were brought to the fore during the pandemic. We also identified new approaches that can be used effectively for partnership activities during normal times. In our case, future efforts will be driven by new relationships that were formed and lessons learned throughout the past months. We describe our findings and suggestions in the following paragraphs.

LESSONS LEARNED ABOUT STEM PARTNERSHIPS

Appropriate Access to Technology by All Students is a Baseline Requirement for Virtual Partnerships and STEM Distance Learning.

The dramatic pivot to online teaching during spring 2020 was a jarring reminder that many students do not have access to adequate devices and Internet access for remote education. In Texas, one in four students was reported to be without devices at home for distance learning and one in three lacked Internet access (Homer, 2020). Not only did these deficiencies impact virtual school attendance, but they raised barriers to participating in STEM enrichment activities designed to bolster skills, develop science identity and build career awareness. To enable participation in virtual summer bridge camps at both Baylor-affiliated middle schools, mobile “hotspots” and tablets or laptops were loaned to students who did not have adequate Internet access or computer resources at home. For the summer health careers enrichment program, DocPrep, vouchers were offered to cover the costs of Internet access for 45 rising high school seniors who normally would have attended the program on the Texas Medical Center campus.

Because of increased familiarity with online video and teaching platforms that developed over the past year, it is likely that more STEM enrichment programs will be provided virtually in the future. However, planning for these programs routinely will need to include technology resources, devices and Internet access as necessary expenses to achieve program goals.

STEM Enrichment Programs Do Not Translate Directly to Online Delivery and Must Be Redesigned with Virtual or Blended Learning in Mind.

Home learning environments are not ideal for many online learners and program participants. Numerous environmental factors detract from the online educational experience of K–12 students or teachers. Examples include background noise from other members of a household, lack of a private learning space or the need to share a computer or tablet for Internet access. We found that some high school students had difficulty staying engaged in sessions throughout the day because family members would ask for help with childcare or household tasks, or because it simply was challenging to stay engaged online for several hours at a time. To address concerns about "Zoom fatigue" and competing priorities, the DocPrep Virtual Summer Program was adjusted to include two 30-minute breaks and an hour-long lunch break during the full-day program for high school students. Programs at the two middle schools found that appropriate communications to parents about expectations for participation enhanced student engagement and program completion. Requiring students to keep their device cameras "on" also was effective in promoting students' full engagement in the programs during interactive presentations and group discussions. We will continue to apply these practices during our virtual programs in summer 2021.

Student Collaborative Work Can Be Accomplished Virtually, But it Requires New Instructional Approaches and Software Applications.

Before COVID-19, our curriculum and teacher development efforts fully supported students working together in small collaborative groups to conduct hands-on science investigations or work through cases and problems together (Michaels et al., 2008; National Research Council, 2012). This approach is effective in developing students' critical thinking, communications and teamwork skills, as well as their abilities to build and apply science knowledge in the context of a problem or question (National Research Council, 2007).

Changes in instruction during the pandemic, however, made science teaching using small groups as before, almost impossible. For students who attended school in person, most local schools separated students at tables using clear plastic partitions or kept individual desks well-spaced in rows, with all students facing in the same direction. Students were not allowed to work together in close physical proximity. Shared use of materials was discouraged, and teachers were required to sanitize supplies or equipment after each student. These arrangements likely reduced the spread of COVID-19 disease in classrooms, but they also eliminated traditional approaches to group work.

The dramatic switch to online learning further complicated any efforts to have students work in small groups. Most teleconferencing platforms allow the instructor to assign participants to virtual breakout rooms for discussions. However, hands-on collaborative investigations or activities were not possible. In addition, with many video platforms, a single online teacher cannot monitor all small groups simultaneously as they would while teaching an in-person class. Instead, the online instructor must drop in on each group separately. Adding even more complexity—many teachers have been teaching online and in-school learners at the same time.

To accomplish group work successfully in a virtual teaching environment, Eagle Camp at the Baylor College of Medicine Biotech Academy at Rusk Middle School assigned students to “hangout” groups of about 15 students for the duration of the camp. Each “hangout” met every other day for an hour on Microsoft Teams to do icebreakers, work on STEM challenges together, and receive “mission briefings.” Students completed their missions offline and used a scavenger hunt app to submit their evidence. Each individual mission completion contributed to their hangout group’s team score and hangout groups competed against each other. This approach demonstrated the need to use multiple digital approaches and apps to support students in groups, and to design science lessons and activities that offer more than one way for students to report and submit their work, post results or interact with one another.

STEM Curriculum Activities, in General, Must Be Compatible with a Range of In-class and Virtual Teaching Arrangements.

When members of our team began working with teachers and schools in spring 2020, we quickly realized that individual districts, schools and even teachers were using different video conferencing tools, such as Microsoft Teams® or Zoom®; different learning management systems, such as Google Classroom®, Blackboard® or custom systems; and different apps for student collaborative work, online whiteboarding, video creation and other tasks. Teachers employed MS PowerPoint® slides as interactive teaching tools or as “workbooks” in which students provide responses or work together synchronously or asynchronously.

These changes forced us to rethink how students and teachers might use the STEM curriculum modules and lessons that we develop, evaluate and disseminate on our website, BioEd Online (www.bioedonline.org). During summer and fall 2020, we created a menu of lesson activities on the COVID-19 pandemic for students in four grade band sets: K–2, 3–5, 6–8, 9–12. Unlike most of the other lessons on the site, the new COVID HACKS (Healthy Actions, Community, Knowledge, and Science) resources were developed to be taught virtually online or in-class. Students’ group work was designed to enable in-person or virtual large or small group discussions. Electronic collaborative tools took the place of paper charts and posters to present findings or brainstorming outcomes.

Rather than providing PDF printable student data or problem sheets, we made student documents available to teachers as MS Word or PowerPoint files so that the content could be converted easily to other interactive formats or provided electronically to students. Teachers expanded their use of PowerPoint slides through apps that allow students to annotate and share slides.

Hands-on materials pose a challenge for virtual teaching in two ways: students don’t always have needed materials at home and sharing of supplies or equipment is discouraged for in-person learners, at least while COVID-19 precautions are in place. In response, we developed hands-on activities that could be conducted by a single student, followed by group discussions or data sharing sessions. Some science investigations were designed with simple pages that could be printed at school or at home to create tools, such as paper rulers;

experimental devices, such as an anemometer to test mask fabrics; or models, like a 3D model of the SARS-CoV-2 virus.

Other hands-on materials were selected to involve household items or consist of components that could be sent directly to each students' home. A similar approach was used for the DocPrep summer program for rising high school seniors. Each participating student received a backpack, suture kits, knot tying kit and skills book, baseball cap, t-shirt, State of Texas Joint Admissions Medical Program (JAMP) paraphernalia including first aid kits, sticky note pads and hand sanitizer. Thus, students typically had their own sets of materials if hands-on work was required during periods of at-home learning and social distancing in schools. Group or team activities were conducted virtually, using real-time video conferencing or with collaborative web-based tools, such as Google Slides®.

Familiarity with Two-way Videoconferencing Opened the Door for Future Collaborations among STEM Professionals and Students or Teachers.

Schools now have appropriate technologies and most stakeholders have become fluent with videoconferencing as a means of bringing people together. Significant barriers to bringing students and STEM professionals together, such as conflicting schedules and lengthy drive times, have been reduced. It is now possible for students to visit laboratories and other STEM or healthcare settings virtually. Similarly, STEM professionals can meet for short periods of time with entire classes or small groups of students. At the Baylor College of Medicine Academy at James D. Ryan Middle School (Biotech Academy), students worked with 22 Baylor medical students to develop project proposals for NASA's Genes in Space program and collectively earned the school a Constellation Prize for the most submissions. The school also collaborated with Rice University faculty and students, who developed short videos to support teachers with teaching neuroscience to approximately 150 sixth-grade students. Currently, Baylor medical students are providing virtual academic coaching to students at the same middle school.

For teachers, access to high quality teacher professional development by STEM professionals and university-based STEM educators has been enhanced. For our location, travel times to attend professional development courses or workshops often exceeds one hour in each direction. Virtual sessions enable greater participation in a range of after school professional development programs, in addition to one-on-one consultations or collaborative project development. We have observed higher levels of attendance for virtual workshops related to field testing of curriculum materials as compared to in-person workshops in previous years.

Acceptance and use of video conferencing and online collaborative tools for teaching and learning increased dramatically during the pandemic (Wang et al., 2021). Even though proficiency with two-way video conferencing and other e-learning resources has increased, continued training for teachers, university partners, students and their families will be necessary to allow these technologies to continue to be used to their fullest potential.

Virtual Delivery of STEM Enrichment Programs, Such as Summer Camps or Afterschool Clubs, Has Potential to Broaden Participation.

At the Baylor College of Medicine Biotech Academy at Rusk, all incoming students (6th and 7th grade) are invited to participate in Eagle Camp, a one-week introduction to middle school and the STEM and health related focus of the school. More students participated in the virtual 2020 camp (161 students) than participated in the 2019 in-person sessions (108 students). The virtual format enabled the addition of new sessions, such as a group discussion with current Baylor medical students on their pathway "From Middle School to Medical School," which ended with all incoming Biotech Academy students setting short-term and long-term goals for themselves.

To further enhance participation, school personnel ensured that students had all the materials they needed. Each student received a STEM Pack, filled with supplies organized by day and mission with 100% of the needed materials for each, as well as a task card detailing each mission. If students could not come to pick up materials, the packs were hand delivered by camp staff or mailed to the student's home. Challenges and activities ("missions") included reading the book, *Terrible Typhoid Mary*, building a foldable paper microscope (from Foldscopes), examining objects using their microscopes, building a "BrushBot," coding, and playing the role of an epidemiologist to solve a mystery (Bartoletti, 2015).

Similarly, we converted in-person afterschool STEM clubs for students in grades 4–5 at seven elementary schools to virtual learning formats led by the same club teachers. The teacher leaders at one participating elementary school used the activities to supplement the regular science program for 137 students, thus expanding the reach of the afterschool STEM activities. Students, for example, investigated scale and measurement, and identified different types of clouds and recorded observations using the GLOBE Program, Clouds Module (2021).

By removing barriers caused by factors such as transportation or scheduling, online programs can create opportunities for more students to participate in STEM enrichment programs. However, even when programs are delivered virtually, attention must be paid to whether students and teachers have access to all of the resources needed for full participation.

Program Evaluations and Assessments Also Must Adapt to Virtual Settings.

Just as curriculum development requires new approaches, different evaluation and assessment approaches should be considered for an online environment. Technology, while helpful, should not be a limiting factor in providing opportunities for students to demonstrate knowledge and understanding. Electronic student work products, such as slides developed collaboratively, offer new ways to assess student engagement and knowledge gains. For field test activities of curriculum modules with middle and high school students, we converted paper student assessments to online surveys to collect pre- and post-assessment data related to science and health knowledge and attitudes.

For our afterschool clubs, we changed from a content knowledge assessment to images of student products that can be scored using a rubric. We also focused more on evidence of the

development of science identity and asked students to provide written paragraphs about their own perceptions of themselves as scientists.

In-person Experiences Should Continue to be Part of STEM Programming.

Even though the pandemic demonstrated that virtual visits increase opportunities for students to connect with STEM professionals, we also observed that in-person educational experiences are necessary. Many, if not all, students need face-to-face interactions with one another and their teachers to achieve meaningful learning. The culture and emotional supports provided by schools also contribute to students' success and satisfaction. For example, graduating students at the Michael E. DeBakey High School for Health Professions were surveyed informally shortly before completing their studies in May 2020. All 164 graduates of the Class of 2020 completed the survey (distribution of the respondents was 35.6% Asian, 28.2% Hispanic, 16.6% African American, 9.8% White, 8.6% no response and 1.2% Other). Not surprisingly, when asked to provide one word to describe their feelings about their educational experiences during the COVID-19 pandemic, 74.4% of the responses were negative, and only 3% expressed positive feelings. The top 5 negative responses in descending order were: 8 – worried, 8 – stressed, 7 – uncertain, 7 – frustrated, 6 – disappointed. When asked about their future aspirations, 26% of students reported that the pandemic affected their plans for college. Given these responses, blended or hybrid approaches to STEM programming and enrichment activities may offer the most benefits because they balance convenience with students' needs for in-person experiences.

Biomedical Science and Health Teaching in the Context of STEM Should be Expanded.

National and state-level science standards pay too little attention to critical public health concepts that would have enhanced public understanding of viruses, infection and the immune system and public health throughout the pandemic. Widespread misinformation hindered efforts to contain SARS-CoV-2 in our own region and throughout the country (Butcher, 2021). Lack of health literacy, which is the capacity to obtain, process and understand basic health information needed to make appropriate health decisions, contributed to the problem (Office of Disease Prevention and Health Promotion, n.d). Many citizens, including members of underrepresented and low socioeconomic groups, have not had educational opportunities to develop essential knowledge about healthy behaviors and risk reduction (Rikard et al., 2016).

Further, the accelerated efforts to develop COVID-19 treatments and vaccines demonstrate why we must have a diverse and innovative STEM and biomedical workforce to respond to complex societal issues. Black/African American and Hispanic/Latino citizens made up 27% of the US workforce in 2016, but continue to be underrepresented in STEM fields, including health-related occupations and life science (National Science Foundation, 2017). Not preparing all students in STEM shortchanges the pool of future scientists, healthcare specialists and engineering innovators who must take on new challenges and drive scientific, biomedical and technological advancements.

CONCLUSION

STEM higher education partners, particularly those who are engaged in biomedical research and healthcare, have vital roles to play in ensuring that teachers, students and families have access to accurate science and health information and know how to identify reliable sources. The pandemic demonstrated the incalculable value of these partnerships and taught us new ways to connect STEM professionals and schools to benefit students. As a STEM community, we can apply what we have learned during the long months of the pandemic to create a better learning ecosystem that supports students through virtual interactions with scientists, engineers and clinicians, optimized applications of technology for learning and in-person experiences that provide the necessary social and real-world contexts for learning.

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ABBREVIATIONS

Baylor	Baylor College of Medicine
COVID-19	Coronavirus Disease-2019
COVID HACKS	Coronavirus Disease Healthy Actions, Community, Knowledge and Science
Houston ISD	Houston Independent School District
JAMP	Joint Admissions Medical Program
K–12	Grades Kindergarten through Twelfth
NASA	National Aeronautics and Space Administration
NIH	National Institutes of Health
PDF	Portable Document Format
SARS-CoV-2	Severe Acute Respiratory Syndrome-Coronavirus-2
STEM	Science, Technology, Engineering and Mathematics

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