Iron Range Engineering, US

Case Study Part B – Institutional context

Student intake to both Iron Range programmes (2020/21):	**≈ 70**
Number faculty/instructors (across both programmes):	**23**
Duration of undergraduate engineering degree (to BSE):	**2/2.5 years**

1. Defining features of the Iron Range Engineering education

Iron Range Engineering provides a bachelor-level education for students who have already completed two foundational years of higher education engineering study (typically in a 'Community College' setting). Iron Range offers two such 'upper division' programmes, both in integrated engineering and both credentialed by Minnesota State University, Mankato (through Bachelor of Science in Engineering degrees).

The first programme – the **Iron Range Engineering** (IRE) programme – was founded in 2009. It is a two-year (four semester) programme, with each semester structured around a 16-week team project. The student intake for the programme is small, currently 25 students per semester, and drawn largely from IRE's home state of Minnesota. An opportunity was identified, however, to 'scale up' intake numbers by applying the IRE model to a programme delivered predominantly online – in parallel with work-based learning experiences – that could be accessed by students from across the US.

This second programme – the **Iron Range Engineering Bell** (Bell) programme – was founded in 2019. It is a two-and-a-half year (five semester) programme. Prior to COVID-19 restrictions, the first semester (termed the 'Bell Academy') was delivered in-person on the Iron Range campus in Minnesota. For each of the remaining four semesters, students are employed in paid work placements (typically in their home region) and access the majority of their education remotely, predominantly via asynchronous online learning. Students are recruited to the Bell programme from across the US, with their tuition costs offset by the salary they receive during their four semesters on work placement.

Despite their difference in delivery method (predominantly face-to-face vs predominantly online) and student intake pool (state-wide vs country-wide), the two programmes are informed by the same project-led and self-directed educational approach. Both programmes also share a common curricular structure, as illustrated in Figure 1, that brings together three core threads:

- **technical:** students study 32 technical courses in all, of which half are core competencies (such as fluids or digital logics) and half are student-led advanced (SLA) competencies (which are identified by students, based on their personal interest or the needs of their design project);
- **design:** each semester, students engage in a new team-based design project, which forms the spine around which the curriculum is built. These projects are complemented by a series of intensive problem-solving exercises and workshops to build students' design capabilities;
- **professional:** students engage in a suite of activities to build their professional capabilities and employability, supported by guided self-reflection.
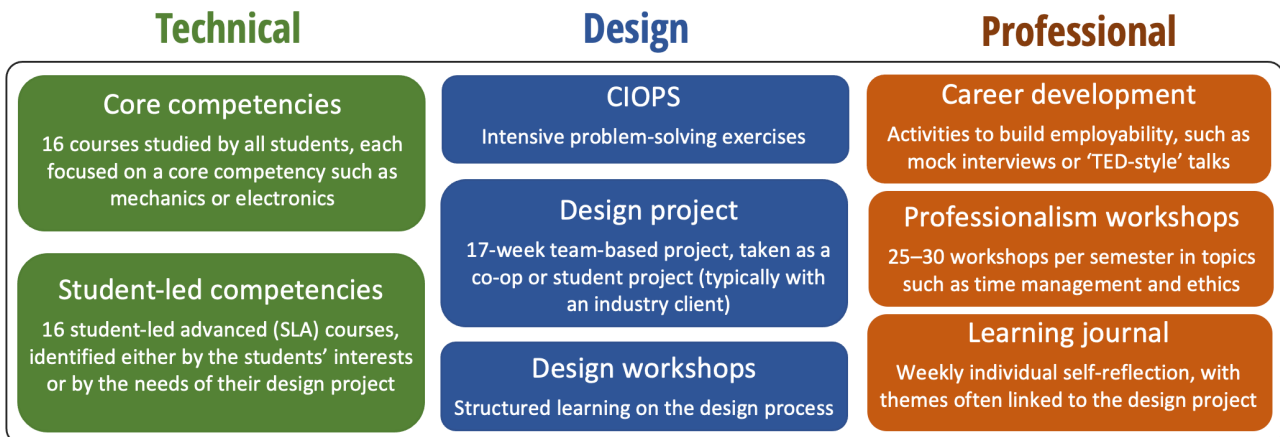
Technical

Core competencies
16 courses studied by all students, each focused on a core competency such as mechanics or electronics

Student-led competencies
16 student-led advanced (SLA) courses, identified either by the students' interests or by the needs of their design project

Design

CIOPS
Intensive problem-solving exercises

Design project
17-week team-based project, taken as a co-op or student project (typically with an industry client)

Design workshops
Structured learning on the design process

Professional

Career development
Activities to build employability, such as mock interviews or 'TED-style' talks

Professionalism workshops
25–30 workshops per semester in topics such as time management and ethics

Learning journal
Weekly individual self-reflection, with themes often linked to the design project

Figure 1. Curricular structure of the IRE programme and Bell programme

In addition to a common curricular structure, the two programmes also share a number of features that set them apart from peer engineering programmes. Four were repeatedly noted by interviewees:

- **project-based learning:** inspired by the Aalborg University model[1], IRE and Bell students engage in immersive team projects – delivered to an external client – from programme entry and throughout their studies. Most other curricular elements are linked to these semester-long projects, offering many opportunities for students to connect, apply and deepen their learning.

- **community of support:** IRE and Bell student interviewees spoke at length about the distinctive culture of mutual respect, trust and peer support brokered across the community of students, alumni and instructors. Students described how it was built on "*the deep personal connection*" fostered between students and instructors, and an expectation that students adhere to a code of professional conduct and communication throughout the programmes.

- **professional engineering emphasis:** a major focus for both programmes is developing students' professional engineering capabilities and employability skills. Students dedicate up to 10 hours per week to the development of their professional competencies (in areas such as ethical responsibility and technical writing) and their employability (through activities such as practice interviews and resume development) throughout their studies. Self-reflection is also an important focus, with students engaging in around 150 self-reflection exercises each year.

- **self-directed learning:** self-determination theory[2] is central to the IRE/Bell approach and is utilised to foster engagement and capacity for life-long learning. The emphasis on student autonomy and self-directed learning is particularly prominent. For example, in the majority of SLA courses, students not only identify the topic they wish to study, but also take the lead in writing the syllabus, identifying the key principles they must master, and devising the assessment protocol (subject to guidance and approval by a faculty member). In a second example, a course in 'learning to learn' is embedded throughout both programmes which, in the words of one interviewee, "*helps students to reflect on their learning and understand the meaning and the structure of what they're doing… and understand and practise how they learn best*".

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[1] The Aalborg model for problem-based learning: https://www.en.aau.dk/about-aau/aalborg-model-problem-based-learning/

[2] Self-determination theory (as defined by Edward Deci and Richard Ryan) proposes that three factors – autonomy, competence and relatedness – facilitate intrinsic motivation and growth.

One additional distinctive feature of IRE/Bell connects many of those listed above: continuous improvement. Both programmes take an evidence-based approach, drawing on pedagogical research, global best practice and ongoing stakeholder feedback. One consequence of this approach is the adoption of non-traditional pedagogies and practices throughout the programmes, such as the use of oral exams for assessing technical courses. Another consequence is that the programmes are constantly changing and updating. While key founding principles (listed above) and the overarching structure (illustrated in Future 1) have remained constant, it is estimated that around 10% of the curriculum changes each year. The scale of this ongoing change was apparent in the interviewee feedback, and is one in which instructors and students alike clearly play an active role.

2. Iron Range's experience of emergency teaching

2.1. Emergency teaching restrictions

Throughout the COVID-19 pandemic, the IRE and Bell programmes followed the emergency teaching restrictions set out by the Minnesota state government. The spring vacation in March 2020 was extended to three weeks to prepare for a fully online return for the final five weeks of the semester.

During the early weeks of the fall 2020 semester, some curricular components in the IRE programme were offered in hybrid form, with students given the option to participate online or in person. However, after a few weeks, the programme defaulted to a fully online mode, which remained in place until the end of the academic year in May 2021. For the 2021/22 academic year, it is anticipated that both the IRE and Bell programmes will be delivered in hybrid form.

2.2. Managing the transition to emergency teaching

The IRE and Bell programmes both operate on a semester-long (rather than year-long) intake cycle: a new cohort of students joins the programmes each semester, twice per year. The Bell programme was launched in August 2019, but a decision was made that enrolment for the second cohort would be postponed until August 2020 to allow time and space for student feedback and programmatic improvement during the programme's crucial first year. This decision proved prescient. When emergency teaching conditions were introduced, therefore, the Bell programme was only supporting a single student cohort, whose first semester had been spent learning face-to-face as part of the Bell Academy and who were already acclimatised to studying remotely while on paid work placements.

Both the IRE and Bell programmes also clearly benefitted from the expertise of Bell instructors, who had devoted much of the previous two years to developing and incrementally improving active, project-based online learning experiences. Much of the three-week break taken in March 2020 was therefore dedicated to discussing and sharing these experiences with IRE instructors and the regional Community College network. This included a series of workshops, delivered by the Bell programme director, on fostering student engagement and active learning in an online setting.

An early focus of attention was to ensure that students had the tools they needed to access their education remotely. For example, all IRE and Bell students were provided with an iPad and Apple Pencil, and instructors prepared and shipped out kits of parts to allow students to conduct lab-based or hands-on courses from home. Another priority was to simplify and signpost the curriculum in a way that helped students to manage their workload and priorities. As one IRE instructor put it, "*give them some rungs on the ladder to hang on to as they tried to climb that wall*". For example, some elements of the IRE curriculum were switched from concurrent to sequential delivery to simplify the learning experience and reduce the number of tasks that students had to manage at any one time. In addition, new systems were established via Google Classrooms to allow students to access their learning, track their progress and submit course deliverables online.

One unexpected barrier faced was students' unease about remote learning and their expectation that it would inevitably lead to an inferior learning experience as compared to a face-to-face education. However, interview feedback from students and instructors alike suggested that not only were many of these fears unrealised, but that some aspects of online learning offered significant and unexpected benefits above the face-to-face experience. One was the increased pool of industry contacts, prospective employers and alumni from across the US who were willing and able to engage with IRE/Bell students as part of design projects, showcase events and recruitment activities. Another reported benefit was the increased flexibility offered by online interactions, allowing students to schedule meetings or engage in asynchronous learning from different locations and at different times of the day. Combined with the culture of personalised support and mentorship provided by the IRE/Bell programmes, this flexibility offered new opportunities for students to ask for and receive one-to-one online support on-demand from facilitators and instructors in a way that would not have been feasible in a face-to-face setting.

2.3. Addressing the challenges of emergency teaching

Interviewee feedback pointed to three major inter-related challenges faced by the IRE and Bell programmes during the period of emergency teaching, as outlined below.

The **first** challenge was student recruitment. Both IRE and Bell are new programmes with relatively small intake numbers. Their enrolment is heavily dependent on in-person recruitment events in Community Colleges, which are held across the state (for the IRE intake) and across the country (for the Bell intake). The high levels of engagement and interest typically generated at these face-to-face events was not replicated when recruitment activities moved online from March 2020. Anecdotal feedback also suggested that some negative experiences of online learning in the Community College setting may have deterred some prospective students from considering a predominantly online programme such as Bell for future study. Probably as a result of both of these factors, applications to join the IRE and Bell programmes dipped significantly for the January 2021 intake. It was noted, however, that application numbers for the August 2021 intake had "*bounced back*" and the Bell programme is on track to grow its annual student intake to 150 in the coming years.

The **second** challenge was particular to the Bell programme and concerned student disengagement. The first semester (the Bell Academy) is designed as an immersive face-to-face semester that introduces students to the programme ethos, approach and community. As a result of emergency teaching, the second student cohort (Cohort 2, that joined the programme in August 2020) participated in the Bell Academy almost exclusively online. It quickly became clear that Cohort 2 was demonstrating much lower levels of engagement that either their IRE peers[3] or the cohort that had joined the Bell programme the previous year. As the one Bell instructor noted: "*we had students not coming to class, which in IRE and Bell just doesn't happen, and many of them would have their cameras turned* off". Two strategies were employed to address this issue. Firstly, a six-week pre-enrolment orientation course was devised for Cohort 3 (enrolled in January 2021) to establish clear guidelines for the professionalism and self-directed learning expected of Bell students. Secondly, ten minutes were allocated each day in the Bell Academy schedule to a 'morning meeting' that brought students together to "*engage them, pump them up, run through the day and frame how these activities bring value to their career*". Taken together, these two interventions were described as "*game changers*" for improving engagement levels among Cohort 3: "*by setting a higher bar of expectation at the beginning and then having these regular meetings, we completely solved the engagement problem that COVID put on our doorsteps*". It was noted, however, that establishing high engagement levels in Cohort 3 proved easier than reversing the disengagement of Cohort 2: "*those who were disengaged, they're still disengaged. We can't re-grab them*".

The **third,** and perhaps most significant, challenge identified by interviewees was that of student mental health and social isolation from the IRE/Bell community while learning remotely. Many spoke about the "*family-like*" community of peer-support that spans the IRE and Bell programmes. Their feedback suggested that face-to-face interaction has historically played a major role in this community-building, with many recalling with fondness social events such as barbecues and camping trips that had brought together students, instructors, and alumni prior to March 2020. The loss of this face-to-face community was clearly keenly felt, and considerable effort has since been invested in finding new ways to connect students and staff remotely. Instructors worked to establish more frequent and regular contact with students: "*creating familiarity, showing compassion, and having that be a part of every day… using zoom to create that social connection that used to come from the unscheduled contact on campus*". A range of optional social activities was also organised to connect the community remotely, such as take-out meals ordered and delivered to students' homes during evening activities, and virtual walks where "*everybody would turn their cameras on, and we'd go on a walk, and talk through Zoom*". With many students presenting with potential symptoms of anxiety and depression, programme directors, instructors and project team facilitators have also paid particular attention to identifying at-risk students and directing them to professional support services. In addition, new activities were embedded into the professionalism workshops to support students' growth mindset and help foster resilience, mindfulness and well-being.

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[3] Interviewee feedback suggested that similar problems were not experienced with incoming IRE students because most of this cohort had followed IRE's dedicated foundational ('lower division') programme prior to enrolment and so had already connected with the IRE community, culture and expectations. Feedback also suggested that the vertical integration of courses (in which students from all semesters of study work together) helped to infuse a culture of intrinsic motivation into the incoming cohorts.

3. **Impact of emergency teaching on future aproach**

Interview feedback suggested that the experience of emergency teaching is set to have a profound impact on the IRE/Bell programmes. In the words of one IRE instructor, "*we learned a bunch of new things [from emergency teaching] and we're going to do things differently as a result of this. There's no question in my mind, it's a game-changer*".

Some of these impacts represent an acceleration to and validation of changes already planned prior to the online pivot. However, many are innovations inspired and informed by the experience of emergency teaching. For example, 'morning meetings' that frame the working day and build community will continue to punctuate Bell Academy's daily schedule. Similarly, the integration of activities to build resilience and well-being are also expected to become permanent elements of the IRE and Bell programmes. As the Bell director noted "*we hadn't talked about self-compassion prior to emergency teaching, but it's so important, not just during a pandemic, but in any part of engineering education and in practicing being an engineer... We're going to keep doing those workshops*". However, perhaps the most far-reaching impact of emergency teaching will be to increase the use of hybrid learning, as outlined below.

While the Bell programme was established to offer more flexible ways for students to learn, some limitations were imposed. For example, all students were required to travel to Minnesota to attend the first semester (Bell Academy) in person. It had been assumed that the professional capabilities and intrinsic motivation necessary to propel students through four semesters of remote learning (while on engaged on paid work placements) was best fostered via an intensive semester of face-to-face learning. However, in the words of the Bell programme director, the experience of emergency teaching demonstrated that "*you can have a very intense life-changing event from your bedroom... We've found a way to use technology to create social contact which is so important for [student] motivation*".

From August 2021, the Bell Academy will be offered as a hybrid experience, such that incoming students can opt to participate online or on campus, depending on their personal circumstances. It is anticipated that this flexibility will help to open up the programme to new pools of prospective students, particularly those who are based in what have been termed 'STEM deserts': areas of the US where no higher education opportunities currently exist in STEM (science, technology, engineering and mathematics). Similarly, plans are underway to offer selected IRE technical courses in hybrid mode, allowing students more flexibility to access this learning asynchronously, as and when needed. The limiting factor for these changes will be the programmes' ability to access technology for hybrid learning that is not prohibitively expensive and "*where folks in the physical environment and folks who are beaming in through a virtual environment are having roughly the same experience*". In the shorter term, while new technology is being developed and tested, the delivery of some 'hybrid' experiences involving group collaboration and/or hands-on learning will require the student cohort to be divided into two discrete streams – one for those engaging online and one for those engaging face-to-face.   It is anticipated, however, that a truly integrated hybrid programme experience will be rolled out in the coming two years.

The changes outlined above will serve to reinforce and build upon the already striking focus on student autonomy and self-directed learning evident throughout the IRE and Bell programmes. They are also nurtured by the deeply-rooted IRE/Bell culture of educational experimentation and ongoing programmatic change, features that will undoubtedly continue to regenerate the priorities and approaches of both programmes for many years to come.

Source of evidence

The case study for Iron Range Engineering (including Part A, the review of the IRE/Bell design projects, and Part B, this review of the 'institutional context' across the IRE and Bell programmes) drew upon one-to-one interviews with 16 individuals. The interviewees included: the IRE programme director; the Bell programme director, two industry representatives who have acted as 'clients' for IRE/Bell design projects; one IRE alumnus; one IRE design project team facilitator; four IRE and/or Bell instructors; three IRE students; and three Bell students.

Further information about the methodology for development of CEEDA case studies is given at the project website[4].

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