INTRODUCTION

TO A SPECIAL SECTION ON

The Chemical Engineering Community's Ongoing Response to COVID – Innovations in Education and Finding Lasting Positive Impacts of Suddenly Going Remote!

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This special issue includes empirical studies and a reflective practice piece that explore some responses of the chemical engineering education community to the COVID-19 pandemic. The onset of the COVID-19 pandemic marked a rapid and abrupt change for faculty, staff, administrators, and students in their daily work and personal lives. A sudden shift to remote teaching in Spring 2020 brought a host of challenges for chemical engineering educators and students. Many students relocated, some into less than ideal learning environments, as on campus residences were shuttered. Many individuals struggled to pay bills, including tuition. Some became full-time caretakers and/or P-12 teachers as child care and schools closed. Some supported family with COVID-19 or became ill themselves. This period was marked by uncertainty and fear, as across the world and in the United States there was also significant political and social unrest. The murder of George Floyd in May 2020 brought broader consciousness of the systemic, regular impacts of racism across social contexts. Even as colleges and universities began a second term with a mix of remote, hybrid, and some in-person teaching during COVID-19 in Fall 2020, many of these issues persisted. This term had the benefit of faculty and students having had more experience and time to plan, but still presented challenges for learning regarding technology, student engagement, and wellbeing.

As with all challenging situations, COVID-19 also brought opportunities and innovations, some of which may last far longer than the pandemic. These "COVIDends" (COVID dividends) for this community include increased technical savvy with Zoom and similar platforms, learning management systems, online assessment options, etc.; more experience making screencasts or videos, supporting future class flipping; broader awareness of existing online resources (learncheme.com, AIChE Concept Warehouse…); accelerated adoption of more authentic learning opportunities and assessments like projects over exams; and better awareness of our students' diverse learning styles and lives outside of school. While it is important to recognize that the remote courses developed during the pandemic do not necessarily represent what a well-designed and facilitated online course can be, the skills and lessons learned during this time certainly accelerated the pace of the movement toward more online offerings in higher education. Students are more prepared to take and participate in such courses, and faculty are better equipped to offer them. While online courses may not be for everyone, the flexibility afforded by them can be a significant advantage, or even a "deal

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maker," for learners with various backgrounds, schedules, and/or learning styles.

Collectively, the articles in this special issue of *Chemical Engineering Education* describe curricular, community, and pedagogical innovations created to meet both student and faculty needs during the pandemic. There are valuable lessons to be gleaned from these studies and reflections that can guide chemical engineering education far beyond this pandemic.

Three of the papers in this special issue focus on novel approaches to laboratory courses. Vasquez, Bohrer, Noe-Hays, Davis, DeWitt, and Elsass explored how entrepreneurial-minded and community-based learning in a unit operations laboratory supported students' teamwork, motivation, and interactions during remote learning. However, this approach also brought challenges in communication and time allocation in solving complex and open-ended problems. Vigeant and Golightly examined differences in hands-on and video experiments for student learning in a thermodynamics course. The results suggest stronger learning gains for students who had a full semester of hands-on experiments, though it is important to recognize the inability to control for the mode difference alone. Panebianco, Iatridis, and Weiser implemented at-home experiments to teach biomaterials. Student surveys and pre- and post-test scores indicated positive learning outcomes. Each of the papers provides useful strategies for teaching hybrid and remote labs based on prior research and the authors' own experiences.

As mental health issues and awareness have expanded over past years, previous studies have considered strategies for increasing student learning gains through better motivating and engaging students in their own learning. Two studies in this special issue address these aspects of the student experience. Adamarola, Godwin, and Boudouris studied how student motivation and stress influenced student learning during the pandemic in an energy and materials balances course. They found that generally, students' motivation decreased over the semester and that increased motivation correlated inversely with student learning outcomes (lower final grades) for women. The study explores how stress negatively impacted motivation and how the pandemic affected students in a fully remote course. Koretsky also examined student experiences with remote instruction during the pandemic. Surveys of chemical engineering students found that the most common challenge (amongst many others) was staying engaged in their learning. The results of this survey were shared in focus groups with graduate teaching assistants and undergraduate learning assistants. These studies on the broader student experience emphasize the importance of considering student wellbeing and overall life situations and the effects of those elements on student learning under any circumstances, not just during a pandemic.

Two of the special issue papers focused on faculty experiences during the pandemic. Lewin provided a reflective practice piece on teaching plant design during the pandemic. He discussed how the structure of his course changed over time in response to the pandemic and personal lessons learned through teaching. Liberatore, Lepek, Ford, Carter, Pascal, Lamm, Patton Luks, Silverstein, Ford Versypt, Butler Velegol, Vogel, Raikar, Kipper, and Wheeler West described an American Institute of Chemical Engineers (AIChE) Education Division initiative, creating Virtual Communities of Practice. These communities provided spaces for faculty to share experiences and best practices, and provided a network for emotional support engaging over 190 participants from 100+ institutions and nine countries. This effort had a large positive impact on faculty teaching during the pandemic and its effects will last for years to come.

While the events of the past two years have not been welcomed or easy, the "silver linings" from this pandemic can have a lasting positive impact on chemical engineering education. It is interesting to note the range of ideas implemented and outcomes reported in this special issue, from limitations realized to maintenance of standards and values in ways we might otherwise not have tried, to innovations in educating, developing, and supporting those in our communities. Everyone has a COVID-19 story about how the pandemic has affected their life. We encourage you to consider how your story aligns with those reported here, lessons you've learned through this experience, and traditional teaching practices vs. those offering more flexibility or more authentic learning opportunities. The COVID-19 pandemic affected chemical engineering education globally, and this collective experience can create momentum for significant, positive shifts in how chemical engineers are educated. We applaud the dedication and innovation displayed by faculty and staff represented in these articles while they were dealing with some of the same challenges as their students. We believe that *CEE* readers will be inspired by the stories in these articles, and we urge you to consider adopting and adapting the many lessons learned and suggestions included as we all move forward together. ❐

1. Gardner, T.Q. *Creating and facilitating engaging, rigorous fully-online technical courses (or just online content for face-to-face courses) – an MEB example*. ASEE Conference, presentation and full paper, Virtual Online, June 22-26, 2020. https://peer.asee.org/34346

2. Gardner, T.Q. *A framework to guide design of interactive and constructive learning opportunities*. ASEE Conference, presentation and full paper, Salt Lake City, UT, June 24-27, 2018.