MIT, US

Case Study Part B – Institutional context

Undergraduate engineering student year group (2nd year cohort 2020/21):	**≈ 850**
Number of engineering faculty:	**≈ 400**
Duration of undergraduate engineering degree (to BSc):	**4 years**

1. Defining features of MIT's engineering education

A striking feature of the Massachusetts Institute of Technology (MIT) undergraduate curriculum is the disciplinary breadth to which students are exposed. Regardless of their major, all MIT students are required to study what are termed *General Institute Requirements* (GIRs) which comprise around half of the undergraduate curriculum (17 of the 35 subjects). While some GIRs focus on foundational sciences (such as Biology and Mathematics), a significant proportion are devoted to the liberal arts, including four courses in Communications and eight courses in Humanities, Arts and Social Science.

Arguably, the defining feature of MIT's engineering education, however, is encapsulated in its motto "*Mens et Manus*" – mind and hand. It is a model that, in the words of one interviewee, "*blends the practitioner and the theoretician*" with an apprenticeship-style approach to experiential and 'hands-on' learning. This experiential approach can be seen most clearly beyond the core engineering curriculum: in MIT's elective courses, co-curricular activities and suite of maker-spaces across campus[1]. For example, over 90% of MIT's undergraduate engineers participate in the *Undergraduate Research Opportunities Program* (UROP)[2], where they engage in research projects in collaboration with MIT faculty, typically as a co-curricular experience. Supported by a broad infrastructure of resources, training programmes and opportunities, many co-curricular activities also blend experiential learning with entrepreneurship and innovation. One example is the *Sandbox Innovation Fund Program*[3].

The past five years has marked a new chapter in the university's blending of 'mind and hand' through the establishment of NEET[4] (*New Engineering Education Transformation*). This programme brings together MIT's emphasis on experiential learning with a project-based, multidisciplinary approach designed to better prepare students to tackle the major challenges facing society. Since its launch in 2017, NEET has grown to represent the fourth largest undergraduate programme at MIT. NEET students follow one of five interdisciplinary 'threads' in areas such as *Autonomous Machines* and *Digital Cities* that are drawn from courses in different engineering departments and connected by hands-on, authentic projects. Building students' skills and mindsets is a major focus of NEET, with its design guided by what are termed 'NEET Ways of Thinking': 12 capabilities that include 'creative thinking' and 'analytical thinking'.

[1] MIT Makersystem, Project Manus: https://project-manus.mit.edu/mit-makersystem

[2] Undergraduate Research Opportunities Program (UROP): https://urop.mit.edu

[3] MIT Sandbox Innovation Fund: https://sandbox.mit.edu

[4] NEET (New Engineering Education Transformation): https://neet.mit.edu

2. MIT's experience of emergency teaching in engineering

2.1. Emergency teaching restrictions

On 16th March 2020, the MIT President announced the closure of the university campus, with spring classes to resume fully online from 30th March. Soon after the semester relaunch, MIT established a suite of resources[5] to support university operations during the period of COVID-19 restrictions. This included the development of an app – the *Covid Pass*[6] – to manage campus access, testing, contact tracing and vaccinations of MIT staff and students in collaboration with the campus medical centre.

Throughout the 2020/21 academic year, the majority of MIT classes were delivered online, under an institutional approach characterised as "*anything that can be remote, will be remote*". However, from September 2020, seniors (final year students) were given dispensation to return to campus to participate in specific hands-on or lab-based courses that could not be delivered remotely. From February 2020, all students were invited back to campus to work remotely from dorm rooms and to engage in specific hands-on or lab-based courses face-to-face.

2.2. Managing the transition to emergency teaching

As in many universities across the world, the online pivot at MIT was rapid: instructors had two weeks to prepare for a fully online educational delivery. To support this transition, the university communicated two clear messages to its faculty.

The **first** was to recalibrate what could be achieved in 'emergency teaching' conditions, particularly in the early weeks of the online pivot. In the words of one university leader, "*two thirds of the content, two thirds of the quality is enough*". Instructors were encouraged to focus on the core objectives and content of their courses and the emphasis on 'high stakes' assessments, such as mid-term tests, was significantly reduced: "*you don't want a winner takes all environment when you're living in a pandemic*". For the remainder of that semester, MIT moved to a 'pass/no record' grading system for all undergraduates (such that students either passed the class or receive no record of having taken it).

The **second** message for instructors was, in the words of one university leader, "*to make a plan, decide how you are going to teach [remotely] and then come ask us for help and support*". In line with the deeply embedded MIT culture of faculty autonomy, the onus was first placed on instructors to revise the design and focus of their courses for online delivery. The university then facilitated delivery of these plans by establishing an infrastructure of support and resources, many of which were in place prior to semester relaunch on 30th March 2020. For example, a number of MIT's functions – including the *Teaching + Learning Lab*, *Information Systems and Technology*, and the office of *Open Learning* – came together to establish a common hub for resources and materials for instructors to support remote

[5] MIT Now: https://now.mit.edu

[6] MIT Covid Pass: http://covidapps.mit.edu

emergency teaching[7], with a complementary website for students to support their remote learning[8]. At the same time, the budget for the university's office of *Experiential Learning Opportunities* (ELO) was significantly increased, such that it was able to offer rapid funding to facilitate the delivery of remote course elements or activities that practiced 'learning by doing'.

Enabled by ELO funding, MIT has fashioned a response to emergency teaching that preserves the 'mind and hand' character of its education and hands-on experiential approach. While some 'design-build-test' and lab-based experiences were postponed, removed or replaced with online simulations, a surprising number were retained through, in the words of one university leader, "*mailing out kits of parts and have students build things at home*". It was estimated that, in Mechanical Engineering alone, kits were sent out to students in 16 separate courses during the 2020/21 academic year. Examples included the first year elective *Toy Product Design* (class 2.00b[9]) and the second year elective *Design and Manufacturing* (class 2.007[10], as outlined in Box 1). A range of mechanisms were put in place by the university to support the logistics of constructing and using these kits. As well as the establishment of a dedicated on-campus office for shipping materials to students, this included the launch of an online framework[11] to help students and instructors identify the level of risk associated with different hands-on activities undertaken from home. Where providing students with at-home shipping kits was not feasible, other approaches were used to re-create students' hands-on experiences. For example, the NEET *Advanced Materials Machines* and *Renewable Energy Machines* threads were combined into a shared introductory course, where students designed a machine online that was subsequently 3D printed and tested by instructors on campus. A number of interviewees went on to suggest that many of these remote experiential learning activities offered significant potential for scaling-up or franchising the approach to the benefit of leaners outside the MIT community and outside the US.

When reflecting on MIT's approach to emergency teaching as a whole, interviewees pointed to the progressive improvement in the quality of the online provision, from April/May 2020 when "*what we delivered wasn't even close to being great*" to the courses offered in the spring of 2021. Three elements of this progressive improvement appeared to be key.

The **first** was an improvement to MIT's digital learning infrastructure, facilitating greater flexibility in online teaching and learning. While MIT's innovations in massive open online courses (MOOCS) through *MITx*[12] have been world-leading, the infrastructure for supporting many of its residential undergraduate programmes lagged behind. Within weeks of the online pivot, a suite of online tools such as *Zoom*, *Panopto*, *Slack*, *Piatsa* and *GradeScope* were introduced. By October 2020, MIT had also replaced its 'homegrown' learning management system, *Stellar*, with *Canvas*.

[7] Teach Remote: https://teachremote.mit.edu

[8] Learn Remote: https://learnremote.mit.edu

[9] 2.00B: Toy Product Design: http://meche.mit.edu/featured-classes/toy-product-design

[10] 2.007: Design and Manufacturing I: https://me-2007.mit.edu

[11] MIT Remote Making resource site: https://wikis.mit.edu/confluence/display/make/Remote+Making

[12] MITx Massive Open Online Courses: https://openlearning.mit.edu/about-mitx

Box 1. Remote delivery of 2.007: Design and Manufacturing, Spring 2021

2.007 is an iconic course that exemplifies MIT's apprenticeship model of education, where instructors, in the words of the course co-lead, "*are teaching by doing next to the student*". The course culminates in a robotics competition, where students each design and build a device to accomplish a specific (and often whimsical) task based around a different theme each year. 2.007 seeks to build students' confidence and competence in the hands-on construction of their robots, as well as offer an authentic context to experience mechanical engineering principles in action, such as friction and compliance. Working in a machine shop, students are given 'physical homework' during the first half of the semester, where they are guided step-by-step through the construction of a simple autonomous robot (named 'Mini-me') that meets some of the competition criteria. During the final five weeks of the course, students design and build their own machine. At the end of the semester, the capabilities of each robot are tested on a custom-made 'game board', reflecting that year's theme, in a major showcase event designed to foster excitement, camaraderie and community across the student cohort.

The online pivot to emergency teaching came mid-way through the spring 2020 delivery of 2.007. With no time to prepare, students were forced to abandon their robots under construction in the machine shop and 'complete' them through the production of CAD drawings online. Soon after, it was decided that the 2021 course would be a fully remote activity, where robots would be constructed from home by "*turning students' dorm rooms into a workshop*". A particular priority was to ensure that all students – regardless of their prior hands-on experience, physical location or home environment – could participate equally and fully in this remote course. Over the six months that followed, the course co-leads worked with a group of students and a teaching assistant to iteratively design, test and construct an adaptable kit of materials that students could use to build their robots at home.

The fully remote 2.007 was launched in February 2021. Each of the 130 enrolled students was sent a kit comprising materials, a workbench, tools and a 3D 'game board' on which their robot would be tested. The competition theme was based around the 1990 movie *Home Alone*, and students were asked to design a robot that could evade the various 'booby traps' devised by the lead character to repel burglars; the 'game board' was modelled on the house in the movie, with many of the booby traps in place. Building students' confidence and competence with using their kits was a major priority. During the early weeks of the semester, as students explored their kits and built the simple 'Mini-me' robot, instructors demonstrated the use of each of the tools provided in the kit, one at a time. Instructors used a range of cameras at home to "*give students that hands-on type feeling even in the remote environment*", allowing them to show the tools and materials from different camera angles during the demonstrations. Machine shop staff were also on-call by Zoom during the day to respond to any questions students may have.

2021 'game board' sent to students in flat-pack form within their kit

The **second** element was to clarify the information given to students about their courses. For the 2020/21 academic year, MIT called upon instructors to prepare courses for a range of different delivery 'scenarios', including fully online as well as blended and hybrid modes, that could be rolled out depending on the COVID-19 restrictions in place. This led many instructors, in the words of one interviewee, "*to go back to first principles*" to reconsider the core learning goals and outcomes for their courses before identifying "*how do we meet these in a different way*", depending on the scenario taken. This refinement and articulation of the course objectives provided students with greater clarity over the expectations and structure of their classes, allowing them to better plan and manage their time.

The **third** element of the change was an increased adoption of student-centred pedagogies. Soon after the online pivot, it became apparent to many instructors that fostering student engagement would be a major challenge, and one which would not be combatted by simply posting recorded lectures online. As a result, and guided by a suite of workshops and webinars provided by the university[13], increasing numbers of faculty redesigned their courses into "*really top quality MITx style online sequences*" to support student-centred learning. These included, for example, interspersing short lectures with discussion-based problem-solving, polls to canvas students' ideas and responding to students' questions in the 'chat' function of Zoom. Even after MIT moved away from the mandatory 'pass/no record' system in the spring of 2020, many instructors opted to introduce formative assessments, such as quizzes with regular feedback, in place of mid-term examinations. Feedback from undergraduates suggested that this reduction in the use of summative grading had, in many cases, helped to build their intrinsic motivation and enable deeper learning. In the words of one student:

> *"The pass/fail system is one of the good things that's come out of the whole situation. It shifted the mindset from like 'what do I need to do to get an A in this class?' to 'all right, how do I maximise my learning?'... it completely changes the dynamics of the class. If everyone's there knowing that they are going to pass, they can put that aside and actually learn. I think that's really exciting".*

2.3. Addressing the challenges of emergency teaching

When describing the challenges faced during the period of emergency teaching at MIT, interviewees pointed to a range of issues, such as the difficulty of scheduling classes across multiple time-zones, facilitating whole-class discussion sessions, arranging the delivery of hands-on kits to students outside the US, and the impact of 'Zoom fatigue' on students and instructors alike.

However, for almost all interviewees, one challenge stood out: that of fostering student-to-student collaboration and peer learning in an online setting. While collaborative and group activities are embedded in courses across MIT's undergraduate curriculum, where peer learning has been most prominent is in informal interactions, fostered independently by students. The MIT campus has historically played a central role in facilitating these interactions, be they ideas arising from 'drop-in' events (often accompanied by free food), collaborations emerging from hands-on projects, or informal

[13] Preparing to teach remote: Spring 2021 semester: https://tll.mit.edu/preparing-to-teach-remote-spring-2021-semester/

mentorship fostered in shared spaces (such as common-rooms, dorms, labs and maker-spaces). Following the online pivot and move off campus, opportunities for such informal interaction were suddenly reduced and concerns were raised about the impact this would have on students' peer-learning and communities of support.

In response, the university sought to recreate, in the words of one interviewee, "*the lost opportunities for engagement*" while students were away from campus. Particular attention was paid to Psets: the university's 'Problem Set' homework assignments often tackled by students in informal study groups. Following the online pivot, students had struggled to identify, and interact with, peers for synchronous working on Psets. MIT established a number of innovations to foster such collaboration remotely. This included launching websites[14] that allowed students to identify and connect with peers who were tackling the same Pset at any point in time, and a scheme to loan all MIT students an iPad and Apple Pencil that could be used as a virtual whiteboard to facilitate ideas sharing and collaboration. Other mechanisms were also put in place to build students' networks and community remotely, both within and outside the curriculum. So, for example, within NEET, a suite of new online social events was established, a team-based learning component was embedded into every class (if one was not already in place) and plans are underway to engage the full MIT community in a new end-of-semester showcase event for selected NEET projects.

Despite these innovative interventions, interviewees noted that many elements of students' face-to-face collaborations could not be replicated online. What was missing in particular were the 'unscripted' interactions. It was noted that, online, almost all student-to-student and instructor-to-student interactions were pre-planned and pre-scheduled. In the words of one interviewee:

> *"every interaction has to be deliberate. There are no accidental interactions. And I don't think we've figured out how to do this. How can you bring back those serendipitous interactions in a virtual environment? For me, that's the biggest challenge: the way everything now has to be planned".*

Almost every interviewee spoke at length about the centrality of these 'serendipitous' in-person student interactions to MIT's educational culture and the challenges associated with fostering equivalent interactions remotely. Interviewees characterised these interactions as "*accidental*" and "*low stakes*", bringing no fixed agenda or planned outcome. In particular, students spoke at length about "*the lovely tradition of upperclassmen helping out the underclasses that is passed on to every new generation*" at MIT, which, again, were often seeded from these unplanned on-campus connections. While considerable effort has been devoted to recreating these types of interactions online – for example through peer-to-peer mentorship programmes or through the establishment of 'virtual dorm rooms' to connect students who would have been co-housed in dormitory corridors – students characterised them as "*very planned, very intentional; sterile isn't the right word, but something is missing somehow*".

[14] Websites include Explain.mit (https://explain.mit.edu) and Pset Partners (which requires an MIT student ID to access).

While this was a loss keenly felt by students and instructors alike, interviewees also suggested that one compensation had come in the form of a new connectivity forged across instructors and students since the start of emergency teaching. They pointed to a number of indicators of this connectivity, including the increased use of faculty 'office hours'. Contrasting their experience prior to March 2020, many noted that faculty had "*really got to know each of the students*" in these sessions, which often moved beyond purely technical questions into broader discussions about students' 'home life'. In addition, soon after the online pivot, MIT established the *Student Success Coaching Program*[15], in which students were offered one-to-one weekly coaching sessions to identify problems, offer support and enhance their capacity for distance learning. Five hundred and fifty staff, administrators and instructors volunteered to become coaches for this programme. Not only did this offer individual and personalised support for MIT students, it fostered new networks across the community of coaches. Indeed, many interviewees described how the experience of emergency teaching had brought together administrators, instructors and support staff, across functions and organisational hierarchies, to establish new communities of practice around teaching and learning. Many went on to speak about their pride in the university's response to COVID-19 and the connectivity, common purpose and 'espirit de corps' it had fostered across the MIT community. Speaking for many, one interviewee simply said: "*I have never felt so proud to say that I work at MIT*".

3. Impact of emergency teaching on MIT's educational approach

When asked to reflect on the legacy of emergency teaching on MIT's engineering education, some noted that it was "*still too early*" to determine its longer-term impact. Instructors and students were still living through it: "*everyone has been keeping their nose above the water… the synthesis that's needed has not yet been done*". For those looking beyond the COVID-19 emergency, the first priority for most was to re-establish the university's distinctive on-campus culture. As one interviewee put it, "*getting the energy back and the vibrance and the curiosity*" by reconnecting with peers in a face-to-face environment.

However, looking longer term, feedback suggests that the experience of emergency teaching was likely to impact the MIT's education in two distinct ways.

The **first anticipated impact** was on the pedagogical practices of instructors. The experience of re-designing courses for online delivery had led some instructors to fundamentally review their learning goals and increase their adoption of student-centred and blended learning. It was suggested that many of these attitudinal and pedagogical changes were likely to be permanent. In reflecting on the impact of emergency teaching, one university leader noted:

> *"a big part of the value is just going to come from the fact that everyone has spent a much larger fraction of their time thinking about how do students learn, what do I want them to learn, what are my learning goals for my students, and how do I teach so as to achieve those goals? So people were forced*

[15] MIT Student Success Coaching Program: https://covid19.mit.edu/undergraduate-students-student-success-coaching-program

> *to ask all those questions because they're teaching in a new way by a new medium. I think the fact that they have asked themselves those questions will yield benefits when we return".*

The **second anticipated impact** was through identifying new opportunities to enhance global connectivity and off-campus experiential learning for MIT's students. In the words of one university leader, "*the pandemic has taught us that it's easier to do these things than we thought*". Many of the practices described are likely to be incorporated permanently into MIT's educational approach. For example, the introduction of world experts as guest speakers into classes using video conferencing was seen as an innovation that would become standard practice at the university. New opportunities are also apparent in the cooperative design and delivery of large-scale courses that bring together MIT instructors and students with peers from other universities across the world.

In addition, the experience of emergency teaching opened up new avenues to broaden students' learning experience. Historically, one of the major barriers to increasing the external and global exposure of MIT students has been their reluctance to leave campus. Take-up for off-campus experiences such as semesters abroad or internships has long been low. The online pivot pointed to opportunities to overcome students' concerns by offering experiences that blend off-campus experiential learning with continued connectivity with MIT. A significant minority of MIT students engaged with emergency teaching by forming 'pods', typically of 6–10 individuals, and renting a shared residence close to their home region. Feedback suggests that the ability to collaborate and engage in face-to-face peer learning within these pod groups provided students with a more positive learning experience than those who engaged with their courses while living alone or within family homes. Interviewees suggested that the key difference was that the pod groups were able to "*preserve the pieces of the campus experience that are important to students, which is to bring their friends with them".* The pod model was seen to offer considerable potential for engaging students in immersive, experiential opportunities off-campus – such as in public service, the voluntary sector or in start-ups – as part of a peer MIT group where "*they still had enough MIT connection to make it worthwhile*".

However, when reflecting on how the legacy of COVID-19 emergency teaching might influence the future of MIT's education, most interviewees suggested that another factor was likely to have an even more profound impact: the US-driven movement for racial equality. It was consistently noted that the most passionate and far-reaching conversations across the MIT community centred around diversity, equality and inclusion (DEI). While the experience of emergency teaching will undoubtedly influence the modalities and mechanisms used to deliver to MIT's mission, it was suggested that the movement for social justice was likely to influence the university's core values and was therefore the one more likely to trigger enduring cultural change. In the words of one university leader:

> *"The place where I am seeing different attitudes emerge is in the DEI space. I think that has moved the needle more than COVID… We have always taken pride in the diversity of the student body, and I think that what has come out this year is that that's probably not enough… people are thinking about how can we be deliberate in moving that needle and playing a leadership role in that space".*

This priority given to DEI is evident in recommendations emerging from a taskforce launched by MIT's President in July 2020. The *Task Force 2021 and Beyond*[16] was established to examine the lessons learnt from COVID-19 and chart a future direction for MIT. One of the Taskforce groups was charged with examining MIT's education. At the heart of its recommendations is a call for MIT to educate the 'whole student'. They note that:

> *"Such an education should help students to both take ownership of their lives and beliefs and listen carefully to new ideas and different perspectives that reaffirm, or help them to reimagine, what they believe is true and right and just. A focus on the whole student also recognises that well-being, satisfaction, and engagement are entwined throughout college and life".*

To enable such an approach, the education Taskforce group proposed mechanisms to help students "*recognise and engage critically with the structural, systemic and institutional hierarchies that shape our professional, civic and personal lives*". Additional recommendations made by the education group included: nurturing students' 'experiential empathy' for addressing regional, national and global societal challenges through engaging them in immersive experiential learning opportunities outside MIT; exploring new opportunities to advance 'unscripted' student interaction and collaboration in a remote or online setting; developing new mechanisms to support life-long learning across the MIT community; and realigning institutional incentives to better support and reward teaching excellence.

Taken together, the university's engagement in DEI and its commitment to harnessing the lessons learnt from COVID-19 point to an reinvigoration of its distinctive educational philosophy. These two developments appear to be coming together in a reaffirmation of MIT's 'mind and hand' approach to educating tomorrow's engineers.

Source of evidence

The case study for MIT (including Part A, the review of the Design Challenge One in the Systems Design & Management (SDM) programme, and Part B, this review of the 'institutional context') drew upon one-to-one interviews with 22 individuals: the Associate Dean of Engineering; the university Vice Chancellor; the Dean for Digital Learning; the Director of the Teaching + Learning Lab; the Executive Director of NEET; the NEET curriculum designer; two faculty members (and instructors from 2.007); the Executive Director of the SDM programme; the Academic Director of the SDM programme; three Teaching Assistants from SDM; three SDM students; five engineering undergraduates and one Councillor from the City of Cambridge.

Further information about the methodology for development of CEEDA case studies is given at the project website[17].

[16] Task Force 2021 and Beyond: https://tf2021.mit.edu

[17] CEEDA case study structure and approach: https://www.ceeda.org/about#case-studies