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# Engineering Education: Resiliance And Purposeful Change

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Engineering education is undergoing rapid change. Programs across the world have instituted route-and-branch reforms and are navigating a path towards new educational models. This transition has been proactive, carefully planned and rolled out over time frames determined by the institution. Over the past eighteen months, the COVID-19 pandemic has necessitated major changes to program design and delivery. Here, changes have been reactive, unexpected, and introduced at speed. The timing of the Special Issue places it at the conjuncture of these two contrasting change processes. The editorial considers global developments in engineering education in this unique context. It begins by looking back to 2018. It then moves forward to the present and considers how programs have progressed along their planned change pathways, despite the sudden program changes instituted by the pandemic.

In 2018, a review of *The global state of the art in engineering education* was published (Graham, 2018). The review was undertaken to inform the design of the New Engineering Education Transformation (NEET) at MIT, a multidisciplinary, project-based program that saw its first graduating cohort in June 2020. Drawing on consultations with 50 global thought-leaders in the field, the report identified the most highly-regarded current and emerging engineering education programs from across the world. Using a case study approach, it investigated the features that distinguished this group of current and emerging leaders from peer engineering programs worldwide.

The group identified as **current leaders** in engineering education were predominantly based in the US and Europe with an established reputation in engineering research, including the University of Cambridge in the UK and Stanford University in the US. The leading programs were distinguished by their focus on user-centered design and technology-driven entrepreneurship. While established research-led universities also featured in the list of **emerging leaders**, the overall profile of this group was markedly different. Universities identified as emerging leaders were more likely to be drawn from outside the global north, with particular clusters in Asia and South America, and offer engineering programs that are based on a unified curricular design and

are shaped by distinctive regional societal needs. These features came together in an education that emphasized practice-based, multidisciplinary, and self-directed learning.

Alongside this review of the cutting edge of engineering education, the 2018 report undertook a horizon scan of the future trajectory of the field. It suggested that features distinguishing the emerging leaders were likely to become more deeply embedded in world-leading engineering education programs in the future. Their curricula would be outward-looking and responsive to a rapidly-changing world, seeking to develop a future generation of engineers with the knowledge, mindsets and skills to respond to the economic, social and environmental challenges of the 21st century.

The report therefore anticipated that world-leading programs would inculcate a collegial culture of teamworking, exploration and entrepreneurship to enable students to work across different contexts and adapt as these contexts changed. It was anticipated, too, that the focus on widening participation evident in the current and emerging leaders would become more pronounced as part of a wider institutional commitment to equality, diversity and inclusion (EDI). The report also noted that sustainability was likely to be a central theme of the leading engineering programs of the future, ensuring that tomorrow's engineers are able to support industry, governments and societies to mitigate and adapt to climate and environmental change. It described how the delivery of these features – a student-centered culture, a commitment to EDI and an engagement with sustainability – was likely to be facilitated by strong institutional commitment. Ambitious and effective change at curricula level was seen to rest on an unwavering institutional commitment to university education as a force for social good.

Three years on from the publication of *The global state of the art in engineering education*, this Special Issue describes the achievements of programs representing the cutting edge in the sector. It brings together contributions from the group of institutions identified as current and emerging leaders in engineering education. Individually and collectively, the papers demonstrate how far engineering education has progressed along the pathway of change anticipated in the 2018 report.

With respect to instilling a culture of creativity, innovation and entrepreneurship, Loh and colleagues describe how the Innovation and Design program at NUS seeks to nurture students' entrepreneurial mindset using experiential project-based activities that run in parallel to the four-year undergraduate curriculum. The focus on an entrepreneurial mindset is echoed in other articles, including those from Chalmers University of Technology (Karlsson-Bengtsson and colleagues) and the Pontifical Catholic University of Chile (Hilliger and colleagues). Indeed, a growing curricular emphasis on nurturing students' mindsets or 'ways of thinking' is a prominent theme across many of the engineering programs represented in the Special Issue. In particular, a number of articles focus on ethical mindsets and values. For example, Lavi and colleagues from MIT outline a plan to embed ethics and other 'ways of thinking' into NEET projects in the future. More broadly, Adams and

colleagues describe the evidence-driven approach taken at Purdue University to develop pedagogy and assessment tools for ethics education.

Strongly linked to engineering ethics, the Special Issue illustrates how leading programs are engaging with sustainability and equity. Outlining Delft's engineering ethics program, Van Grunsven and colleagues note that 'engineers shape much of our modern world'. The products and services designed by engineers have changed people's lives – and changed the planet. Today's ethical challenge is 'to (re)design a system that is fairer, more inclusive and more sustainable'. A range of articles point to student team-based projects framed around the United Nations' 17 Sustainable Development Goals (SDGs). For example, Bertel and colleagues highlight the new Megaprojects at Aalborg University that bring together interdisciplinary teams of students from across the university to tackle authentic challenges that address one or more of the SDGs.

Looking across the innovative approaches described in the Special Issue, two features stand out. The first is an emphasis on continuous change. An appreciation that change is not a single moment or stage but an ongoing process runs as a thread through the articles, and can be seen in the continuous improvement model adopted at Iron Range Engineering that led to the establishment of the Bell program (Ulseth and colleagues). This is made explicit in the paper by Adams and colleagues on Purdue University's mission to widen access and impact, by building 'an innovation cycle' into its program. As Adams et al explain, the innovation cycle is driven by cross-fertilization between research and practice. Educational practice generates new ideas for research which in turn informs practice, an iterative process that is enabling their programs 'to scale, adapt, and personalize, and make education inclusive and global'. Secondly, the Special Issue points to the importance of program changes that embody the institution's defining mission and values. The phrase used by Sheppard and colleagues at Stanford University is 'purposeful change' in their efforts to situate the engineering programs within a liberal education. This drive to align practices with institutional values is also evident in the reform of the reappointment and promotion systems at Olin College of Engineering, as described by Martello and colleagues.

The Special Issue describes innovations in engineering education that were in train before COVID-19 developed into a global pandemic in 2020. The coronavirus first identified in December 2019 continues to take a heavy human toll. By May 2021, the World Health Organisation recorded over 175 million confirmed cases of COVID-19 worldwide, including almost 4 million deaths.[1]

The context in which the models of engineering education described in the Special Issue were designed and implemented is therefore very different to the one in which engineering programs are now operating. As has been widely observed, the COVID-19 pandemic has acted as a 'stress test',

[1] WHO Coronavirus (COVID-19) Dashboard, https://covid19.who.int/ (accessed 25 June 2021)

exposing both strengths and weaknesses in the systems on which societies depend. Much of the attention has been on supply chains and healthcare services – but higher education systems have been tested too.

While digital technologies have long played a role in engineering education, the COVID-19 pandemic necessitated a rapid pivot to partial or fully online learning. Most of the universities represented in this Special Issue, in line with peer institutions worldwide, designed and rolled out this pivot within a two-week time window. An important question is therefore how well the models of engineering education developed by global leaders have withstood the stress test of the COVID-19 pandemic. Have the face-to-face modes of teaching that underpinned many of the experiential, collaborative and student-centred approaches exemplified in the 2018 report been resilient to this move online? How have programs, students and faculty been able to absorb and adapt to this sudden and far-reaching change? What will be the long-term impact of the period of emergency teaching on the engineering education sector?

A new review[2] is exploring the experiences and lessons learned from the sudden shift to online teaching and how this might impact the future direction for the sector. In addition to canvassing views from thought-leaders, instructors and university leaders in engineering education worldwide, the CEEDA review is using a case study approach to explore the response of programs identified as current and emerging leaders in the 2018 report. Themes noted in *AEE*'s Special Issue on COVID-19 are also emerging in the case studies, including a concern with student welfare and the challenges of course design and delivery in an online setting (Chen et al, 2020).

The ongoing CEEDA review points to an increasing focus on ensuring that the engineering curriculum and its modes of delivery build student wellbeing and resilience. Linked to this challenge is the development of new techniques for fostering informal peer-to-peer interaction between students engaged online. Case studies are also capturing how sector leaders are responding to the challenges of program delivery by identifying new opportunities for the establishment of online courses and experiences that span institutions and countries. The changes to the design and delivery of engineering programs precipitated by the pandemic have also brought the ethical foundations of engineering education more strongly to the fore.

As these examples suggest, emerging evidence about the impact of the COVID-19 pandemic on leading engineering programs provide grounds for cautious optimism for the future. While still in progress, the CEEDA review suggests that leading engineering education programs are not retreating back along their pathway of change. They have not lost momentum in their drive towards a more student-centred curriculum, with its emphasis on teamwork, self-reflection, personal development

[2] Collaborative Engineering Education in the Digital Age (CEEDA), https://www.ceeda.org (accessed 20 May 2021)

practice-based learning. The programs have also continued to be outward-facing, with an increased focus on societal needs and the global sustainability agenda. Indeed, instead of prompting a retreat, the COVID-19 pandemic appears to be acting as a change accelerator, moving engineering education programs more rapidly along their change pathway. There is a broad consensus that many of the changes catalysed by the pandemic are here to stay. They are being fashioned in ways that are enabling leading engineering education programs to maintain their direction of travel – but at a faster pace. Student welfare is a case in point. Already a concern of engineering education programs, the pandemic, and the remote ways of working it has required, has moved student wellbeing to the top of many institutions' agenda.

Indeed, in their response to the COVID-19 pandemic, many of the leading engineering education programs are putting into practice the competencies they are seeking to develop in their students: innovation, teamworking, flexibility, and responsiveness to societal needs. In deploying these skills, the engineering education sector is displaying the hallmarks of system resilience. Global leaders are demonstrating an intrinsic capacity to adjust to exogeneous shocks. They are innovating and adapting to the COVID-19 pandemic in ways that protect the quality of their programs and the richness of the student experience.

## REFERENCES

Chen, John, Clark, Renee, and Lichtenstein, Gary. 2020. "Introduction to this special issue of engineering educators response to COVID-19." *Advances in Engineering Education*, 8(4).

Graham, Ruth. 2018. *The global state of the art in engineering education.* Massachusetts Institute of Technology (MIT) Report, Massachusetts, USA.

## AUTHOR

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- a global study on the lessons learnt from the current period of 'emergency teaching' resulting from the COVID-19 pandemic and how this might impact the trajectory of engineering education in the future (www.ceeda.org);
- a global initiative to improve the reward and recognition of teaching in higher education that is now supporting reform to the tenure and promotion systems of over 50 universities worldwide (www.advancingteaching.com);
- a cross-institutional and multi-year survey to capture and track the culture and status of teaching amongst faculty, in which 21 universities from 10 countries are participating (www.teachingcultures.com).

Further details can be found on Ruth's website – www.rhgraham.org – which provides an outline of recent projects as well as copies of her published reports.