

Executive Summary

The decade leading up to 2020 was a period of fundamental change in engineering education. It saw the emergence of a new generation of globally-recognised programmes that took an experiential and collaborative approach to learning, underpinned by face-to-face problem solving.

In early 2020, the COVID-19 pandemic prompted an immediate pivot to online learning for universities worldwide – including those planning or delivering such innovative programmes. As the engineering education community grappled with the challenges of this period of emergency teaching (ET), it was also confronting questions about how to deliver student-centred, collaborative learning experiences remotely. Hand-in-hand with these questions was the wider issue of the longer-term impact of COVID-19 and ET on the future trajectory of the sector and the innovative emergent practices of cutting-edge engineering programmes.

Informed by the perspectives and experiences of the global engineering education community, the *Crisis and Catalyst* study takes stock of the sector-wide impact of ET. It addresses two central questions:

1. What were the experiences of the engineering education community during emergency teaching?
2. How will this systemic shock impact the direction of travel for the sector beyond emergency teaching?

The study draws on interviews conducted between August 2020 and April 2022 with university leaders, engineering instructors/faculty, educational specialists and engineering students. The 226 interviewees were located in 36 countries, spread across six continents. Interviews were conducted on the basis of anonymity; quotes included in the report are therefore unattributed. Examples of educational innovation developed or delivered during the period of ET are included throughout the report.

1. What were the experiences of the engineering education community during emergency teaching?

ET represented a system-wide shock to the engineering education sector. It was abrupt and unforeseen, and it destabilised practices, priorities and cultures that had been deeply embedded in engineering programmes for decades.

ET was also noted to have exposed and exacerbated major challenges facing engineering education. Two stood out. The first was **inequalities in digital access**. Of particular concern was how students without a dedicated place to work, reliable internet access, and a smart device were denied access to much of the learning opportunities and communities of support available to their peers. The second was **wellbeing**. The combined impact of increased workloads, social isolation and uncertainty about the future took a heavy toll on the mental wellbeing of students and instructors alike. So, for example, the sudden switch to online learning left many students feeling overwhelmed by the amount of new information they needed to manage at a time when they were struggling to foster meaningful connections with peers. A range of interventions were rolled out by engineering programmes to address these challenges, such as the adoption of activities to foster student-to-student empathy and promote peer connectivity across the physically-dislocated student cohort.

While acknowledging the long shadow cast by these challenges, interviewees also characterised ET as an unprecedented time of educational experimentation and collaboration. Supporting student learning and wellbeing were quickly established as the explicit and primary priorities of university leaders at all levels of the institutional hierarchy, opening up new opportunities and resources for educational reform at a

course and programmatic level. At the same time, ET brought into focus the weaknesses of teacher-centred pedagogies for many instructors that had hitherto taken a lecture-based approach to their teaching. Student engagement during transmissive online 'lectures' was often low, with many turning off web-cams and reluctant to ask questions during synchronous sessions. With limited opportunities for peer-to-peer interaction, teacher-centred pedagogies also exacerbated student isolation, with few opportunities to build trusting and collegial relationships with peers in the online environment. As a result, the online pivot catalysed a fundamental change in the pedagogical approach of many engineering instructors. It was a change that often came in two stages: the rapid redesign of courses for online delivery and then, in the months that followed, the incorporation of active, collaborative and/or blended learning as mechanisms to address growing concerns about student isolation, overwork and wellbeing.

Experiences across this two-staged process prompted many instructors to reconsider the aims, structure and learning modes for their courses, often working for the first time with educational developers to embed active learning pedagogies. A wealth of new pedagogical ideas and practices emerged, ranging from the development of novel kits-of-parts for student to engage in hands-on learning from home, to the use of low-stakes online graded quizzes in place of written proctored exams. ET also saw increased numbers of instructors embrace team teaching as a mechanism to meet the wide-ranging demands of online and blended learning. Such developments were often informed and advanced by new communities of support brokered with the regional and global engineering education community.

ET was also noted to be a time that forged a new connectivity between students and instructors, as they together navigated the challenges and uncertainties of this unprecedented period. Indeed, many instructors went onto describe how this experience had given them a new insight into the lives of their students and had thrown into sharp relief inequalities that had not previously been visible. The experience was one that brought social responsibility to the fore, with an increasing recognition of the diversity of barriers faced by the student community. Awareness was heightened by the movement for racial equality catalysed in the US and gaining wider global support from 2020. As a result, some interviewees, particularly those based in the US, reported that the most passionate and far-reaching conversations across their academic community during ET centred around diversity, equity and inclusion.

In the transition out of ET, interviewees consistently noted their relief and joy at the opportunity to re-establish in-person learning and interaction. They spoke at length about how the online pivot had underscored the importance of in-person connectivity and hands-on engagement for student wellbeing and engineering learning as well as the unique role played by the university campus in enabling such transformations. Indeed, many interviewees pointed to wide-ranging debates precipitated by ET at their universities on how the campus footprint should be used to add most value to student learning and development. At the same time, it was widely acknowledged that the flexibility offered by blended learning and remote working had been embraced by the university community with a strong and vocal expectation from students that many 'taught' engineering courses would continue to be delivered online.

2. How will the systemic shock of COVID-19 and emergency teaching impact the direction of travel for the sector?

Interviewee feedback made clear that COVID-19 and ET would re-chart the trajectory of the engineering education sector. The next generation of leading programmes will undoubtedly embed educational cultures and practices that were tested, refined and/or catalysed during ET. Taken together, interviewee reflections on the influence of COVID-19 and ET on the cutting edge of engineering education point to two major long-term effects. As outlined below, these are: **(i) precipitating new directions** for the sector; and **(ii) accelerating trends already in train** prior to 2020, respectively.

i. Precipitating new directions for engineering education

ET was noted to have catalysed new cultures, priorities and practices in many engineering schools and universities across the sector. Although often long advocated in the pedagogical research literature and appearing in pockets of good practice, such approaches were unlikely to have emerged or been embraced at scale but for the systemic shock of ET.

ET prompted instructors and university leaders alike to confront fundamental questions – and challenge deep-rooted assumptions – about the purpose and place of engineering education in the 21st century. It exposed the weaknesses of teacher-centred pedagogies – particularly with respect to student engagement and peer-to-peer connectivity – and precipitated a step-change in attitudes and practices amongst a significant minority of instructors towards **active and collaborative learning**. For many in this group, the extended period of ET had served to embed these changes to cultures and practices. For example, in recognition of the benefits they afford to instructor flexibility and student support, it was anticipated that **diverse teaching teams** would become increasingly evident in coming decades, with undergraduate teaching assistants playing an active role. In addition, the root-and-branch reform of **assessment practices** precipitated by ET was expected to lay the foundations for a more diverse and dynamic approach to assessment across the sector, with approaches such as group projects and one-to-one oral exams playing a more prominent role.

At the same time, ET brought the issue of **student mental health** to the fore, with strategies to enhance wellbeing often placed at the heart of programme-wide responses to COVID-19. The idea that engineering schools should play an active role in fostering student wellbeing was noted to represent a profound change and one would be retained at many institutions in the future. ET was also noted to have had a far-reaching impact on educational strategies in many universities. For example, building on the rapid, agile and community-informed approach to educational decision-making that emerged at many universities during ET, it was anticipated that **co-produced educational strategies** – drawing on in-house expertise and pedagogical research – were likely to play a more prominent role in shaping institutional policies for teaching and learning in the future.

ii. Accelerating trends already in train prior to 2020

Interviewee feedback suggested that ET would accelerate and enhance many of the cultures, priorities and practices already under discussion or implementation in engineering programmes prior to 2020. The online pivot provided an opportunity for universities and instructors alike to ‘stress test’ new educational approaches – and the infrastructure needed to support them – at a scale that had never been imagined. It also worked to demonstrate the role and value of many evidence-based practices to instructors and students alike. So, for example, the online pivot both validated the benefits of **blended learning** and enabled its acceptance across the academic community. ET also appears likely to accelerate a trend towards programme-wide blended approaches that emerged in the years leading up to 2020, in which all technical engineering learning is disaggregated into online ‘micro modules’ that students access independently to help them address on-campus team-based challenges. At the same time, ET fast-tracked the development of the **digital infrastructure** and amassed the asynchronous learning resources needed to enable such large-scale adoptions of blended learning.

Stemming from a wider adoption of **flexible learning pathways** and student choice, interviewees also anticipated that engineering schools and universities would increasingly establish **programme-wide scaffolding** to ensure that all students progressively build a core set of professional competencies over time. Another prominent theme was **social justice**, with the experiences of 2020 and 2021 expected to foster a greater emphasis on social responsibility in both engineering curricula and the wider culture in engineering schools.

In anticipating the direction of travel for leading engineering programmes, interviewees cautioned that a positive sector-wide post-ET transformation was by no means inevitable. Instead, interviewees were clear that the changes outlined above would likely be restricted to well-resourced universities already operating at the cutting-edge of engineering education and/or those that took an agile and community-led approach to navigating ET. Interviewees based outside such institutions often took a much more pessimistic view of their institution's future trajectory, and particularly its capacity to drive positive change or to engage instructors to support such efforts.

Their pessimism spoke to a wider concern among interviewees – across institutions and countries – that the period of ET would drive the further stratification of the engineering education sector. ET exposed and exacerbated inequalities within the student community, among university staff and between institutions and countries. Interviewees noted that the resources to mitigate these impacts are also unequally distributed. For many universities, the lack of institutional resources closed off opportunities for innovation both during and after ET. Conversely, institutions with the resources to invest in a new generation of educational technologies and specialist staff were now well-positioned to take leading roles in the sector.

A related concern was that, in an increasingly competitive higher education market, some institutions and programmes will emerge from ET with a culture in which students – their learning, advancement and wellbeing – are not a central priority. ET was characterised as a time when speed of deployment often took precedence over the quality of student learning in the rush to deliver online courses and activities. As a result, much of the online learning delivered worldwide during this time was passive and teacher-centred. While of questionable benefit to student learning, such forms of online education are also quick and cheap to deliver: without costly experiential, interactive or mentorship elements and without the need for on-campus spaces, such online 'lectures' can be scaled up to almost any student cohort size, offering a significant cost savings to universities. Without a clear set of educational values underpinning the use of digital learning, deep concerns were voiced about the proliferation of such forms of online learning and the impact this might have on students' learning, mental wellbeing and communities of support. Interviewees also cautioned that, while ET represented a time of unprecedented change across higher education, for many universities, these changes were simply a temporary response to a crisis situation. As a result, it was suggested that some of the potential benefits of practices adopted during ET would not be fully realised. There may therefore only be a narrow window of time to enable evidence-based and long-term change before many institutions revert to the pre-2020 status quo.

However, despite the concerns expressed about the barriers and risks facing the engineering education sector, most interviewees sounded an optimistic note for the future. The consensus view was that, while ET has undoubtedly been a period of **crisis** – placing unprecedented demands on the sector and testing its adaptive capacity – it will also act as a **catalyst** for a new generation of leading engineering programmes in which the opportunities, learning and wellbeing of students are placed at the forefront.

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