AAAS | IUSE

Lessons Learned During COVID-19:

Strategies Transforming the Future of STEM Education

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Introduction

As we build the future of undergraduate STEM education, how can we leverage lessons learned from teaching and learning during the COVID-19 pandemic and move towards a healthy STEM ecosystem?

Beginning in the Spring of 2020, faculty and administrators in higher education were forced to quickly adapt to an online environment. While there were challenges to navigating remote teaching and learning, especially in the STEM field, there were also creative ideas for making the best out of a difficult situation and improving the way we teach and learn STEM.

This report is inspired by the healthy ecosystem model detailed in the *STEM Reimagined Manifesto*, which serves as a guide for faculty and administrators looking to broaden access and participation in undergraduate STEM education (August et al., 2020). This approach to STEM education places value on well-being of educational stakeholders, centers on experiences over content delivery, recognizes individual difference, is driven by reflective assessment, and honors diversity (August et al., 2020). In this report, we look at strategies from the **AAAS-Improving Undergraduate STEM Education (AAAS-IUSE)** community focused on broadening participation for students typically underrepresented or excluded from STEM. Despite the STEM education inequities students faced, which were exacerbated by the COVID-19 pandemic (Means & Neisler, 2020; Means et al., 2020), the faculty, administrators, and educators featured in this report were able to implement strategies that create more inclusive learning environments.

Throughout this report we feature case studies connecting curriculum with students' communities and cultures, reimagining assessments, leveraging technology, rethinking mentoring, learning from online lab experiences, and cultivating student-faculty connections that can foster equity and inclusion to ultimately transform our learning ecosystem.

As many institutions transition back to in-person learning, we strive to learn from the changes brought on by the pandemic to continue thinking creatively, to engage undergraduate students in STEM, and to create a more equitable education system.

CONTRIBUTORS & ACKNOWLEDGEMENTS

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OVERVIEW OF AAAS-IUSE

The AAAS-IUSE Initiative is funded by the NSF Improving Undergraduate STEM Education Program: Education and Human Resources (IUSE: EHR). This initiative supports faculty, administrators, students, and the greater undergraduate STEM education community by disseminating research and knowledge about STEM teaching, learning, equity, and institutional transformation.

OVERVIEW OF THE CALL FOR SUBMISSIONS

In the beginning of 2021, the AAAS-IUSE Initiative asked the community of undergraduate STEM faculty, researchers, and professionals working in higher education how they are adapting to the challenges of teaching and learning during COVID-19. After reviewing over 100 submissions, we found that the IUSE community had gone beyond creating best practices for teaching in a pandemic and instead developed strategies with implications, after the pandemic, for broadening participation, increasing accessibility, and transforming the way we teach STEM.

Submissions from the AAAS-IUSE community addressed issues on a range of topics including:

- Course Design
- STEM Labs
- Internships and Skills Building
- Student Support and Connections
- Faculty Support

This report highlights case studies of promising practices and lessons learned from STEM and education faculty and professionals across the country that have implications beyond the COVID-19 pandemic to broaden participation in undergraduate STEM.

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Course Design

How did faculty redesign their courses to facilitate engagement in online environments while also adapting to student needs? In what ways will these changes transform course design beyond the pandemic? In this section, we highlight faculty who are making their courses more engaging, differentiated, and accessible by changing components of their course broadly or adding projects/assessments that engage students in new ways.

Compared to traditional lecturing, engaging students in active learning in undergraduate STEM courses is shown to have a beneficial impact on exam scores and course grades, especially for students historically underrepresented in STEM (Theobald, et al., 2020). However, remote instruction made it difficult to engage students through active learning. In this section we highlight examples of faculty who redesigned their courses to increase student engagement.

In addition to being engaging, STEM courses need to be accessible and inclusive. Utilizing universal design principles and culturally sustaining pedagogy can create inclusive and welcoming classrooms for all students (Grier-Reed & Williams-Wengerd, 2018). Below we will see innovative examples of implementing reflective pedagogy and universal design to build more inclusive learning environments. Additionally, there are examples of faculty who engage students in creative projects to connect science with their everyday lives and faculty who utilize AI technology to provide differentiated assistance to facilitate learning.

In addition to making courses more engaging, we look at faculty who are rethinking traditional assessments to focus on intellectual engagement and taking exam pressure off students while maintaining learning objectives. Recent research from Goodman (2020) and Theobold (2021) shows how group oral exams are effective in assessing learning and facilitating deeper engagement in undergraduate STEM courses. Below faculty share how they changed assessment and grading practices to incorporate new strategies to assess student learning.

Designing Courses to Meet the Needs of Students

I teach an elementary teacher education course in science methods. During the pandemic, I recognized that equitable participation for my students to attend class was a challenge that needed to be addressed in the way I designed and implemented my course. To tackle this issue, I developed:

- Flexible grading centered on feedback rather than points. I used a badging system for grades in my course.
- Intentional design of learning tasks that involved active student participation and interaction both synchronously and asynchronously, regardless of whether the student could log on during a live course meeting or not.
- Opportunities for students to workshop ideas for their instructional designing efforts in a social manner, both during course meetings and asynchronously using online discussion tools (e.g., discussion board on our learning management system (LMS), blog-based discussions, FlipGrid, etc.)"

My main takeaway is the importance of exercising critical, reflective pedagogy in how faculty design and implement teacher education courses. We must be flexible and empathetic to our students' personal lives and the shifting nature of the schools in which they will teach, **while not sacrificing rigor or engagement in science and STEM discourses.**

-Aaron R. Gierhart, Columbus State University

Encouraging Student Creativity in Science Courses

I designed a mini-project quest assignment to increase students' knowledge of local and worldwide scientific issues, encourage students to spend time in nature, apply science in everyday life, and bring students' personal talents and interests to the projects. Students in my Biology course complete three quests from a list of 20+ unique activities. Variety and trans-disciplinarity in student mini projects are key to engaging students in the project. Students incorporate art, music, photography, and other interests in these quests to have fun and find value in the science.

"[This activity] really put into perspective just how underrepresented women are [in science], and it made this quest much more important in my eyes... this quest focuses on switching the spotlight over to the female scientists, which is long overdue." -Student

See examples of our students' work.

-Emily Walter, California State University – Fresno

> *"I honestly came to relaxation with myself and nature. I haven't written anything in a while either, so I really took this time to reflect on 2020 and my mental health. I'm going to do more [of this activity in the future]."*
> *-Student from Dr. Walter's course*

"Students with disabilities in college STEM are often excluded due to inaccessible course design during COVID-19 and other crises." -Dr. Gin

Focusing on Accessibility in Course Design

Students with disabilities in college STEM are often excluded due to inaccessible course design during COVID-19 and other crises. But we can change this. Identifying ways to deliver accommodations and resources to students with disabilities during crises should be discussed by all institutions whether it's returning to in-person classes or preparing for future disruptions such as common weather events or natural disasters that may result in the closing of institutions and transition to remote instruction for days, weeks, or months. Specifically, instructors can:

- Incorporate universal design for learning in planning their courses to alleviate or lessen the need for students to ask for accommodations,
- Be transparent with students with disabilities, letting them know they should contact their instructor if a problem with their accommodations arises, and
- Take the burden off students with disabilities by being an advocate for them and their learning

Learn more about our research efforts which aim to improve STEM experiences for college students with disabilities and to provide guidelines for implementing accommodations in different learning environments.

-Logan Gin, Arizona State University

Student in Dr. Goodman's course participating in an at-home lab.

Changing Assessment Practices to Improve Intellectual Engagement

I hope to re-imagine the education system to one that is driven by the joy of learning and a sense of community. Here are some ways I changed assessment and grading practices in my class to be more intellectually engaging:

1. Using group oral exams provides more opportunities to engage with students, question their understanding, and guide learning. Group settings allow instructors to scale the assessment and encourage students to give each other feedback during practice team activities.
2. Switching from points-based grading to specifications-based grading incentivizes everyone to learn fundamentals and takes pressure off students to be perfect. For example, I give weekly graded quizzes that students can take multiple times, requiring a score of 75% or higher to pass. The tests and oral assessments are also graded credit/no credit.
3. Providing students with multiple ways to succeed gives students more agency and power in their learning. The main distinction between higher grades (A, B, and C) in my course comes not from performance on exams but from completing mini-projects that demonstrate mastery of the course learning objectives (e.g. **annotating genes with GEP projects**, folding proteins using **FoldIt game**, writing stories and practice questions related to course content).

-Anya Goodman, California Polytechnic State University, IUSE Awards #1710538 and #1915544

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Using Different Types of Assessments in Place of High-Stakes Exams

During the pandemic, I moved away from traditional exams and instead implemented short video assignments, using a tool called **FlipGrid**, where students explained how they solved complex problems. In this approach, all students were required to justify their problem-solving approach and explain their work. This approach ensures individual accountability in a format that is not too far off from how they might be expected to perform in a STEM workplace in the future.

Students found this approach to be an accurate and useful measure of their learning. Many used their personal devices (smart phones or web cams) to record images of their notebook or a whiteboard, showing work as a sort of presentation. Others submitted a "selfie" of their work, and narrated voice over style, to describe their thought process. For students who are digital- and social media-natives, this exam structure felt similar to using SnapChat. This made it approachable and informal, lessening anxiety around test time.

> *"For students who are digital- and social media-natives, this exam structure felt similar to using SnapChat. This made it approachable and informal, lessening anxiety around test time."*
> *-Dr. Wainman*

While students were allowed to collaborate before their "video exam", students' explanations still revealed differences in their levels of understanding and their ability to communicate their approach. These differences allow for an individualized assessment of learning while permitting collaboration on the exam.

-Jacob Wainman, University of Minnesota

> *" ...this class did not have the traditional 'professor vs. student' feel to it, more like professor AND student vs. physics. Once again THANK YOU!!"*
> *-Student from Dr. Chen's course*

Providing Soft Due Dates and Low-Stakes

With a diverse student body facing a range of challenges such as work conflicts, technological access, and family needs, I recognized the need to re-design my course with flexibility in mind to meet the needs of my students. To accomplish this, I implemented:

- Mastery-based learning modules that facilitated self-regulation during the learning process.
- Soft due dates with a daily penalty instead of hard due dates for assignments.
- Extra credit incentives to encourage early completion of homework assignments and participation in classroom discussions.
- Reducing the weight of infrequent, summative, high-stakes exams and replacing them with frequent, lower stakes formative quizzes.

Despite the flexible policies and online exams, early observation showed no clear evidence of consistent widespread cheating on homework, quizzes or exams. A careful **follow up analysis** showed that some students do start to answer copy on homework more frequently towards the end of the semester. However, it is still unclear as to what was the cause of such behavior, and the exam scores weren't significantly different from previous years. Therefore, I'm still collecting more data and conducting further analysis. We are also planning to implement more "helper" modules since some students are seen to switch to guessing or copying mode when the difficulty of the content is higher than they can handle.

-Zhongzhou Chen, University of Central Florida, IUSE Award #1845436

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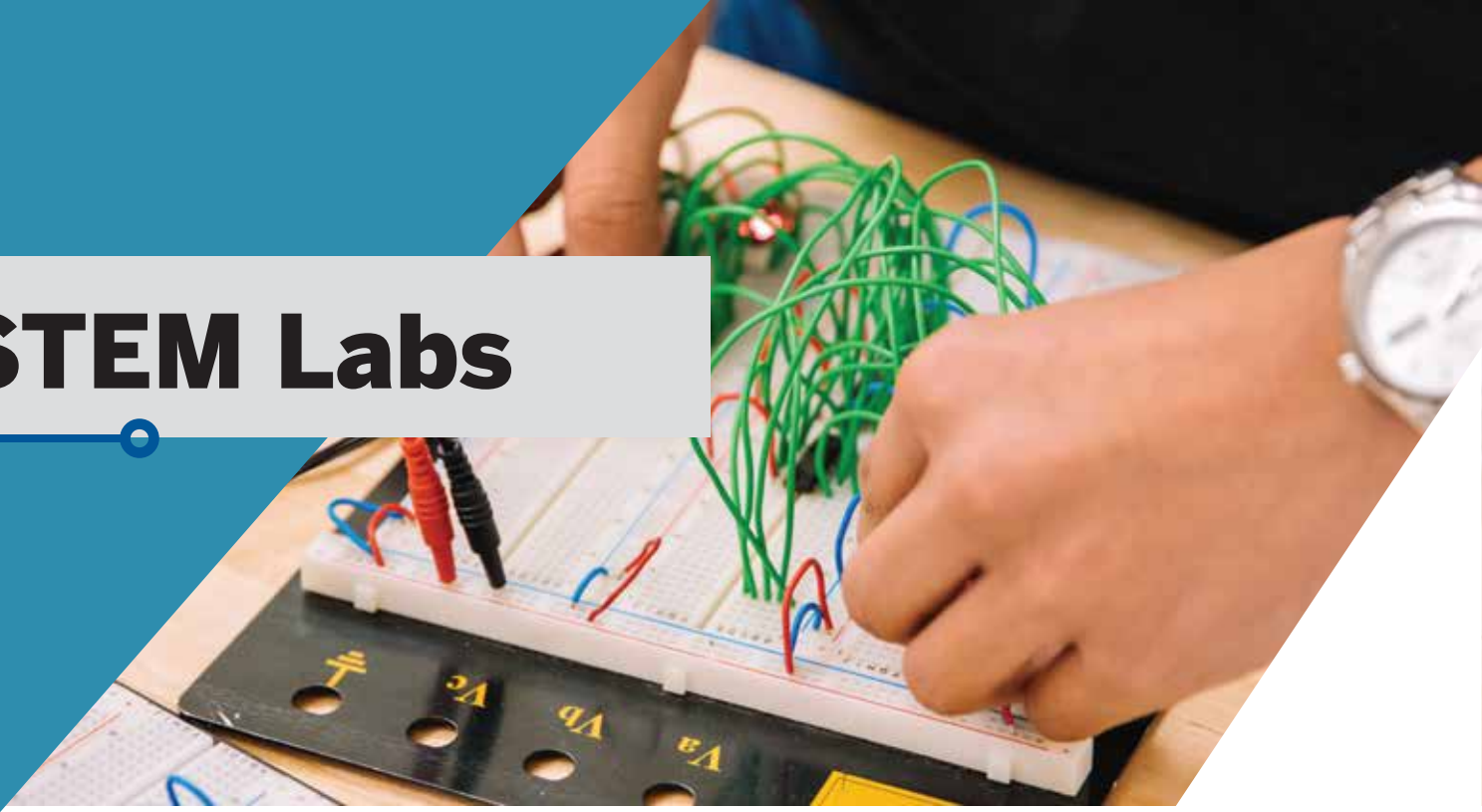
STEM Labs



During remote instruction, lab courses were especially challenging to move online. While lab courses will likely return to an in-person format, what can we learn from remote teaching to make labs accessible, engaging, and collaborative?

Labs incorporate research experiences into STEM coursework at the undergraduate level. Exposing students to research experiences is shown to improve students' sense of belonging in STEM as well as increase their confidence in understanding content (Gentile et al., 2017). Therefore, making sure that STEM labs are accessible and engaging is crucial to improving equity in STEM.

Additionally, labs promote collaboration and exploratory learning, which are essential to the STEM workforce. In this section we highlight examples of how faculty utilized technology and active learning pedagogy to promote engagement, collaboration, and exploratory learning in STEM lab courses in the online environment. By learning from these promising practices, we can develop more accessible and engaging labs that lead to better collaboration between learners.

"I think the GUI is a terrific way to visually show the engineering theories and how slight changes will affect the system behavior."
-Dr. Tekes

Open Source Virtual Laboratories to Demonstrate Fundamentals of Vibrations and Control Theory

To meet the needs of creating a virtual lab, I developed a user-friendly and open source MATLAB Simscape graphical user interphase (GUI) program and a video series focused on course concepts. The program can be developed from **here.** The following program attributes led to the lab's success promoting student engagement in the course materials:

- Videos that explain course concepts and provide clear instructions for labs.
- User interface program designed specifically for course concepts (in this case, mechanical vibrations and control theory).
- Step-by-step instruction manuals to help guide students through the lab activities.
- A scaffolded approach with videos on course concepts and clear expectations for lab experiments allowed students to identify the "why" for the activity and gain deeper learning.
- Several concepts are combined in one package for extended learning using the same system.

Developing instructional videos and a scaffolded approach to the assignment was essential to student success. They were in love with the assignments and told me, "This is easy!" Implementing these strategies into the courses and laboratories will prepare our students for success whether we are in-person or remote.

-Ayse Tekes, Kennesaw State, IUSE Award #2002350

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Making Physics Labs More Relatable Through Observation Journals

The heart of science lies in observing your environment and building understanding from those observations. Digital lab facsimiles teach students how to interact with cartoons and other virtual models which may not necessarily connect with lived, physical experience.

At the beginning of each new physics unit, I had students write an observation journal that focused on their lived experiences. Over time, students worked to improve these observation journals to strip out assumptions and other people's ideas about how the world works and focus purely on what they were experiencing through all their senses. The students then used these lived experiences in labs to conduct controlled versions of their field observations to deepen understanding, find patterns, and derive the descriptive mathematics.

-Lev Horodyskyj, Science Voices/University of the Virgin Islands

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Dr. Horodyskyj showing a version of the Cavendish experiment to his students over Zoom.

> *"Covid has really affected so many lives in pretty horrific ways, and has also forced assignments like this to be done differently than it originally would have been done... But I will say that because of Covid, the way that we now had to do it was very beneficial for me... I liked that we had much more free rein in the options we had in how we depicted our final research." -Student in Dr. Zovar's course*

Using the Local Environment to Create an Archaeology Lab Course

An integral part of my Archaeology class is a course-based undergraduate research project that allows students to see how material objects can be used to understand cultures at different times and places. This is normally a very hands-on and interactive project, drawing on the analysis of collections in the lab, landfill garbage, recycling, or litter, as students work through the process of hypothesis formation, data collection, and analysis.

With the move to online, students took advantage of the environment around them to complete the research project, which made the course more accessible and provided an opportunity for students to apply their learning to their own communities by:

- going to cemeteries to take notes about stylistic changes in different times and places,
- observing trash on trails, using photos as a tool for virtual information collection, and
- using online museum databases to analyze objects (e.g., Museum of Anthropology at the University of British Columbia)

The takeaway from moving archaeological research online is a simple reminder that different students will want to engage with the materials in different ways. As we reenter into the physical lab space, I would like to maintain – and even expand -- this sort of freedom by keeping the focus on the learning objectives and adding more flexibility about how students get there.

-Jennifer Zovar, Whatcom Community College, IUSE Award #2021546

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Utilizing a Virtual Program to Create an Interactive Online Lab

In our *Introduction to Computer Science* course, we created a virtual space that simulates a physical lab or classroom setting, allowing students (as avatars) to work on completing lab activities. Important characteristics of the online lab space include:

- A scheduled lab meeting time where students and instructors are available to connect and interact with complete lab activities.
- A virtual environment (we used Gather Town) that allows for individual, group and paired-work within the same space.
- A virtual space that allows multiple groups of people to hold separate conversations in parallel without interference because only the avatars of participants that are nearby can hear the audio and see the video of each other.
- Marked areas in the virtual space for each section of the lab as well as open work and social areas. Giving participants visual cues of what other participants are working on allows for ad hoc formation of groups and collaboration.

Prior to the COVID-19 pandemic, the in-person model of the course utilized paired-programming. At the start of each session pairs of two students were formed to complete lab activities, and students had to work at the same pace throughout the entire lab. During the pandemic, we structured the lab to allow for more flexibility. The virtual lab space facilitated immediate connections between the participants in the lab, gave students the freedom to complete lab activities at their own pace, and allowed for collaboration with peers. Going back to in-person labs, we plan to consider such a structure rather than having fixed stations and fixed groups during a lab session.

-Nadia Najjar, University of North Carolina at Charlotte

Dr. Najjar's virtual lab room.

> *"The virtual lab space facilitated immediate connections between the participants in the lab, gave students the freedom to complete lab activities at their own pace, and allowed for collaboration with peers."*
> *-Dr. Najjar*

Developing Engaging Labs that are In-Person and Remote

Over the past decade, our cross-institution and cross-disciplinary research team developed *Our Place in Space!* - a robotic telescope-based lab curriculum for survey-level undergraduate students that makes use of Skynet telescopes distributed around the world. The curriculum works equally well online as in person. Since implementing the in-person curriculum, we've seen a 100% enrollment increase in introductory astronomy courses, and a greater than 300% increase in the number of astro-track majors and minors. Key components that make this lab successful include:

- Students use professional research telescopes to collect their own data.
- Tutorial videos are publicly available to make the lab easily accessible online.

Personally, I think this project has created an increase in enrollment and engagement because of the combination of (1) data ownership ("I did this. It's mine.") and (2) realness (students use "real" telescopes that are simultaneously being used by "real" astronomers to do "real" science). Maintaining this lab both in-person and remote allows all students to benefit, regardless of disruptions that would normally hinder learning.

-Dan Reichart, University of North Carolina at Chapel Hill, IUSE Award #2013300

Creating Accessible Labs for Field Based STEM Courses

COVID made it impossible to offer geology field trips for our Introductory Physical Geology students. Instead, we created a series of online field trips using Google Earth Tours. These are now available for any student. The virtual nature of the traditionally in-person field experience also creates opportunities for students with physical disabilities to participate in field trips in future semesters. Overall, the transition to online learning taught us to be flexible and to use technology as an asset. This broadened participation in the geoscience course and produced a learning environment centered on accessibility.

View our Virtual Geology field trips.

-Virginia Sisson, University of Houston

> *"The virtual nature of the traditionally in-person field experience also creates opportunities for students with physical disabilities to participate on the field trips in future semesters."*
> *-Dr. Sisson*

Internships & Skills Building

Open access and online resources provide opportunities for more undergraduate STEM students to participate in internships, skills building, and other learning opportunities. Research shows that undergraduate STEM students were more confident in their ability to "think and work like a scientist" when they participated in out-of-class experiential learning opportunities (Thiry et al., 2011). These opportunities contribute to both personal and professional gains in STEM. In this section, we highlight examples of how faculty utilized online environments to broaden access to internship and skills building opportunities for students.

Some of the experiential learning opportunities below also focus on the role of clinical experiences in STEM pre-service teacher education. Research shows that clinical experiences are an important aspect in preparing pre-service teachers to be successful teachers (Goldhaber & Keesler, 2019). This section, in addition to highlighting online internship and skills building opportunities, offers examples of faculty creating "classroom" experiences for pre-service teachers in the online environment.

"Our findings suggest that the learner's degree of agency while participating in Virtual Internship (that is, the extent to which a learner has agency over the project and the learning they extract from it) is significantly impacted by their teachers' perspective and subsequent moves in taking up this innovation."
-Dr. Jona and Dr. James

Designing a Virtual Internship Program for STEM Students

Since 2017, our research team at Northeastern University has been developing a virtual internship and team project model. The original focus of these efforts was to broaden participation in experiential learning for non-traditional and underrepresented students.

Helpful practices that can be applied by other institutions include:

- Creating an open-source library of various STEM projects that give students project options and ideas that are achievable and useful for a variety of businesses in an internship setting.
- Structuring virtual internship and team project designs that provide students with step-by-step guides for project completion and skill development.
- Establishing strong feedback loops, using technology, from the industry partner or internship hosts.
- Implementing just-in-time learning content that helps the intern or project team connect the dots between what they have learned in the classroom and how they can apply it to their industry project.
- Crafting a learning analytics dashboard that provides real-time insights for the faculty or internship coordinator so they can effectively support students and industry partners when needed.
- Constructing a professional development course designed to support educators and coordinators in the set-up, implementation, and pilot of a virtual internship or virtual team project.

-Kemi Jona & Nikki James, Northeastern University, IUSE Award #1725941

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Organizing Online Skills Building Workshops to Broaden Participation in Undergraduate STEM

The COVID-19 pandemic led to the suspension of many summer research opportunities for STEM students. In response, the IRIS Education and Outreach program, in collaboration with Miami University, offered a free online Seismology Skill Building Workshop to increase undergraduates' knowledge, skills, self-efficacy, and interest in observational seismology and scientific computing.

We received and admitted 773 registrants from 60 countries for our 2020 summer research workshop. U.S. participants consisted of 56% women and 29% from populations traditionally underrepresented in the geosciences. The workshop design:

- Focused on developing computing skills.
- Created six topic modules, wrap-ups, and optional final projects that combined webinar and interactive assignments.
- Provided seminars about graduate school, employment, and networking.
- Used Slack for communication and cooperative learning.

The tutorial-style, active e-learning, instructional design was a key factor for the strong performance on assignments, remarkable retention, and high level of satisfaction. Key outcomes include:

- >60% normalized gain in scientific computing skills.
- Inclusive design of the workshop was able to attract and retain a diverse population. (Additional investigation is needed to ensure benefits are evenly experienced).
- Participants perceived the workshop positively: 92% described it as high to very high quality, 73% satisfied to very satisfied with their experience, and 61% very likely to recommend it to peers.

Workshop Summary Website
Video Presentation about the Workshops

-Mike Brudzinski, Miami University (Ohio); Michael Hubenthal, IRIS Consortium

"The COVID-19 pandemic led to the suspension of many summer research opportunities for STEM students. In response, the IRIS Education and Outreach program, in collaboration with Miami University, offered a free online Seismology Skill Building Workshop to increase undergraduates' knowledge, skills, self-efficacy, and interest in observational seismology and scientific computing."
-Dr. Brudzinski and Dr. Hubenthal

teachHOUSTON STEM Interactive participants showcase their STEM projects created during the program.

Creating Opportunities for Pre-Service Teachers to Interact with Youth and Parents

With many K-12 schools closed during the pandemic, I needed to find an alternative to the in-person field experiences for the PreK-4 teacher candidates during their STEM Practicum course. In response, I put together an alternative, asynchronous remote-learning STEM program, free to families in the community.

College students in the STEM Practicum course were assigned a grade level and were asked to prepare about 3 hours of asynchronous instruction that parents could do with their child at home. The program was promoted through local networks and colleagues with education connections. Materials were sent to families for the hands-on learning components of the program. Overall, students:

- Gained experience in remote instruction that they never would have received otherwise.
- Engaged with parents and families more than they would have in traditional classroom field experiences.
- Earned valuable learning experiences creating hands-on curricula that is doable at home with limited supplies.

-Sharon Brusic, Millersville University

Providing Virtual Summer Internships for Pre-Service STEM Teachers

For the past twelve years we have provided opportunities for students to work in STEM summer camps. Through these endeavors aspiring STEM educators gain valuable informal learning experiences and serve students from high-need, at risk schools through inquiry driven STEM lessons.

teachHOUSTON STEM Interactive participants showcase their STEM projects created during the program.

A team of professors from *teach*HOUSTON (*t*H), the secondary STEM teacher preparation program at the University of Houston, along with *t*H graduates and graduate assistants, worked together to create the program's first ever virtual STEM experience known as the *teach*HOUSTON STEM Interactive. STEM Interactive served over 4300 students worldwide during the summers of 2020 and 2021, and, employed preservice teacher candidates at the University of Houston. Key program components included:

- Synchronous and asynchronous opportunities for students to conduct STEM activities using easily accessible materials from home.
- Multiple zoom sessions with an average of 900 participants each day.
- Interaction and collaborative components so students could interface with teachers and other students.
- Opportunity for preservice STEM teachers to see that it is possible to create and deliver engaging lessons, as well as build relationships with students in an online environment

Learn more about STEM Interactive.

-Mariam Manuel, Paige Evans, Jacqueline Ekeoba, and Ramona Mateer, University of Houston, NSF Noyce Award #1557309

"The use of simulated experiences is so successful at Saint Leo that its use has spread to numerous disciplines and even beyond the university walls..."
-Drs. Altfeld, Atkins, & Berry

Using Simulation Technology to Create Clinical Experiences for Pre-Service STEM Teachers

Under normal circumstances, providing teacher candidates with real-life teaching situations is of incredible value. Given the COVID pandemic, the opportunities for teacher candidates to enter brick-and-mortar classrooms were substantially limited.

Advances in simulation technology are providing teacher preparation and professional development programs with unique opportunities to augment applied experiences. Education faculty at Saint Leo University are using virtual reality simulations to provide teacher candidates with virtual classroom environments and student avatars portrayed by live actors to address the decreased availability of in-person field experiences.

Faculty at Saint Leo have been using simulated experiences in their education classrooms since 2014 and value this unique form of active real-time coaching model, particularly as it enhances field experiences. Simulations can provide experiences with administrators and parents so students can practice professional meetings and parent conferences in a low-risk environment. This experience further develops their self-efficacy through real-time feedback from peers and faculty.

The use of simulated experiences is so successful at Saint Leo that its use has spread to numerous disciplines (e.g., social work, criminal justice, human services, and marketing) and even beyond the university walls where in-service teachers utilize them for professional development.

Learn more about Simulated Experiences at Saint Leo.

-Laura Altfeld, Holly Atkins, and Cheryl Berry, Saint Leo University, Noyce Award #1949914

Student Support & Connections

Supporting students during this challenging time is important to ensuring that students feel engaged in their learning and a sense of belonging in STEM. Throughout this section, we learn how faculty promoted inclusive learning environments by breaking student-professor communication barriers, focusing on student well-being, and designing courses to facilitate peer-to-peer connections.

Creating supportive, collaborative, and inclusive environments is critical to supporting students. Affirming social inclusion through kindness and building connections is essential to creating a sense of support and belonging for historically underrepresented students in STEM (Estrada et al., 2018). Another way to create supportive networks for students is through mentoring, which is shown to improve persistence in STEM career pathways (Estrada et al., 2018).

In this section, we explore how educators responded to the shifting needs of online instruction by creating welcoming environments and forming meaningful connections with and between students, while also discovering practices that facilitated future in-person connections.

"Although sometimes cringy, I really do enjoy and appreciate the personality Dr. Chen puts in his various lecture videos and conversations in Teams. It helps engage me and sometimes facilitates learning the material."
-Student in Dr. Chen's course

Breaking Communication Barriers Between Professor and Student

Instant messaging and threaded discussions through Microsoft Teams allowed me to frequently and informally interact with students, and in turn, create a more welcoming and inclusive learning environment. In my class of 250, I utilized Microsoft Teams to lower communication barriers and psychological distance between myself and students. Through instant messaging, I learned significantly more about my students' challenges both in school and in life, and their courage and dedication in trying to overcome those challenges. Those new insights motivate me to continue making the learning environment more equitable and accessible to students.

-Zhongzhou Chen, University of Central Florida, IUSE Award #1845436

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Studying the Role of Student Connections in Facilitating Learning

We are looking at the importance of student connections and the role of social supports to facilitate learning. We found that instructional strategies to support students' social ties and connections with the course community benefit from:

- Establishing mechanisms for informal conversations between students and between students and instructors such as starting class 10 minutes early and staying 10 minutes after while facilitating student-to-student introductions.
- Utilizing a consistent weekly routine that includes some level of real-time verbal communication.
- Being available for just-in-time feedback through a communication platform that students can readily access and setting norms for communication.
- Using a hybrid approach that makes the most of synchronous time.
- Getting to know students and instructors as "real people" by sharing more than purely course focused information. Even small personal bits like talking about a pet can help build a connection and a sense of community.

-Kerrie Douglas, Purdue University; Julie Martin, The Ohio State University; Amanda Johnston, Purdue University; NSF EEC Award #2030133A

Focusing on Student Well-Being

For many years, I required students to write a weekly journal which I used to assess student understanding of the concepts covered the previous week. In light of the struggles many students faced during the pandemic (namely increased anxiety, concerns over their mental health, lack of motivation, and engagement in classes), I altered the assignment to include two additional prompts asking how students were doing and whether they were getting the support they need.

Small changes to better understand students holistically can have huge impacts on students. I suggest supporting students by:

- Creating a space to get to know students – this can be a virtual space even if the class is taught in-person.
- Using some class time to acknowledge outside influences that impact student learning – even a couple minutes can help students feel supported.
- Reinforcing the idea that we do not expect students to be perfect – this can be demonstrated by sharing our own experiences to relate to students.

-Rivka Glaser, Stevenson University

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Facilitating Connections with and Between Students

I redesigned my online course to better connect with students and assist them in forming connections with each other by:

- Changing the format of class for one day. Instead of focusing on course content, I met with students in small groups to learn about them, their interests, and passions.
- Assigning students to established groups and changing the group after each unit, this format allowed students the space to form a community.
- Providing credit for group work. The students lobbied for changing grading policies to give more credit for group assignments. They valued the interactions and ability to connect over the content. I was happy to change the policy to honor their efforts and intellectual growth.
- Telling students on a regular basis how proud I was of them and that I knew what they were doing was not easy. I let the students know that I greatly admired them.

> *"I have never met any of my online students in person, but I am so close to this class. It brings tears to my eyes thinking about what we accomplished together."*
> *-Dr. Smith*

Connecting with students early, modeling and rewarding effective group work, and enjoying the opportunity to connect with students were all important aspects of my course. I have never met any of my online students in person, but I am so close to this class. It brings tears to my eyes thinking about what we accomplished together. Part of it is learning evolution, but another big part is the shared humanity of building a community during an incredibly difficult time.

-Michelle Smith, Cornell University

> *"Learning the content of the course is important so that students can move to the next level in their education. However, building relationships with each other and the instructor is just as important." -Dr. Pitterson*

Creating a Supportive and Enriching Community for Students

With the change to online learning, first year engineering instructors, like myself, had to figure out how to deliver a highly interactive problem-based course over Zoom. To account for the personal interaction the classroom provides, I re-designed our class activities to ensure that students not only engaged with me and my graduate teaching assistant but with each other. The key steps we took to create this interactive virtual environment were:

- Placing students into groups based on their completion of the CATME (Comprehensive Assessment of Team Member Effectiveness) survey. We used defined Zoom breakout rooms to ensure students were always with their groups when class activities required group discussions.
- Designing course assessments with individual and group submissions so students had ample time to work together and get to know their team.
- Providing cross group feedback sessions at various points in the semester so students could meet other students in the class.
- Offering space for weekly reflection where students were expected to complete a Canvas check in assignment so the instructor could know how they were adjusting to the course/school/virtual campus etc. The questions were left open to the students' interpretation so that they were free to share as much or as little as they felt comfortable doing.

Based on the intentional interactions built into the online learning environment, students were able to make friends, build connections and learn a bit about each other as they would have in a face-to-face environment. Learning the content of the course is important so that students can move to the next level in their education. However, building relationships with each other and the instructor is just as important.

-Nicole Pitterson, Virginia Tech, IUSE Award #1841980

Creating Spaces to Help Students Feel Connected to Each Other and the Course Material

Concerned about the impact of the COVID pandemic on my students' educational experience, I wanted to foster intentional opportunities for students to engage with content and with each other outside of class. These included:

1. Renaming "Office Hours" to "Study Sessions with Instructor" and including specific topics for review for each session and an expectation of studying together. This can attract more students and be used to further help students build trust with the instructor (an important contributor to learning), connect with other students, and continue to improve their study skills. This is also helpful for instructors to assess where students may need additional support.
2. Organizing Zoom study groups for students to meet without the instructor present to take advantage of peer learning power and become empowered as leaders in the class. This can be especially helpful on weekends when students have a harder time getting help and studying.

-Iglika Pavlova, University of North Carolina Greensboro

Students in the OSU STEM Leaders Program.

Providing Mentorship to Support "Non-Traditional" Pre-Service Teachers

The pandemic heightened many existing challenges (such as work-school balance, working multiple jobs, family obligations, etc.) for non-traditional pre-service teachers. To support non-traditional pre-service teachers, I integrated "student mentoring" as a key part of the methods course curriculum. Actions taken to facilitate mentoring:

- Non-traditional students who had already completed a science methods course were invited to serve as mentors.
- Mentors and mentees met on Zoom. However, because of scheduling challenges with jobs and family care, some of the synchronous course meeting time was devoted to large group discussions with mentors.
- Mentors shared their own classroom experiences, lesson plans, reflections, and learnings as science teachers. This offered adult non-traditional teacher candidates an online community with their peers where they could openly discuss their feelings about teaching and reflect on their own science learning experiences.
- Mentors were also requested to share experiences with the culture of science teaching and learning in their schools to provide a bigger picture about elementary science teaching.

-Meenakshi Sharma, Mercer University

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Creating New Opportunities to Facilitate Student Connections in a Mentorship Program

Students in STEM fields are craving meaningful connections but are having a difficult time making them happen on their own. Based on our experience with the STEM Leaders Program, here are some steps towards creating a successful mentorship program at other colleges/universities:

- Securing buy-in across STEM colleges, departments, and units.
- Engaging campus leaders committed to diversity, equity, and inclusion efforts.
- Reducing barriers for students to schedule brief check-ins with program coordinators or STEM faculty.
- Increasing flexibility so that students can choose an in-person or online experience for the fall research-ready course.
- Focusing on student professional development that will set them up for success beyond the program.
- Monitoring and evaluating your efforts for program improvement and sustainability beyond grant-funded cycles.

Students in the OSU STEM Leaders Program.

-Stephanie Ramos, Juriana Barboza-Sagrero, and Daniel López-Cevallos, Oregon State University, IUSE Award #1432810

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Faculty Support

In addition to supporting students, the need to support faculty is salient given the additional stressors of moving courses online, balancing family needs, and more. In this section we learn how faculty and administrator-led efforts improved support for educators during this difficult time.

Creating supportive environments for faculty development and well-being ensures that educators are better able to teach and help students. Professional development helps educators adapt to challenges by gaining knowledge, forming connections with colleagues, and increasing expertise (Robinson, 2019). Additionally, professional development through communities of practice (CoPs) can increase STEM faculty organizational knowledge, improve department/institutional culture, and serves as a driving force to scale-up reforms to promote institutional change (Gehrke & Kezar, 2017).

In this section, learn how a statewide Community of Practice effort was a crucial resource for helping STEM faculty flourish, and how an administration responded with professional development opportunities and clear communication to help faculty succeed during the transition to online learning.

"This was a lifesaver when we were suddenly forced online. Thank you! I think the reason I keep going is a chance to share ideas across the colleges. It's worth it."
-Faculty CoP Participant

Supporting STEM Faculty and Advancing Equity Through Communities of Practice

Through the creation of an online Community of Practice (CoP) for STEM faculty across the state, the Washington State Community and Technical Colleges system provides professional development and support for faculty while also creating a space to discuss broader initiatives like racial equity in STEM education.

Key takeaways from this work include:

1. Centering faculty leadership in professional development increases buy in from all faculty. With faculty being the leadership structure in this setting, trust increases as they develop a sense of shared experience and begin to trust the professional development process. The faculty leadership model creates a space for authentic development, adaptation, and community development across the state.
2. Building a network of peer support is paramount for supporting faculty during strenuous times. The CoP network provides a weekly/monthly place for faculty to ask questions, receive affirmation on their work, grow as educators and practitioners, and support educators' mental well-being. This supportive environment also creates the space to discuss long-term goals and challenging topics like incorporating equitable practices in STEM courses.
3. Using technologies like Zoom, Instructure (Canvas), and Google furthers faculty development. Through Zoom, the CoPs can hold meetings with faculty from 30+ institutions across the state. Canvas and Google support CoPs by providing a shared space for collaboration where faculty post work, resources, templates, discussions, etc. for the mutual benefit of all participants.
4. Developing equitable, low-cost, low-tech STEM education that results in significant learning experiences supports students through resources like those featured in the link below.
5. Meeting in STEM CoPs provides an avenue to align work with broader statewide goals, like Guided Pathways, to improve consistency across state institutions and to allow for discussions and action on topics like improving introductory STEM courses through a racial equity lens and supporting 2 to 4-year transfer pathways.

-Lucas Meyers, Lower Columbia College, Washington State Community College System

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Supporting Faculty with Technology, Training, and Clear Communication

One of the obstacles that the faculty faced during COVID-19 was transitioning their classes to a completely virtual environment with very little warning. These challenges were met through providing technology to students and faculty, training regarding the use of technology, and communication so that the transition to a completely virtual learning environment could occur as smoothly as possible.

1. Technology: Faculty, who mostly taught in face-to-face settings and used their office computers for asynchronous online teaching, also needed laptops, webcams, document cameras, etc. to conduct their courses online. We created a check-out system for both students and faculty in need of technological resources. Requests from students and faculty were met by sending items directly to their home addresses to minimize contact.

2. Training: Not all faculty had previously taught in an online format, and the following steps provided professional development opportunities in the new environment:

    - Faculty development programs were initiated to help implement online courses and improve student experiences in the online environment.
    - One-on-one sessions with learning education consultants were provided to help faculty recreate their curriculum in an online format.

3. Communication: Implementing so many tools and processes required disseminating these resources. Avenues of communications included:

    - A COVID-19 webpage provided resources and tools to help individuals quickly find the help they need.
    - A learning management system home page hosted information regarding training and other resources to aid in implementing online coursework and accessing technology.
    - Emails provided information and resources to faculty as different technologies or training were deployed and when policy changes were made.
    - Virtual meetings with faculty and deans enabled assessment of needs and responses to questions.
    - Student forums helped faculty understand student needs and questions.
    - Town Hall virtual meetings provided up-to-date information.

-Julie Fickas, St. Louis Community College

"Our intent is that these conversations will provide useful information and actionable insights to instructors as well as help to engage our community in a larger conversation about effective ways to navigate the 'new normal' of blended and online learning in STEM to develop effective modes of teaching."
-Drs. Perova-Mello & Pitterson

Supporting STEM Faculty Through a Professional Development Podcast

During the switch to online learning, there was an immediate need for faculty professional development on how to create effective and engaging STEM courses online. In the podcast Reflective Teaching in a Digital Age, we share conversations with professionals working in STEM education or related fields. Our guests share their personal experiences of adapting to an online teaching mode as well as their professional wealth of practical and theoretical knowledge relevant to blended or online teaching. Many topics are discussed, including effective course design, teamwork facilitation, assessment, educational technology integration, social support, instructor's trust development and many others. Our intent is that these conversations will provide useful information and actionable insights to instructors as well as help to engage our community in a larger conversation about effective ways to navigate the "new normal" of blended and online learning in STEM to develop effective modes of teaching.

Listen to our podcast and **view our website.** (The podcast is also accessible through iTunes, Amazon Music, and Spotify.)

To get in touch with inquiries, comments, questions about webinars and professional development classes, please email us at: **info@reflectiveteachinginadigitalage.com** or directly through our LinkedIn accounts.

-Natasha Perova-Mello, STEM Learning Consulting, LLC & Nicole Pitterson, Virginia Tech; IUSE Award #1841980

Next Steps

Within this report, our aim is to spotlight the ideas, innovations, and lessons gleaned from online and hybrid teaching and learning during the COVID-19 pandemic; especially those that promote greater inclusion in undergraduate STEM. As many institutions continue operating with a mix of online, hybrid, and in-person classes, we challenge postsecondary educators, researchers, and leaders to reflect on this unprecedented opportunity for innovation and learning.

As a community, there are many accomplishments and triumphs to celebrate, and yet, we know we have even more to learn. The pandemic spurred educational environments that both increased access and inequities (in addition to making those present inequities more visible). The faculty, staff, researchers, and administrators highlighted throughout this report worked to create engaging and inclusive courses, labs, and experiences for STEM students; however, the fact remains that the pandemic exacerbated inequities. Students who are typically excluded from STEM have faced even more challenges when it comes to learning and participation in STEM education. We encourage future research that examines organizational structures, policies, and practices that mitigate the inequities in learning opportunities and the learning loss that persists by asking, "What are the long-term impacts of this loss of rich talent?" and "What strategies might institutions, government, and funders support to recapture this talent and mitigate future loss?"

While this is a challenging time for faculty, staff, administrators, and students, this disruption to traditional learning must be used as a catalyst for change to re-think and re-design undergraduate STEM curriculum, practices, and systems to promote equitable participation in STEM education and the workforce. The contributors featured in this report challenged themselves, their colleagues, and their students by redesigning and rethinking traditional classes, labs, assessment practices, engagement strategies, and methods for facilitating inclusion in STEM. We challenge our readers to follow their example and do the same. We encourage our readers to start by implementing at least one of the innovations included in this report into your practice this year.

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