Pathway to a New Engineering Education Paradigm: The COVID-19 Factor

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A lot has changed over the last two years in how engineering faculty teach and how their students learn. Engineering educators were contemplating imminent changes in 2019/2020 when the COVID pandemic struck. The discussion was almost two decades old. Social, economic, and developmental factors coupled with advances in technology paved the way for more multidisciplinary engineering. Engineers have been tackling new problems to solve and more sophisticated systems to design. Globalization meant that they should acquire certain personal, social, and cultural skills. They have to be more aware of the impact of their work on society and on the environment. Experiential learning, project-based learning, and research-based learning became themes of a new engineering education paradigm, the signs of which were emerging on the horizon. Changes in the philosophy, disciplines, and pedagogy of engineering education were under discussion. The demand for these changes varied, however, in terms of their motivation, scope, scale, and implementation from one country to another.

In the United States, the case for changing Science, Technology, Engineering, and Mathematics (STEM) education paradigms is strong. We discuss this particular case here as an important benchmark with special attention to engineering. The status of STEM education became problematic in the United States due to the lack of a sufficient supply of able STEM professionals to meet the needs of the 21st century. Most of the growth in the United States in the 20th century was due to innovations and advances in STEM. In 2005, a committee of the national academies[1] delivered a report, known later as the "Gathering Storm" report, raising concerns about the future. The report shed light on alarming phenomena including a decline in federal funding of research and development, a majority of engineering Ph.D. recipients from U.S. universities who are not U.S. citizens, and a STEM-lagging K–12 educational system [1]. Five years later, another report depicted a worsening outlook and predicted that the U.S. ability to compete in STEM and in the global 21st century STEM jobs market further deteriorated [2]. Poor participation of U.S. minorities in STEM is an important part of the problem. Demographic changes suggest that these minorities may outnumber the current majority during the 21st century, thereby exacerbating the situation. Baby boomers, who hold about a quarter of STEM jobs, are retiring, while these jobs are projected to increase rapidly. This enlarges the gap the country should expect in its STEM capabilities [3, 4].

In 2012, it was projected that in order for the United States to retain science and technology leadership, there is a need for approximately one million more STEM professionals than what the country would produce over ten years. Less than 40 percent of the students who start university in a STEM major were completing a STEM degree. Students were citing difficulties with introductory STEM courses as a factor in their decision to leave. Other STEM students switch to non-STEM majors at later stages of their programs of study. Research had indicated that better teaching methods can make STEM courses more inspiring to students, and that substantial improvements are possible by diversifying teaching strategies and utilizing evidence-based practices [5]. A new interdisciplinary field of research blending the expertise of scientists and engineers with theories and methods of learning was growing. This field, discipline-based education research (DBER), investigates learning and teaching in a discipline from the perspective of its views, priorities, knowledge, and practices. DBER has a number of goals including achieving better understanding of how students learn the concepts, practices, and ways of thinking of science and engineering; of the nature and development of expertise in STEM disciplines; and of how to identify and measure learning objectives and the best instructional approaches to fulfill them [6].

Research revealed that a large part of the problem lies in the way courses are traditionally taught: lectures, taking notes, labs with predetermined procedures and results, and assignments. DBER showed that research-based instructional strategies are more effective than these traditional methods in acquiring conceptual knowledge and in improving students' attitudes toward STEM. Effective instruction is student-centered and involves various approaches, such as making lectures more interactive, utilizing technology in the classroom, incorporation authentic problems and activities, adopting project-based instruction methods, team-based work, replacing standard lab courses with discovery-based research courses/labs, shifting instruction from what an engineer/scientist knows to how he/she thinks, and helping students to develop soft and professional skills [6, 7]. The conclusion of the work of many scholars was that undergraduate engineering education in the United States needs reform and systematic change so that effective teaching methods become the norm rather than an exception. This reform requires a cultural shift from reliance on traditional lecturing to activities that engage students. It also requires an orchestrated effort to grow a student body that fully represents the diversity of the U.S. population [3].

The pursuit of changes in engineering education is not limited to the United States. There has been worldwide progress in education, pedagogy, innovative instruction strategies, advancing knowledge, and investing in primary, secondary, and higher education. Some argue that many countries in Europe and Asia have actually pursued key recommendations of the "Gathering Storm" report more than the United States has [1, 2, 8–10].

Hence, as indicated earlier, paradigm changes in engineering education were under consideration when COVID-19 happened. Many pandemic-induced changes — such as online education, rethinking traditional labs, large-scale deployment of virtual platforms, hybrid instruction, and workshop-based classes [7, 11] — were already under discussion. However, the practicality of these approaches, the level of their acceptance among engineering faculty, the scale for which we were open to try them, the timing to do so, and their chances of success were probably questionable by most of us. Notwithstanding the fact that the pandemic had a profoundly negative effect on the life and education of millions of students worldwide, we can transform this tragedy to something from which future students can benefit. The COVID-19 pandem-

[1] The National Academy of Sciences, the National Academy of Engineering, and the National Academy of Medicine constitute the collective scientific national academy of the United States. Until 2015, the National Academy of Medicine was called the Institute of Medicine.

ic enforced educational changes on a global scale, accelerated our pace to try new methods, and led to a global experiment we should now analyze as we explore the best pathway forward.

Online and hybrid engineering programs can increase student retention and open the door wide for non-traditional students to enter the field. Engineering education became a field of study in its own right with programs, departments, and even schools dedicated to this study. The engineering education community started to examine the two-year experiment we have lived so far: the pros and cons of online education, the technical and logistic challenges, privacy and security issues, combating cheating, the need to close the digital divide, issues specific to international students, and others [12–14].

As for us, in the communications engineering community, our technologies are central to many of the changes enabling the new paradigm. Network engineering itself is an emerging multidisciplinary area [15] where a new generation of engineers will play a major role in facing a range of modern-life challenges. This provides for numerous research opportunities for us on the technical/technological side, the educational side, and at the intersection of both with socioeconomic issues. I would like to encourage my colleagues to make inroads into these new territories.

Over recent months, many of us have been wondering about tomorrow's higher education, the future of engineering education in particular, and the university operation models that will survive the COVID-19 shock. In the short term, the future of engineering education will most likely be hybrid with varying blends of physical and virtual classes, interactive research-based instruction methods, and DBER-inspired philosophies and pedagogies. The pathway to these changes had started years ago. The last two years have merely taken us through a shortcut!

Once again, our hearts go out to those who have lost loved ones due to the pandemic.

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Biography

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