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Reflections on the Impact of COVID-19 on Pre-College Engineering Education: An Afterword to the Special Issue

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In our call for proposals, our aim was to explore and document how COVID-19 has impacted pre-college engineering education (Alemdar et al., 2021). During COVID-19, engineering pre-college educators quickly adapted to new learning environments and technologies for teaching and learning. It was important to document these adaptations and lessons learned in formal and informal learning settings. The papers that made up this special show how lessons learned during this challenging time can inform the future of precollege engineering education. The papers offer both theoretical argumentation and empirical evidence to support their answers to the question of how adaptations during COVID-19 impacted pre-college engineering learning. A recurring theme of these papers is that worthy pre-college engineering learning experiences are possible even during unprecedented times. In this paper, we reflect on the papers, their individual and collective findings, and we highlight the impact of COVID-19 on education.

Keywords

COVID-19 Impact, Pre-College Engineering Education, STEM Education

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Reflections on the Impact of COVID-19 on Pre-College Engineering Education: An Afterword to the Special Issue

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Abstract

In our call for proposals, our aim was to explore and document how COVID-19 has impacted pre-college engineering education (Alemdar et al., 2021). During COVID-19, engineering pre-college educators quickly adapted to new learning environments and technologies for teaching and learning. It was important to document these adaptations and lessons learned in formal and informal learning settings. The papers that made up this special show how lessons learned during this challenging time can inform the future of pre-college engineering education. The papers offer both theoretical argumentation and empirical evidence to support their answers to the question of how adaptations during COVID-19 impacted pre-college engineering learning. A recurring theme of these papers is that worthy pre-college engineering learning experiences are possible even during unprecedented times. In this paper, we reflect on the papers, their individual and collective findings, and we highlight the impact of COVID-19 on education.

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We are pleased to conclude the special issue "The Impact of COVID-19 on Pre-College Engineering Education" with a note that highlights the importance of these unprecedented times in pre-college engineering education. This special issue brings together eight research articles that expand our understanding of the adaptations, shifts, and lessons learned in engineering education during a global pandemic.

In spring 2020, schools throughout the country were forced to shift very suddenly to virtual classes for pre-college students. While virtual instruction has long been on the rise, it was never an expectation to convert an entire school year to an online format. Yet educators, staff, administrators, school and district leaders, and parents rose to the challenge. In a very short time, instruction and learning experiences were reimagined for remote teaching. Whether it was called "distance," "online," or "virtual" learning, educators were challenged to provide meaningful educational experiences to all of their students (Baired, 2020; Merrill, 2020). The challenges for pre-college engineering courses and programs were even greater. Most instruction for engineering courses and programs relies heavily on hands-on activities, manipulatives, and technology in the classrooms. Many educators struggled to mimic the in-person experience in the virtual setting. Some schools completely ignored engineering education, and most engineering teachers were on their own as to how to figure out how teach their students engineering in the virtual environment. The challenges were not confined to formal education settings; even informal learning programs such as summer camps and museums had to pivot to virtual instruction.

With this special issue, our aim is to capture how pre-college engineering programming and instruction were adapted to these trying times; to describe what quality engineering education can look like in a time of great uncertainty; and to support

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engineering practitioners as they work toward their goals in engineering instruction. Providing opportunities for all children to access quality pre-college engineering education is an equity issue. While the pandemic did not cause these inequities, it has unfortunately amplified them (National Academies of Sciences, 2020). Hence, we believe that it is important to document the challenges encountered during pandemic conditions and how lessons learned during this challenging time can inform the future of pre-college engineering education.

Even after three years, the lingering effects of the pandemic on children's learning seem even more significant. For example, on average, students are five months behind in mathematics and four months behind in reading by the end of the school year (Dorn et al., 2021). The pandemic caused even larger achievement gaps, hitting historically underserved and disadvantaged students hardest (Dorn et al., 2021; Kaden, 2020). We believe that engineering education has become even more important as a vehicle for closing this gap, as engineering enables students to connect basic scientific and mathematical principles.

Each paper in the special issue documents the circumstances experienced by educators, parents, and students during COVID-19, their challenges through adaptions to virtual learning, and lessons learned in formal and informal settings.

Snodgrass Rangel, Henderson, Martinez, and Greer (2022) investigate fourth- and fifth-grade students' engagement in an online after-school engineering program and the factors that influenced the students' engagement. Student engagement, especially at the elementary school level in a remote learning environment is a critically important topic for research. The recent studies during the pandemic have showed that science, technology, engineering, and mathematics (STEM) education is suffering from a decrease in student engagement from instruction in remote settings (Leech et al., 2022). This mixed-methods study provides evidence of the four dimensions of engagement (e.g., cognitive, social, behavioral, and emotional) and also disengagement. The paper concludes with recommendations for informal online engineering instructions to enhance student engagement. The findings and recommendations are especially useful for future adaptations of existing programs to an online setting.

Pina, Mazur, Ellis, Rudnitsky, McGinnis-Cavanaugh, Ellis, Huff, and Ford (2023) also focus on enhancing students' cognitive and emotional engagement with engineering design concepts through a curriculum based on the theory of imaginative education. The paper demonstrates the development and virtual adaptations of two versions of an NGSS-aligned principles of engineering design unit for middle school students. Further, it details the modifications that were made to the curriculum elements so that it could be taught online. The mixed-method study included comparison groups, in person and online, to provide evidence of student engagement through different versions of the curriculum. Results included both teacher and student experiences. Further, it provided useful insights into the possibilities of sustaining student engagement across different instructional formats using imaginative techniques.

Simpson and Knox (2022) explore the development of children's engineering identity at home settings during the COVID-19 pandemic. During the pandemic, many parents took on the educator role, seeking strategies for home schooling (Mifsud, 2022). The authors conducted interviews with nine families with upper elementary-aged children. The results of the interviews highlighted how doing engineering along with situational interest and self-efficacy formed children's developing identity as engineers. Parents indicated that as children participated in engineering activities, they demonstrated engineering mindset, and interest in engineering as a career and a hobby, and enactments in new problem-solving processes similar to engineers. This study highlights the great potential of home settings as learning environments for developing the engineering identity of children and changing their career trajectory.

Lane, Vomridi-Ivanovic, Cain, Willis, Ahmad, and Gaines (2023) investigate the impact of a culturally responsive pedagogy in a virtual summer camp aimed specifically at underserved students. The authors examine the outcomes for both student participants and undergraduate student mentors who participated in the camp instruction. This contribution is unique in its focus on informal learning and its explicit focus on racial equity and social justice through both the target audience and the pedagogical approach employed in the camp. In addition to demonstrating positive learning outcomes for all participants, it notes that the online camp is more accessible for many students of color who might not otherwise be available to attend.

Delen and Yuksel (2023) review 25 research articles that studied pre-college engineering during the pandemic to uncover the reaction of the community to the sudden shift in supporting children's learning. The review identifies four categories of reaction: (1) moving to online learning, (2) utilizing different strategies and pedagogies such as blended learning, flipped learning, and maker pedagogy, (3) emphasizing the informal learning environments, and (4) increasing considerations of professional development opportunities for teachers.

Clark and Kajfez (2023) examine perceptions of engineering in Junior (grades 4–5) and Cadette (grades 6–8) Girl Scout troops in the context of virtual and hybrid badging programs. They specifically examine engineering identity development in this informal learning setting. Research revealed that math performance is strongly tied to engineering identity and that students still hold many misconceptions about what engineering is. Even in the virtual and hybrid settings, this program

helped to challenge stereotypical views of engineering with students showing growth in both knowledge of engineering and engineering identity.

Kidd, Kaipa, Gutierrez, Lee, Pazos, and Ringleb (2023) take a relational approach to examining the impacts of an afterschool robotics club for fifth graders that was adapted to a virtual setting. The study specifically looks at the interactions and relationships among elementary education college students, engineering college students, and the fifth-grade afterschool program participants. The different types of partnerships and dependencies between the education and engineering students played a significant role in students' attitudes towards engineering, showing that relationships and interactions cannot be disentangled from student engagement and outcomes.

Jackson, Boice, Cochran, Skelton, Rosen, and Usselman (2023) take a narrative analytic approach to uncover the impact of the changes in educational policy on science, technology, engineering, the arts, and math (STEAM) learning in schools. They take an in-depth look at the experiences of two teachers and a school administrator as they navigated instruction during the pandemic, where they had to switch to virtual and hybrid STEAM teaching. The findings showed that teaching engineering during the pandemic was challenging, but not impossible. Additionally, providing equitable instruction and support was a consideration discussed by all three school faculty in this study.

We hope that this special issue provides valuable guidance as to how:

- pre-college engineering learning experiences can function during disruptions to education systems;
- educators can adapt tools and strategies, as needed, to support children and their families dealing with ongoing changes to instructional and home environments; and
- pre-college engineering education remains important even if some important aspects of the engineering education needed to be adapted to virtual learning settings.

The COVID-19 pandemic will have lasting impacts on education. We cannot afford to simply revert to pre-pandemic approaches, and we cannot ignore the collective trauma that we and our students have endured. It is our duty as educators to continue to close the equity gaps and continually improve our practice, which will require deliberate healing, reflection, and rebuilding. Collectively, the papers in this special issue provide a space for reimagining engineering education. Both the successes and the null results obtained by the trailblazing, diverse researchers represented in this issue provide us with a field guide for moving forward across different grade levels and informal and formal learning spaces. We have learned that high-quality, effective STEM instruction is possible in virtual and hybrid formats, and we have learned that virtual options can expand accessibility for students who may not be able to access in-person offerings. At the same time, we were reminded of the power of engineering education in informal environments for promoting children's engineering learning, interest, and identity.

Finally, these eight manuscripts were written and peer-reviewed during the pandemic. We thank the reviewers for their time, wisdom, and labor that made this special issue possible. We would especially like to thank the authors for their labor, wisdom, compassion, and grit for pivoting their programs and their research approaches in a short timeframe to share these results with our community.

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