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Overview – Special Issue on COVID-19

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INTRODUCTION TO THIS SPECIAL ISSUE ON ENGINEERING EDUCATORS RESPONSE TO COVID-19

With the onset of the COVID-19 crisis in early 2020, higher education students, instructors, administrators, and leaders throughout the world experienced abrupt change in their academic, work and personal lives. Many students moved off campus unexpectedly and thousands of international students returned to their home countries. Some students lost jobs and found their financial aid threatened. Many became caretakers for their families. With PK-12 schools closed, faculty and student-parents found themselves overseeing their children's home-school lessons. Fears of COVID-19 were uppermost in everybody's minds. Some contracted the illness or supported others who did. Collectively, the articles in this special edition of *Advances in Engineering Education* reflect faculty's extraordinary dedication and innovation to accommodate a broad range of student needs during this unprecedented time.

To our great surprise, we received over 100 submissions for this collection. Myriad overlapping themes emerged for the selected articles, which we identified as: *a) course design and content delivery methods, b) self-directed learning and self-study, c) assessment, d) care, compassion, support, and the classroom environment, e) motivation, f) project work, g) senior capstone showcases and presentations, and h) remote laboratory work.* The diversity of themes was matched by the diversity of the institutions represented, including those from Australia, China, Malaysia, Poland, Singapore, the UK, and the United States.

All the articles in this collection except two were submitted in response to this journal's call for papers describing innovations that faculty made in response to remote teaching and learning necessitated

by COVID-19 in Spring 2020. Articles were limited to 1,000 words, but were nevertheless expected to include research questions, data, findings, actionable recommendations, and resources. We selected this format because we wanted to produce the volume quickly and include a broad range of strategies, while also preserving scientific rigor. Each article was peer reviewed by at least two reviewers and went through one or more major revisions. We were impressed by the many submissions that met these high standards and quick deadlines, and we hope AEE readers appreciate the value of this emergent genre. Additional articles in this format will be included in a future special edition.

With the need for the global shift to remote learning, perhaps no single issue occupied educators – in engineering and other fields – more than *course design and content delivery.* In March 2020, relatively few engineering educators had experience with online course design or delivery, yet faculty had one or two weeks to transition from face-to-face to virtual instruction. Streveler and Smith (Purdue) describe the Content-Assessment-Pedagogy framework to guide such redesign by ensuring alignment of these three instructional cornerstones. Deters and colleagues (Virginia Tech) challenge readers to undertake course redesign for virtual delivery by examining our underlying beliefs about teaching and learning, which could lead to more inclusive, equitable and learner-centered courses. Yang at Sichuan University-Pittsburgh Institute (SCUPI) in China and his colleagues address three key challenges of distance learning – engagement, understanding, and assessment—through a case study of an engineering calculus course that integrates active-learning strategies with online activities. Reck (U. Illinois) describes another case study of quickly redesigning an in-person course to one having an online format using the flipped classroom model. Koretsky (Oregon State) describes the use of the Concept Warehouse, an online repository of concept questions for teaching fundamental engineering courses remotely. Wojtowicz and her colleagues describe several creative approaches for helping students at the Cracow University of Technology in Poland visualize descriptive geometry without prepared materials, reliable internet, and students having consistent access to computers. In a study in which the "students" were K-12 STEM teachers who were doubly challenged by the subject matter and instructional mode, Larson and Farnsworth (Arizona State University) described the development of a module to help teachers adapt learning material, including lab activities, for online delivery. Finally, Prince (Bucknell) and colleagues identify and recommend multiple strategies and approaches for achieving active engagement in our current online academic environment.

The sudden and unexpected shift to online, remote teaching in higher education challenged students to quickly adopt new learning strategies and habits. These types of courses demand *self-directed learning and self-study,* since the absence of physical proximity of instructors and students can challenge students' ability to remain focused. Engineering educators designed learning environments that supported students in meeting these challenges. Balakrishnan (Sultan Idris Education University, Malaysia) and Long (Tenaga National University, Malaysia) implemented a smartphone communications app to create a personalized learning environment for students, in which students

exercised autonomy in choosing learning materials and activities as well as when and how to study. Quan from the Sichuan University-Pittsburgh Institute (SCUPI) developed a system consisting of online materials for individual self-paced study, small group problem solving sessions, and support through a live session to resolve questions raised in the small group sessions.

Online instruction requires a deep rethink of common and familiar in-person assessment methods. While some tools are available to proctor and monitor students during traditional-style testing, they are insufficient and, arguably, not conducive to optimal learning, particularly for lab-based courses. Several papers in this collection reflect strategies for effective virtual *assessment*. Teo and Pueh at the National University of Singapore describe an adaptation that is close to traditional testing, applicable to classes with large enrollments (>300 students), and provides some measure of academic integrity. Chadha and colleagues from Imperial College London in the UK detail the revision of an old idea – the open-book examination – that is designed by a department's students and teaching staff with the twin goals of maintaining quality of assessment and ensuring student wellbeing. Clark and colleagues at the University of Pittsburgh describe cooperative assessment of instructors' teaching practices during remote instruction, with the goal of providing formative feedback and promoting effective teaching methods.

Some faculty directly addressed the tremendous emotional stress students experienced, showing *care, compassion, support, and concern for the classroom environment*. Atman (U. Washington) realized that the sudden shift from face-to-face to online learning risked emotional (as well as physical) distancing from students, due to missed incidental contact with students before and after class as well as missed social cues during class, which give instructors clues about students' frame of mind about the course. Atman used reflection activities during and outside of class, in part to "check in" with students. Other instructors (Miller and Jensen, U. Illinois) implemented mindfulness activities at the end of each synchronous class session. A one-credit seminar was created and deployed by Gentry and colleagues (UC Davis) to instruct on time management, wellness, and self-care and to encourage student peer-to-peer discussion and reflective writing. Bhatti and Heffner at Georgia Tech discuss the topic of rapport in the virtual environment and its reliance on open communications among all. In May 2020, the murder of George Floyd created another wave of fear and unrest, and Sheppard from Stanford addresses this "second pandemic" that further unsettled her academic community. She describes strategies for supporting students and faculty with care and compassion across the mechanical engineering department using a learning community approach and a teaching summit that shared achievements in the spirit of planning for the future and moving forward. Morelock and colleagues (University of Georgia) utilized a research platform - SenseMaker® - to obtain real-time data (both qualitative and quantitative) from students, faculty and staff concerning their experiences with the learning change. Their results facilitated faculty development programming in response to the University's transition to online learning. Finally, a concern for loss of student *motivation* and

engagement as a result of COVID-19 prompted Miller at James Madison University to institute a half-semester project with individualized mentoring that encompassed a real-world dynamical system.

Not surprisingly, the articles on *project work* were broad in scope, including remote design practices, international service learning, community engagement work, and the maker movement. COVID forced distributed work commonly practiced by industrial design teams located across the globe, as described by Alling and Knoesen from UC Davis. Arehart (U. Colorado - Boulder) and his co-authors describe limitations of virtual delivery in a service learning course. Students collaborated remotely with the in-country workers but lost out on the immersive experience with the local community. Likewise, students involved in a community-engagement project experienced socio-emotional disappointments and skill-development limitations with a project designed to deliver lessons on wind energy to elementary students. In a second paper from the University of Colorado – Boulder, Batchelor and her associates describe their Research Experience for Undergraduates (REU) that engaged community college students from across Colorado in earth and environmental research projects. They addressed the COVID-19 challenge by creating and implementing a novel two-week, virtual program that maintained key elements of the full REU, including an authentic project, mentoring, a supportive cohort, and professional development. Authors Benitz and Yang from Roger Williams University highlight the unexpected potential benefit of providing students with online teaching skills. Finally, Leung at Hong Kong University of Science and Technology continued authentic maker activities remotely in a first-year engineering course that would ordinarily make use of the campus makerspace.

Three articles describe shifts from in-person to online end-of-semester *capstone showcase* events, in which students present their work to industry judges and panelists. The authors of these articles found very little literature related to capstone showcases and, not surprisingly, online showcase events. Yet, each author team identified notable benefits to an online format, including increased industry participation, improved review of projects by industry panelists, deeper engagement by and with students, and the ability to archive student projects for historical reference as well as recruitment of industry sponsors. These benefits were achieved for small cohorts (Brennann-Pierce and colleagues at Colorado State) as well as larger cohorts (Meuth and colleagues at Arizona State and Rogers and team at University of Florida). The authors include details on the logistics, technical challenges, lessons learned and noted benefits that motivate continued use of online showcases.

Remote laboratory work is a critical topic in the age of COVID-19. A hands-on experience replacing a traditional dynamics module was provided by Leung and colleagues at Penn State, whereby students collected and analyzed Big Data and gained an understanding of machine learning basics. The dynamics module would otherwise have been delivered by a video-recorded experiment with synthetic data for analysis. At the Sichuan University-Pittsburgh Institute, a realistic lab experience for students in a

mechanical measurements course was the goal for lab director Liang, instructor Lu, and their colleagues. Here, lab projects were successfully transitioned to an online environment using a remote-control platform, virtual simulation software, and "pocket labs," in which inexpensive equipment was mailed to students, who also used items available at home. Similarly, at UC Irvine, Wu and colleagues converted a lab in a Mechanical Systems course from constructing an in-person robot to developing a game controller to steer a simulated robot. The controller circuitry was constructed with kits containing mechanical and electrical components, which were mailed to students.

In a *laboratory* course on electrical circuits at UC Davis, students who finished lab assignments early were granted bonus points and the opportunity to serve as "student assistants" to other students still working on the assignment. This was intended to drive proactivity and more individualized support in the remote setting, as described by Del Rosario and colleagues. In another electrical circuits lab described by Li and colleagues at the University of Georgia, a remote laboratory platform was used to simulate the physical lab. At Deakin University in Australia, Mahmud describes challenges and solutions in converting on-campus, studio activities in power engineering design to a virtual, simulated lab involving similar equipment.

The COVID-19 crisis has impacted instruction in higher education globally, as fully evident by the geographic distribution of the universities represented in this collection of articles. What is particularly interesting is the gamut of resulting outcomes, from limitations realized to maintenance of valued experiences to advances in educating, developing, and supporting our STEM students during this special period. For example, while the immersive, in-country experience of an international service learning project could not be replicated, students elsewhere experienced wellness activities and care offered by faculty and gained valuable insight on how industrial design teams operate remotely across the globe. Senior capstone showcases were quickly converted to online events, resulting in increased participation by industrial partners. Laboratory work successfully transitioned to online and/or remote setups using software, inexpensive equipment shipped to students' homes, and items available at students' places of residence. Students undertook more self-regulated learning during this time using systems and materials developed for this purpose. The inability to do K-12 instructional outreach in person raised the possibility that future cohorts of undergraduate students might acquire skills in online teaching, just as faculty are doing.

The dedication and innovation displayed by faculty who were dealing with some of the same challenges as their students is as heartening as students' efforts to continue learning in the face of a life-altering experience. The efforts reflected in this collection took place against a highly stressful and emotional backdrop. In these papers, students reported feeling "overwhelmed," "worried," "anxious," "tired," "depressed," and "lonely." Yet, students also reported feeling "grateful," "okay," and "hopeful," and these feelings changed weekly. Some faculty were initially unsure about addressing

students' emotional needs as part of their instruction. Instructor Jensen shared, *"I was initially hesitant due to concern of students believing the [mindfulness] activities did not belong in an engineering course."* Students expressed surprise that faculty would acknowledge and support their emotional needs in class, and the articles in this special edition reflect student gratitude for the interactions that created community and connection when many felt disconnected and afraid.

Faculty innovations described throughout this collection met students' cognitive, social, and emotional needs during a confusing, dangerous time.

> "The main tenet of design thinking is empathy for the people you're trying to design for. Leadership is exactly the same thing – building empathy for the people that you're entrusted to help." David Kelley, Founder of IDEO

We applaud the efforts of faculty around the world whose empathy, combined with dedication and resourcefulness, were critical to supporting students' learning and living. We believe AEE readers will be inspired by the stories and the suggestions in these articles and we urge you to adopt and adapt the many lessons learned and resources included, building on the momentum COVID-19 has spurred.

AUTHORS

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