COLLABORATIVE ENGINEERING EDUCATION IN THE DIGITAL AGE

MIT, US

Case Study Part A – Best Practice Activity

Design Challenge One

Student cohort: **95**
Location: **100% online**
Duration: **5 days, full-time**
Date delivered: **August 2020**
Activity type: **Master's orientation**
New/existing: **Reformed course**
Hands-on element: **Optional**
Cross time-zones: **Yes**
Case study approved: **April 2021**

Distinctive feature of case study

Facilitating collaboration, peer-support and network-building across the student cohort

Abstract

Activity overview

Design Challenge One (DC1) is a five-day activity designed to immerse students in authentic, complex challenges that call upon technical, societal and organisational skills for their solution. As a result of the global pandemic, DC1 in 2020 was pivoted from a face-to-face format to an entirely online delivery; the challenges were framed around the United Nations Sustainable Development Goals. Using an approach inspired by crowdfunding platforms, teams and other stakeholders were each allocated a virtual currency which they were invited to spend through 'backing' other teams in exchange for help and advice. This 'backer' system provided a gateway for students to seek and provide peer support, helping them to build networks and communities despite collaborating remotely.

Independent review

The 2020 DC1 embedded a novel online 'backer' system that explicitly encouraged and rewarded inter-team collaboration. Interviewee feedback pointed to the success of this approach in fostering collegiality, networking and peer-learning across a cohort of students that had never met face-to-face. It is also a model that holds considerable potential to be scaled-up to larger cohort sizes.

Activity details

DC1 is embedded in the one-week orientation Bootcamp for incoming Master's students to the System Design & Management (SDM) programme that is run jointly by MIT's School of Engineering and Sloan Management School. DC1 2020 was delivered across multiple time-zones to participants located in six continents.

1. Activity overview

Design Challenge One (DC1) is the first of five major team-based design challenges tackled by students during their first year of study on the System Design and Management (SDM) Master's course. It forms the major component of the one-week orientation Bootcamp designed to introduce incoming students both to system-thinking methods and to the values of SDM and Massachusetts Institute of Technology (MIT). These values include building trust, peer-support and collaboration across the student cohort; harnessing students' capacity to build, connect with and draw upon the MIT community network; and combatting 'imposter syndrome' and the low confidence levels often evident in the incoming student population. The need to embed these collaborative learning goals was further highlighted by the shift to 'emergency teaching' where the 2020 incoming cohort would be participating in DC1 remotely, from a range of time zones worldwide and without face-to-face contact.

A new cohort of second-year SDM students are engaged as Teaching Assistants (TAs) each year. Reflecting SDM's culture of ongoing pedagogical innovation and experimentation, these TAs are encouraged to take a lead in evolving the DC1 experience. This has led to many different variants of DC1 over the years; what has been retained throughout, however, has been the hands-on, face-to-face nature of the activity. The group of TAs engaged in 2020 took the pivot to emergency teaching as an opportunity to rethink and redesign DC1 for delivery online to a physically dislocated cohort. What emerged was an activity that utilised a new web platform to enable the distinctive features of the course: collaboration, peer-support and network building across the student cohort.

The 2020 DC1 built on a partnership with the regional city authority. Each student team was asked to develop a "*tangible solution*" to a major sociotechnical challenge facing the City of Cambridge, home to the MIT campus, with each challenge linked to one of the United Nations Sustainable Development Goals (SDGs). For example, one challenge, framed around SGD 1 (No Poverty), asked students to develop a sustainable housing solution for the city's homeless population. The DC1 teams used a public-facing web platform to document the development of their projects in real time. This supported student learning and the wider collaborative ethos of DC1 in two ways. Firstly, it allowed internal and external stakeholders to gain insight into each team's progress and thinking, as well as the evolution of their projects. Secondly, inspired by crowdfunding platforms, it allocated a virtual currency to teams and other stakeholders which they were invited to spend through 'backing' other teams. These virtual coins could be spent as tokens of thanks to a team or a stakeholder for help provided or to signal appreciation of the quality of the project.

All teams benefitted from the giving and receiving of 'coins': in order for all teams to successfully complete the course, a threshold number of 'coins' had to be exchanged in total. Help might come in a variety of forms and included: connecting the team to an expert in regional homelessness; providing training for video editing; and checking foreign language translations on an app interface. This backer system provided a gateway for students to seek and give peer support and helped them to build networks and communities at a time of isolation for this physically-dislocated cohort.

2. Independent review

2.1. Distinctive features

The feature that sets the 2020 DC1 apart from peer experiences worldwide is its approach to fostering a culture of collaboration, peer-learning and network-building across the newly-enrolled student cohort. In particular, members of the teaching team noted that – unlike many ice-breaker activities delivered to incoming students, where the form and focus for collaboration is pre-determined – the 'backer' approach allowed the collaborative element to be voluntary and student-led. As the lead TA noted, each element of the DC1 was designed such that "*teams needed to collaborate to be successful*".

The DC1 teaching team established two mechanisms to advance collaboration and network-building:

- a **dedicated web platform** that showcased each team's progress and allowed peer teams, MIT faculty, SDM alumni and 'guests' from the regional community to award 'coins' to individual teams. The number of coins earned was at the discretion of the backer and could be awarded for a variety of reasons: approval of the team's ideas/approach, recognition of the constructive responses given by the team to external feedback, or gratitude for the help offered by other teams. Coins allocated to backers were released progressively over the five-day activity, to encourage collaboration throughout the week. Teams were asked to provide written feedback to any comments made by current or prospective backers.
- a project **scoring system** that explicitly rewarded inter-team collaboration, and which set the cumulative total points received across all teams as the primary metric of success. In particular, the components of the assessment rubric that were uncapped (i.e. that did not have an upper limit) all related to inter-team collaboration, meaning that teams striving to maximise their scores were further motivated to collaborate. Further information on the assessment rubric is given in Section 3.4.

Students enrolled on the SDM programme were drawn from a range of time zones, cultures and disciplinary backgrounds, and the DC1 'backer' and scoring system offered them a variety of different modes to initiate and advance cross-team collaboration. For example, a student may choose to engage asynchronously, by leaving a comment, asking for help or allocating coins to another team via the web platform; they might also choose to engage synchronously via a Zoom conversation with another team to explore possible areas for assistance. Participants used platforms such as Slack or WhatsApp to reach out to peer teams to identify skills/resources from which they might benefit as well as to ask for help.

Interviewee feedback pointed to the success of this approach in fostering collegiality, networking and peer-learning across a cohort of students that never met face-to-face. It is also a model that offers potential for scaling-up, for example to larger cohort sizes and longer course units. In particular, the coin-based online backer approach could be used as a mechanism to track individual student engagement and flag up individuals who do not appear to be collaborating or interacting through any of the available modes.

2.2. Success factors

The success of the 2020 DC1 was undoubtedly advanced by SDM's long-standing expertise and experience of delivering hybrid learning, with around 40% of SDM students accessing courses online prior to the introduction of emergency teaching. As such, the teaching team and programme staff were already well-placed to deliver distance learning to students across multiple time zones – with effective online tools and support systems already in place – and participants already expected this delivery mode to play a prominent role in their learning across the two-year Master's programme.

In addition to this existing expertise base, interviewee feedback pointed to two inter-related factors that were crucial to the success of the DC1, which are outlined in turn below.

The first success factor was the clarity of vision for the 2020 DC1. Its design and delivery was led by TAs who were predominantly second-year students on the SDM Master's course and had therefore participated in the Bootcamp the previous year. The group was therefore uniquely placed to appreciate both the value of the face-to-face DC1 model and the capacity of the student cohort to adapt to a different approach. This group of TAs brought a clear and coherent vision to the activity, which was underpinned by two priorities: to foster an inclusive culture of collaboration and network-building throughout the cohort; and to advance the MIT philosophy of harnessing innovation and technology for the benefit of society. In redesigning DC1 from a blank slate, the TA team was able to embed these two priorities into every aspect of its design as well as shape its approach around the opportunities offered by the online format, such as through the web platform. As such, they were not simply transferring an existing activity into the online space, but rather exploiting the online environment to create a pedagogical approach that may never have been possible face-to-face.

Secondly, the 2020 DC1 built upon SDM's culture of educational experimentation. This ongoing pedagogical innovation works in synergy with SDM's inclusive and egalitarian approach characterised by one interviewee as "*learning from your peers and the community*". It is in this context that SDM empowers selected members of its second-year student cohort to take a lead in the design and delivery of DC1. The autonomy afforded to the TAs not only allowed them to follow a clear and coherent vision for DC1 (as outlined above), it also exposes the incoming cohort to, in the words of one interviewee, "*the sheer enthusiasm, curiosity and positive tone of the second year students*". In other words, DC1 is used as a mechanism to pass on and foster the distinctive SDM culture of collegiality and common purpose amongst the next generation of students. Interview feedback suggested that this culture was shared by the DC1 participants, teaching team, SDM department, external collaborators and the wider MIT faculty community engaged with the project. Many also noted an "*entrepreneurial team spirit*" amongst the teaching team and a willingness to take on whatever tasks were required to deliver the 2020 DC1; the web platform, for example, was developed by a TA with no professional experience in coding or web design. The focus on tackling authentic sociotechnical challenges facing the region was also understood to bring together the MIT and city community, and foster new ideas and connections which extended beyond the student cohort.

2.3. Challenges faced

DC1 was developed under tight time constraints during the eight weeks prior to the Bootcamp's launch, in a context of some uncertainty about the institutional approach to emergency teaching. MIT had asked the instructors to prepare for three possible emergency teaching scenarios for the fall 2020 semester – fully online, fully on-campus and a hybrid approach – and the decision to shift to fully online teaching was only made a few weeks prior to the start of DC1. The teaching team was therefore required to maintain three different DC1 models in parallel throughout its development process, and only confirm the online model at a relatively late stage. Within this context, interview feedback pointed to three additional challenges facing the development and delivery of the 2020 DC1, as outlined below.

The **first challenge** concerned the perceived risks of moving away from a tried-and-tested DC1 approach. Looking across programmes worldwide, the online pivot for similar hands-on collaborative experiences typically involved the replication of individual components of the activity in the online domain, with the hands-on element often delivered through Arduino/Lego kits shipped out to participants or through asking students to create 3D digital models of the solutions. The proposed model for the 2020 DC1, in which the activity was designed from a blank sheet with no hands-on component, was undoubtedly higher risk. Interviewee feedback suggested that concerns were raised by teaching team members and the SDM faculty in the early weeks of the 2020 DC1 development about the potential risks of root-and-branch reform to the structure and focus of the DC1 project, particularly during a period of uncertainty and emergency teaching. It was also noted, however, that, once consensus was reached to move forward with the new approach, the teaching team was provided with unwavering support from the SDM department and MIT.

The **second challenge** was to balance the drive to build student engagement against the risks of overloading participants with multiple activities and deliverables. The teaching team clearly invested considerable time in the design of each element of DC1 to maximise student motivation and immersion in the MIT culture, regardless of students' background and expertise. As with many of the activities highlighted through the CEEDA project, however, interviewee feedback suggested that student exhaustion and screen fatigue was a prominent issue by the close of DC1.

The **third challenge** was the limitations of the online delivery. While the SDM programme has long been delivered in a hybrid format, DC1 has been one of the few components that, historically, all students have been required to attend in person. The key drivers for this are twofold: it allows students to apply and explore the physical application of their ideas through hands-on building; and it offers an intensity of experience that facilitates rapid team-bonding and multiple opportunities for informal interaction and connectivity. While interviewee feedback suggested that important aspects of the 2020 DC1 approach with respect to community and cooperation were likely to be retained in future years, the activity would almost certainly revert to a face-to-face delivery as soon as COVID-19 restrictions allowed in order to preserve the hands-on learning and intensity of cohort boding.

3. Activity details

SDM is delivered jointly by two of MIT's schools: the School of Engineering and the Sloan School of Management. The overall goal of the SDM programme is "*to educate mid-career professionals to think effectively and creatively by using systems thinking to solve largescale, complex challenges in product design, development and innovation*".

DC1 is embedded into the orientation Bootcamp for the SDM Master's and is the first of eight team-based projects that build progressively in complexity throughout the two-year programme. DC1 is designed to allow students, in the words of one interviewee, "*to apply systems thinking and methods to a local problem*". In previous years, the challenges have included MIT themed robotic contests, novel uses of drones, and the construction of Rube Goldberg machines.

3.1. Structure of the activity

Integrated into the Bootcamp, the 2020 DC1 was a fully online activity, delivered over a five-day period in late August 2020. Most elements of the 2020 DC1 were delivered synchronously, although some material was delivered in duplicate for students across different time zones (see Section 3.4). Synchronous sessions were held in the mornings of the first and final day of the Bootcamp (8am until midday ET).

The four-hour session in the **first morning** of DC1 was devoted to introducing the cohort to the project and assigning the challenges. This included:

- a 'kick-off' session, led by the Mayor of the City of Cambridge, where each of the 17 SDG-linked challenges were randomly assigned to one of the cohort's 17 teams;
- an introduction to the goals and structure of the DC1 project;
- a Q&A session with stakeholders from the City of Cambridge, where students were able to explore the challenges in the Cambridge context and identify potential sources of further information and support;
- skill development sessions, in topics such as team working across cultures, distributed leadership and oral presentations.

The four-hour session in the **final morning** (on day five) of DC1 was devoted to team presentations and wrap-up of the project. This included:

- a three-hour session for all teams to deliver their final 10-minute presentation to the full cohort and the judging panel, followed by a closing ceremony;
- structured sessions for self- and group-reflection on what had been learnt during the week.

During the remaining three mornings, the 'core' four-hour sessions were devoted to non-DC1 activities, introducing students to the SDM programme and the key elements of the core curriculum. Outside of these synchronous morning sessions, teams were expected to work independently on their DC1

projects, with team deliverables scheduled throughout the week (see Section 3.2). Teams were asked to check-in with their assigned TA each day for 15 minutes to outline progress.

Please note: a suite of activities not connected to DC1 were also delivered prior to the Bootcamp to orient students and provide an introduction to both SDM and MIT.

3.2. The challenges and deliverables

Each of the 17 teams participating in the 2020 DC1 project were randomly assigned to a different sociotechnical challenge facing the City of Cambridge. Each challenge was framed around one of the 17 Sustainable Development Goals (SDGs). Teams were asked to develop a "*tangible solution*" to their assigned challenge, which could include (but were not limited to) a website or an app.

One sample challenge brief is given below, which relates to SDG 16 on *Peace, Justice and Strong Institutions*:

> ***Restructuring Police Entity:*** *The City of Cambridge is determined to ensure fairness among its residents. In recent months, the unfortunate death of George Floyd has reignited many constructive conversations on the city's police force. Rather than focusing only on the fairness conversation, the city could also explore ways to improve and modernise current policing practices. Hence, the city is looking for a solution on how to automate routine traffic enforcement to eliminate many nonessential encounters between the police and the civilians.*

These challenge briefs were developed by the DC1 TAs in collaboration with a councillor from the Cambridge City Council.

The key deliverables for the five-day activity are summarised below:

- **by the beginning of day 2**: teams were asked to produce a draft project webpage providing an introduction to the team's challenge and emerging ideas;
- **by the beginning of day 3**: teams were asked to upload a one-minute video to their project webpage to outline their challenge and solution, to be used as a means to collect feedback and foster inter-team collaboration;
- **by the end of day 4**: teams were asked to have both benefitted from and provided significant support and feedback to peer teams, as documented on the web platform;
- **by the beginning of day 5**: teams were asked to deliver an eight-minute presentation to a panel of judges comprising SDM faculty, TAs and stakeholders from the City of Cambridge. These presentations incorporated two core components: (i) an explanation of the problem from a sociotechnical perspective; and (ii) a solution in the form of a tangible demo, which could include an app or website.

3.3. Learning goals/objectives

Designed as an 'onboarding' activity to the SDM programme, DC1 is designed "*to support students in developing the skills, knowledge, attitudes and connections to be successful in MIT*". In particular, the three core goals for both the Bootcamp and DC1 are:

1. **Cohort bonding:** fostering a collegial and collaborative culture amongst the incoming student cohort. Prior to 2020, students had been required to attend the Bootcamp in person; establishing such a community bond was understood to be a priority in a programme in which many students would engage via a blend of face-to-face and remote learning.
2. **Orientation:** introducing students to SDM and providing tools to navigate MIT. This included introductory workshops to key SDM themes (typically delivered during synchronous sessions during the five days) and practical information on MIT, such as the academic integrity rules or registration information (much of which was provided via information packs in advance).
3. **Reintroduction to university life:** support and information on re-adjustment to university life after a number of years working in professional careers, following completion of their undergraduate degree. Particular focus was given to addressing personal concerns (such as 'imposter syndrome' of being accepted into an institution such as MIT) and practical issues (such as securing local childcare) that incoming SDM Master's students might have.

3.4. Cross time-zone working

The 95 students participating in the 2020 DC1 were based across six continents and were therefore accessing the remote activity from a wide range of time zones. The DC1 teaching team accommodated this time zone diversity in a number of ways. They first identified a 'core' four-hour time-window that would be most convenient for the largest proportion of students. This core window (from 8:00am to midday Eastern Time) was reserved for synchronous activities in which all students were required to participate. These activities included the introduction to DC1 on the first morning of the Bootcamp and the DC1 team presentations on the final morning; sessions in the intervening mornings were devoted to non-DC1 activities, such as introductory classes for SDM and MIT orientations. All of these activities were recorded and made available for students to view within a few hours of their delivery. Any Bootcamp activities scheduled outside this four-hour core window were offered in duplicate, across different time zones. So, for example, speakers were asked to deliver each talk in two different times of the day, and recordings of 'live' sessions were played back at alternative times with a TA and/or faculty member on hand to provide feedback and answer questions.

In addition, membership of the DC1 teams was determined by the time zones in which they would be working, while still maintaining cultural and geographical diversity amongst teams. Prior to their participation in DC1, students were asked to identify the most convenient time windows for them to engage in group projects. Feedback from participants suggested that the majority of team-work was conducted synchronously and as a group.

3.5. Team and cohort assessment

Team assessment: the assessment protocol for each team in the 2020 DC1 is given in the table below. Points were awarded across three main components:

1. systemic goal achievement: elements related to systems thinking and the quality of the team's solution;
2. -ilities: performance attributes of the team's solution beyond the system's core function, such as reliability, adaptability, scalability, etc. (terms that typically end in "ility");
3. collaboration: the extent to which each team member contributed to their project, and the extent to which each team collaborated across the cohort.

The three elements where team scores were uncapped, without an upper limit – shown in 1d, 2b and 3c in the table below – were all linked to inter-team communication and collaboration. In the case of 3b, the 'level' of contribution made by other teams (small, medium of large) was determined by the team receiving help and subsequently checked by one of the TAs.

1. Systemic goal achievement	
1a. How well were the problem and the stakeholders defined in the final deliverable?	10 points
1b. How well does the final concept demo work across a variety of use cases?	25 points
1c. Does the proposed concept address one of the UN sustainable goals in Cambridge?	25 points
1d. BONUS – extra points for each additional UN sustainable development goal addressed in Cambridge	5 points each
2. -ilities	
2a. How technically complex is the proposed concept with respect to user input (e.g. how many sources of data is the concept linked to)?	15 points
2b. How multidisciplinary is the proposed concept (e.g. how many engineering disciplines does is draw upon)?	1 point per discipline
2c. How generalisable is the proposed concept beyond the City of Cambridge?	10 points
3. Collaboration	
3a. How involved was each team member in the ideation and development of their team's proposed concept (captured using the TEAMMATES online peer evaluation software[1])?	30 points
3b. Level of external support for the project on the website, based on the website's crowdfunding interface	10 points
3c. Help received by other teams for contributing to their deliverable	+1 point (small) +6 points (medium) +9 points (large)

[1] TEAMMATES: https://teammatesv4.appspot.com/web/front/home

Cohort-wide assessment: for the success of the activity as a whole, a threshold score of 1443 cumulative points had to be achieved across all teams. This threshold score was determined by the teaching team as constituting 10% above the average score that each team would be expected to achieve. The 2020 DC1 cohort surpassed the goal, and students were able to support a local charity.

3.6. The teaching team

The full 2020 Bootcamp teaching team included a large number of SDM faculty, teachers and TAs who contributed to the orientation and introductory material delivered to the new starting cohort. The teaching team engaged in the design and delivery of the DC1 project is listed below:

- lead TA, who led the design and delivery of DC1, and coordinated with other members of the teaching team;
- eight additional TAs, some of whom led critical aspects of the activity design, such as the development of the web platform or the assessment rubrik. Almost double the number of TAs were engaged for the 2020 DC1 than had been involved in previous years;
- two SDM Programme Directors, who provided advice, support and mentorship for the development and delivery of DC1;
- four MIT faculty members who delivered four one-hour sessions to support the 'technical' aspect of the challenges (in system thinking, system architecture, system engineering, and project management) and a number of MIT faculty members and external guest lecturers to deliver sessions to support the 'social' aspect of the challenges (including effective cross-cultural teamwork, ethical standards and diversity);
- one councillor from the City of Cambridge who co-developed the 17 challenges, based around authentic issues facing the city;
- 17 regional contact points. Each team was given contact details for one or more individuals, typically from outside MIT, who would be well placed to offer advice or contextual information about the application of their challenge within the City of Cambridge. Teams were encouraged to reach out to these individuals, and use these connections to further build their networks.

3.7. Participants

95 students participated in the 2020 DC1: the full incoming cohort to the SDM programme. Students were early- or mid-career professionals, typically having 8–10 years of professional experience, with around 80% from an engineering background. In 2020, students were drawn from 23 countries and six continents. In a typical year, around one-third of SDM students engage with the programme remotely, although all are required to attend in person for three group projects during the first year of study (including the DC1) and for one semester during their second year.

The DC1 teams were pre-assigned. Membership of each team was determined in advance by the teaching team to ensure an even distribution of skills, experience and time-zone compatibility.

3.8. Technology used

The following applications and technologies were used in the delivery of the 2020 DC1:

- a new web platform was developed in-house by the TAs to house each team's project web page and operate the 'backer' coin system;
- dedicated Slack and WhatsApp channels were established to connect the full cohort, in which students could ask for and offer assistance to other teams;
- a Kahoot[2] game was created for the cohort to connect and learn more about one another;
- the TEAMMATES[1] online peer evaluation software was used to gather feedback on the relative contribution of each team member;
- Canvas[3] was used to provide materials to students, including video recordings of sessions;
- although teams were free to develop any form of 'tangible demo' for their final solution, they were introduced to App Inventor[4] as a low-barrier-to-entry app development environment.

Source of evidence

The case study for MIT (including Part A, this review of the DC1, and Part B, the 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[5].

[2] Kahoot: https://kahoot.com

[3] Canvas: https://www.instructure.com

[4] App inventor: https://appinventor.mit.edu

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