CASE STUDY

1

TITLE

Recognising stereotypes and the shared habitus of Engineers and Architects: Developing interdisciplinary teamwork and communication skills for first year students in an inclusive environment

Case Study 1

Dr Daniel McCrum and Dr Jennifer Keenahan

Recognising stereotypes and the shared habitus of Engineers and Architects: Developing interdisciplinary teamwork and communication skills for first year students in an inclusive environment

Daniel McCrum

Dr Daniel McCrum is an Assistant Professor in Structural Engineering at the School of Civil Engineering, University College Dublin. Daniel is the Programme Director for the ME in Civil, Structural & Environmental Engineering and has previously been the Head of Teaching and Learning at the School of Civil Engineering. In 2012, he completed a PhD in structural engineering from Trinity College Dublin, Ireland under an Irish Research Council Scholarship. Daniel then joined Queen's University Belfast as a lecturer in structural engineering in 2012. In 2017, he joined University College Dublin. He is a chartered structural engineer with the Institution of Structural Engineers (2016). Daniel is a fellow of the Higher Education Authority, United Kingdom, has a Postgraduate Certificate in Higher Education Teaching and is a published author in engineering education.

Jennifer Keenahan

Jennifer is an Assistant Professor in the School of Civil Engineering at UCD and has been Head of Teaching and Learning there since 2018. She completed the UCD Professional Diploma in University Teaching and Learning in 2021. Jennifer received a Digital Badge in Universal Design for Learning from the National Forum as part of their national rollout in Autumn 2020 and was appointed as a UCD Faculty Partner to support and accelerate the implementation of Universal Design for Learning throughout the University. In July 2021, she was awarded funding under the Academic Advising Project to establish and expand Academic Advising in the School of Civil Engineering. She was invited to support the University Working Group looking at Online Assessment in Spring 2021. Jennifer is module coordinator on three undergraduate modules for mixed groups of Engineers and Architects in first, second and third year, and she has interests in a wide variety of areas including interdisciplinarity, student-centred learning, and integrating the sustainable development goals into curricula.

Outline

Title

Recognising stereotypes and the shared habitus of Engineers and Architects: Developing interdisciplinary teamwork and communication skills for first year students in an inclusive environment.

Abstract

Engineers and Architects require effective communication and interdisciplinary team working to be successful throughout their career, which is often overlooked during formal undergraduate education. This case study disseminates the novel design and evaluation of an inclusive module on communication and interdisciplinary team working in the combined teaching of undergraduate Engineering and Architecture students. An interdisciplinary problem-based learning approach was used and several Universal Design approaches were successfully adopted.

Module Name

CVEN 10060/ ARCT 10150
The Engineering and Architecture of Structures 1

Discipline

Engineering and Architecture

Level

Stage 1, 5 credits

Student numbers

160

Introduction and Context

This module is a new Stage 1 module, created in the 2017/18 academic year. The module is core to the Stage 1 architecture students and an optional module for Stage 1 general engineering students. The aim of this module is to showcase the creative and important relationship between structural engineers and architects, but also to develop effective communication skills and teamwork skills between engineers and architects. The intervention proposed in this case study is to use a Universal Design approach to develop communication skills and teamwork skills between the engineering and architecture students. Due to the interdisciplinary nature of this module, we wanted to implement Universal Design approaches so the key learning outcomes were clear to students, the assessment was flexible, the diversity of background was considered, engagement in learning activities improved and ultimately, students could better achieve and understand the learning outcomes.

The purpose of our involvement in this Universal Design case study is to create a module that takes into consideration the shared habitus, history, and different cognitive styles to best align the learning outcomes of dialogue, communication and interdisciplinary team working with learning strategies. Teamwork and communication skills are developed in this module through hands-on problem-based learning (PBL); however, architects and engineers have a special diverse relationship that needs to be understood (by each other) to aid constructive alignment of learning outcomes with learning strategies. From Figure 1 it can be seen that there is a diverse demographic of students who were registered to this module over the past 4 years (2017-2020). Based on our observations about student performance, we believed that implementing Universal Design principles would support students in achieving the learning outcomes.

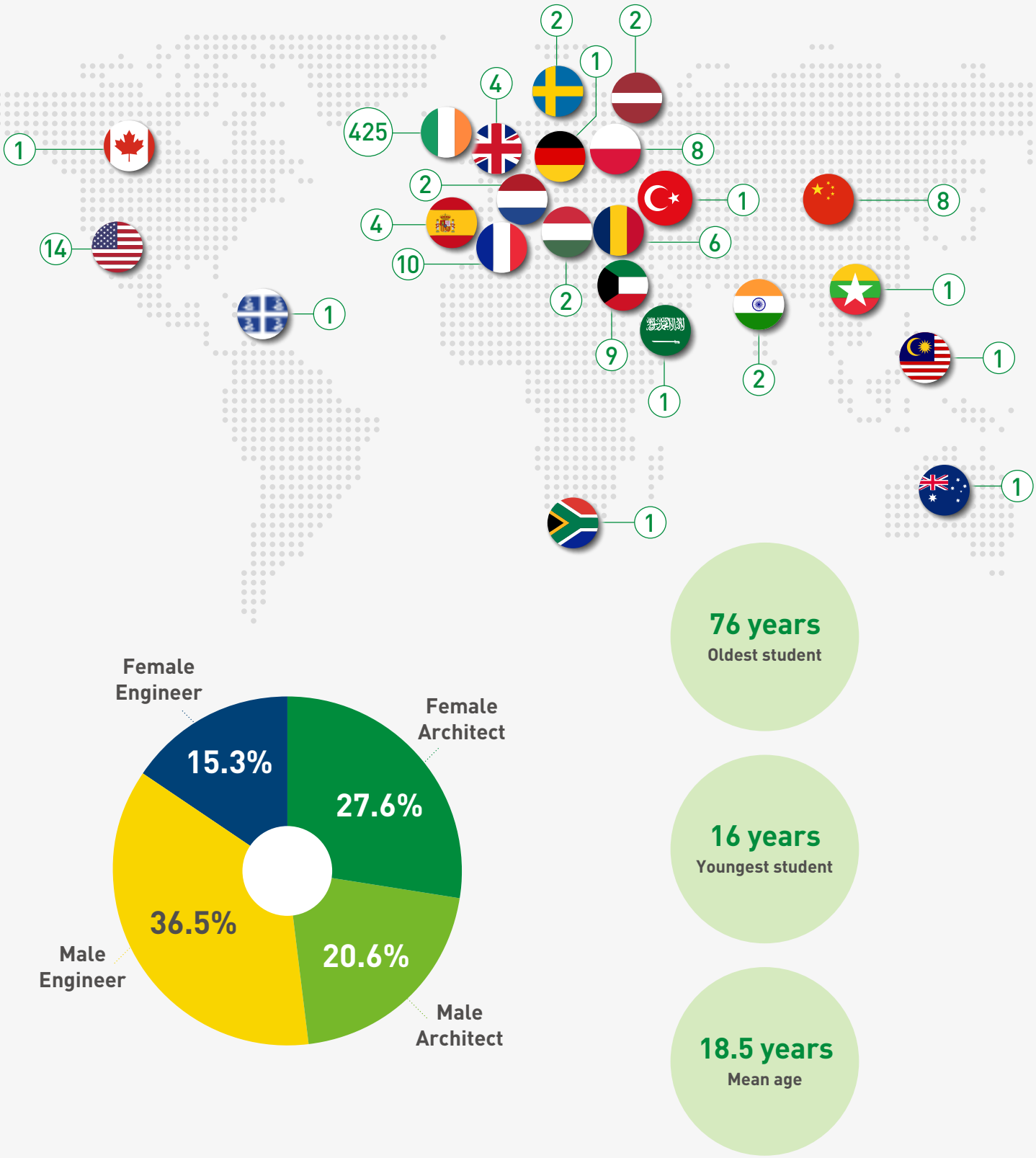

Figure 1. Demographics of students who were registered to this module over the past 4 years (2017-2020)

Design and Implementation Description

The learning outcomes for this module have been created with the recognition of the significant difference in backgrounds, talents and cognitive abilities of the Engineering and Architecture students who take this module. They have been prepared recognising the nine principles for Universal Design for Learning (UDL), using Bloom's taxonomies of learning (Bloom, 1956) and are also in line with University College Dublin's (UCD) code of practice (UCD, 2015). They have also been written cognisant of the existing knowledge and previous experience of students. Engineering students will have entered Year 1 at UCD with a C grade (55-69%) or better in their final second level state-wide examinations higher level maths, as well as one or more science subjects. Most of the Architecture students, however, have only completed Leaving Certificate or equivalent examination ordinary level maths, and possibly no science subject. Taking all the above into account, the learning outcomes for this module are as follows:

1. Differentiate the role of the Engineer and the role of the Architect through group discussion;
2. Develop effective communication skills through role-play, debates and group discussion;
3. Identify, draw and label forces in Engineering structures;
4. Describe and compare the available materials, and their properties for Civil Engineering Projects. Defend the choice of material for a given context;
5. Assess structural forms and describe why they have been designed the way that they have;
6. Assess the stability of different structural systems and subsequently visualise, design and create your own structural model; and
7. Describe structural failures and how Engineers and Architects learn from these failures.

Given that a key learning outcome of this module was to support the development of effective communication and collaboration skills of Engineering and Architecture students, (1) interdisciplinary teamwork and (2) flipped-classroom activities are key learning strategies for this module. In this context, flipped classroom is a form of blended learning where students complete readings at home and work on live activities during class time, which aims to increase student engagement (Schell and Mazur, 2015, Mazur, 2013). The flip-classroom activities are designed as problem-based learning activities, and the principles of Universal Design are used throughout. Further details on our module are described in (Keenahan and McCrum, 2020, Keenahan and McCrum, 2018).

1. Interdisciplinary Team Working:

Teamwork provides students with opportunities to interact and collaborate with others and to develop a community of learners, one of the nine key principles of UDL. It also fosters collaboration which helps to sustain effort and persistence, one of the principles of UDL. Teamwork is used throughout this module and supports students in meeting the learning outcomes. The Architecture and Engineering student teams are tutor-formed, rather than letting students self-select, so teams would have an even mix of Architecture and Engineering students. Students are split into teams of 5, each with a mixture of two to three Engineering and Architecture students. The teams are formed during the first lecture of the trimester and do not change throughout the trimester. To support effective teamwork, students are engaged in team activities in the first week of term, described in latter sections of this case study.

2. Flip Classroom Activities:

The following is a description of the formative flip-classroom activities in which interdisciplinary teamwork and communication skills are encouraged in the students. These activities provide students with multiple means of action and expression, one of the cornerstones of UDL. The activities encourage deep learning by students on concepts of structural analysis of buildings and they are carefully designed to support student engagement with the assessment activities. All activities have summative feedback, whilst all Projects have formative feedback.

Statement of Inclusivity:

Many students find it difficult to approach academic staff to discuss their learning needs. To help facilitate disclosure, a Statement of Inclusivity has been added to course materials, which aligns with the principle of providing an instructional climate in the principles of UDL. This statement is discussed in the first class of the trimester and provides students with clear instructions on the best ways of getting in contact as suggested by (Pedelty, 2003). The statement of inclusivity encourages tolerance of diversity in the classroom and should reassure those who would like to disclose information about their learning needs that this information will be treated with confidentiality and respect.

Activity 1: Hitchhikers Essay

A lecture was created in which the term 'hitchhikers' (team members who refuse to do their share of the work, or domineering team members) is explained to all of the students. Students are presented with a short essay on 'hitchhikers' and an individual reflection is requested from each student on this as suggested in (Oakley et al., 2004). Students submit the reflection online through Brightspace. This activity set enabled each team member to understand group dynamics and how a member of the group not doing work affects the entire group.

Activity 2: Ice Breaker

Given that students will spend the trimester working in their teams, time is set aside at the start of the trimester to allow team members to get to know each other through Ice-breaker activities (not assessed).

Activity 3: Team Expectations Agreement

Within their interdisciplinary teams, students were requested to prepare, sign and submit a 'team expectations agreement', as suggested in (Oakley et al., 2004). The agreement serves as a pseudo-legal document to prevent anyone from making invalid claims about what they were supposed to do. It is intended to unite the team with a common set of realistic expectations that the members generate and agree to honour. In preparing their agreement, students are encouraged to consider outlining team roles and their responsibilities, procedures for working on submitting assignments, strategies for dealing with uncooperative team members, effective team functioning, and expectations for team meetings.

Activity 4: Role Play

Role play allows students to explore realistic situations they will encounter in their future careers. Each set of Architecture students, and separately each set of Engineering students, are presented with a description of a role they need to act out in relation to a building project. Each set of Architecture and Engineering students are allowed 3-5 minutes to discuss the arguments they are going to make. When they are ready – they then engage in a debate about what they should do. The purpose of this task is to encourage students to play out their roles in an educational environment to support their learning and understanding of interdisciplinary teamwork and communication. It is an authentic task and thus aligns with the principles of UDL.

Activity 5: Interactive Development of Rubrics

Rubrics were created for all assessment tasks during lecture time with students (Figure 2 is for Project 1). Students spend time within their interdisciplinary teams deciding the criteria and respective weighting to be used in the rubric. This approach achieves buy-in from students in the assessment process, a greater understanding of the expectations for the assessment, as well as getting students started much earlier (Gibbs and Simpson, 2005). This approach also supports students engaging in a discipline that is less familiar to them, i.e. Architecture students experience more engineering types of concepts and practices. Furthermore, the activity achieves the objectives of being transparent, inclusive and empowering students to be self-regulated learners. This aligns with best practice in inclusive assessments as students are supported as partners in assessment as they are given some control of the design of rubric (National Forum, 2016).

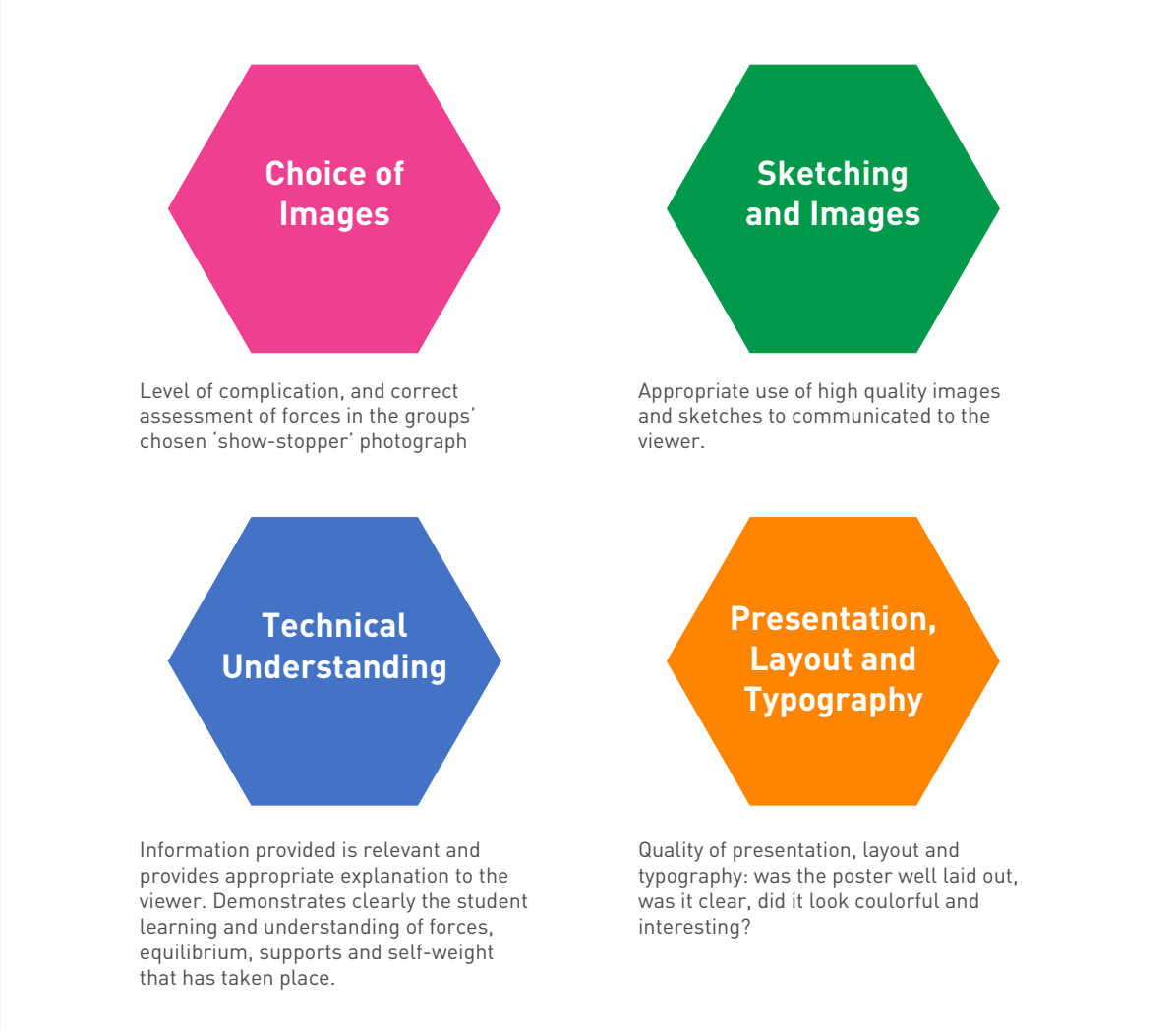

Figure 2. Sample of rubrics created for Project 1

Activity 6: Timeline of Buildings

One of the key pieces of content in this module is for students to have an understanding of the evolution of structure and form throughout the eras of architecture. Students are given a reading to complete between lectures, which is then supported by an activity in class. In groups, students are invited to organise the Padlet Timeline (Figure 3) so that the structures are in order of architectural era from left (earliest) to right (most recent). This activity promotes discussion, supports learning and also provides variety in delivery of learning material, key principles of UDL.

Figure 3. Activity using Padlet timeline

Virtual Learning Environment (VLE) for UDL

Effective use of the virtual learning environment (VLE), Brightspace, is made to support universal design for learning. The VLE model is organised into weeks and each week contains a checklist of items students must complete or engage in. This scaffolding helps to provide multiple means of engagement for students, a key element of universal design for learning. Students are offered content in a variety of formats (e.g. written and video format) which maximises learning opportunities. A discussion thread is provided to facilitate FAQs which supplies background information and promotes understanding of new information. It also allows questions around assessment to be replied to by the lecturers and everyone in the module able to see the responses. These align with providing multiple means of representation, a key aspect of universal design for learning. All learning materials are provided in advance of lectures which facilitates equitable use and flexible use of learning materials and low physical effort by students. To provide variety in learning styles, some of the lectures in the second half of the module are delivered live and recorded.

To create the opportunity of developing a shared habitus between Engineering and Architecture students, students participate in four separate interdisciplinary teamwork summative projects during this module. The assessments are designed to align with best practice in the design of inclusive assessments. The assessments are highly authentic in that they are based on real-world tasks (National Forum, 2017). All projects are submitted and assessed as a team.

Project 1:

For the first project (see Figure 4), students work in their interdisciplinary teams to prepare a poster containing five free-body diagrams. The project deadline is in Week 3. These free-body diagrams are to depict the forces shown in photographs. The photographs are chosen by the team members, thus offering students an element of choice in their assessment which aligns with the principles of inclusive assessment (O'Neill, 2017, O'Neill, 2011). Furthermore, this assessment is scaffolded using the activities described earlier (Padden et al., 2017). Students are taught how to complete the assessment, and this is built into the curriculum (Padden et al., 2017).

Figure 3. Sample of poster submission in Project 1

Project 2:

For the second project, students participate in a table quiz that takes place in Week 6. Questions for the table quiz are drawn from all content delivered to the students in the first half of the semester. The quiz offers students the opportunity to debate their answers amongst team members, as would occur in any typical table quiz. This promotes the opportunity for developing dialogue and a shared habitus between Architecture and Engineering students. After Project 2, the content of the activities becomes more technical in nature. At this point, the first lecturer finishes and the second lecturer takes over.

Activity 7: Bending moment and shear force diagrams

This activity helps students understand how structural engineers describe the stresses in the structural elements. This activity requires students to have some basic understanding of the lecture content and allows them to better understand what the stresses are in simplistic structural forms. The activity links directly to the learning outcomes of Project 1 (free-body diagrams) and content knowledge from lectures, particularly the use of physical models in lectures to explain complex ideas (McCrum, 2017), as shown in Figure 5.

Figure 5. Foam beam bending model with gridlines to indicate compression and bending stresses

Activity 8: Load path exercise

Each group of students performs a load path exercise where they must sketch the path of external loads through the structural elements. The groups must apply content knowledge from lectures. The skill of sketching is reinforced in this activity as students must sketch the structure and remove any non-structural elements. Students each sketch the load paths for a different structure and then explain their solution to their group.

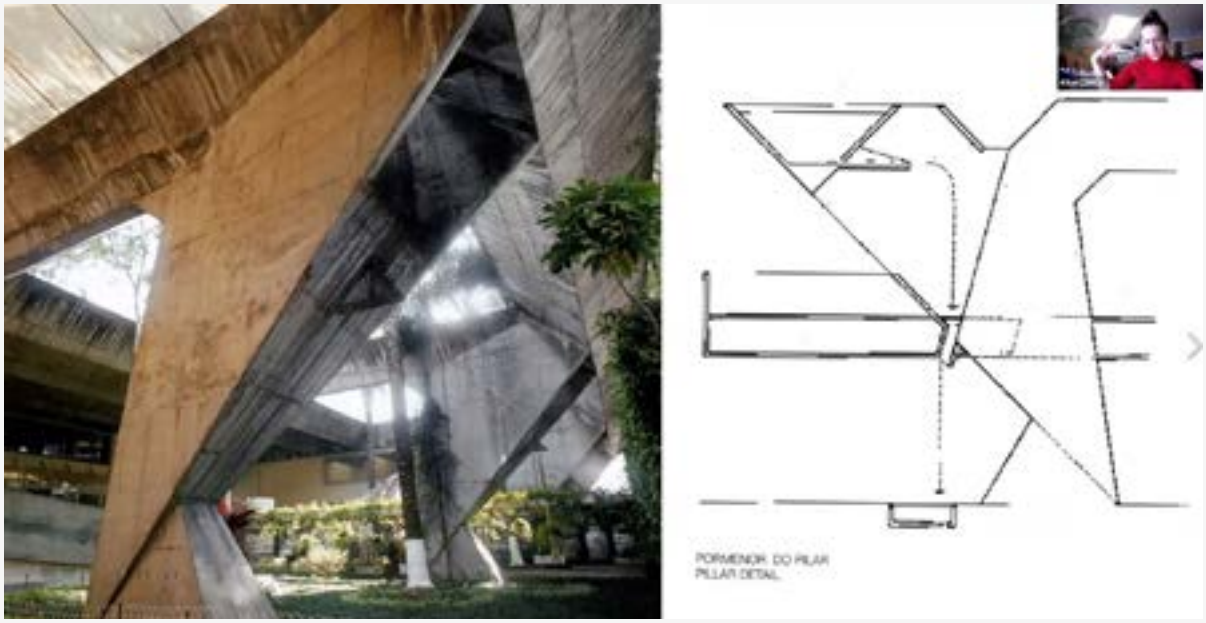

Figure 6. Slide from Architecture lecture given by Dr Alice Clancy

Architecture Lecture:

An Architecture lecturer (Dr Alice Clancy) came into the module for the first time this year to introduce architectural design concepts in relation to structures (see Figure 6). Feedback from a student survey in the previous academic year raised this point about the lack of an architectural perspective on the module. This lecture offered the Engineering students a different means of engagement and different means of presentation from an architecture lecturer.

Project 3:

The third project involved students preparing a video in their interdisciplinary teams that investigates and demonstrates understanding of how the loading, layout and Architecture of a structure or part of a structure influences the final structural design. This submission was a poster and not a video in the previous academic year. As a poster submission, it was too similar to the Project 1 submission (in style) and therefore this year it was changed to a video submission. The video submission provided a different means of expression for the students, a key principle of UDL. The deadline for the third project is Week 9. This year, we also created consistency between all of the rubrics for each assessment, so Project 3 and 4 had the exact same rubric style and layout as Project 1. Keeping the assessment style and rubrics consistent is a key principle of UDL. A portion of the rubrics for Project 3 can be seen in Figure 7. An example of a student's submissions can be seen in Figure 8.

ARCT 10150/CVEN 10060 - Rubric for Project 3				
Definition of Criteria	Excellent	Good	Fair	Poor
Precedent Study Level of complication, and correct assessment of structural forms in the precedent study is required. One of the five structural forms should be discussed in greater detail	- The structural forms chosen were an advanced choice demonstrating a high level of student learning - The structural forms chosen very unique and very different to all other images shown in class - Accurate assessment of likely forces in free-body diagram - Highly relevant reason for selection of structural forms given	- The structural forms presented a good choice demonstrating a good level of student learning - The structural forms chosen were reasonably unique with some differences to those shown in class - Good assessment of likely forces in free-body diagram - Very relevant reason for selection of structural forms given	- The structural forms presented an average choice demonstrating a modest level of student learning - The structural forms were quite similar to those shown in class and demonstrates limited additional learning - Average assessment of likely forces in free-body diagram - Reasonably relevant reason for selection of structural forms given	- The structural forms presented were a poor choice demonstrating a low level of student learning - The structural forms were nearly identical to other free-body diagrams presented in class - Poor assessment of likely forces in free-body diagram - No relevant reason for selection of structural forms given
T**echnical Understanding—Bending and Shear** Information provided is relevant and provides appropriate explanation to the viewer. Demonstrates clearly the student learning and understanding of bending moments and shear forces. Accurate description of moments and forces	- Demonstrates full knowledge and information related to subject - Provides relevant explanations/ elaboration/ assumptions/ examples/ equations/ calculations/ and/ or facts that support the shear force and bending moments - Excellent evidence of student...	- Demonstrates good knowledge and information related to subject - Provides some explanations/ examples/ assumptions/ equations/ calculations and/or facts that support the shear force and bending moments - Good evidence of student...	- Somewhat uncomfortable with information related to subject - Provides weak examples/ facts, which do not adequately support the subject; includes very thin evidence supporting the shear force and bending moments - Some evidence of student...	- Does not have a grasp of information - Information provided is weak and does little to support understanding of the subject gives insufficient support for the shear force and bending moments - Less than adequate evidence of student...

Figure 7. Partial rubrics for Project 3

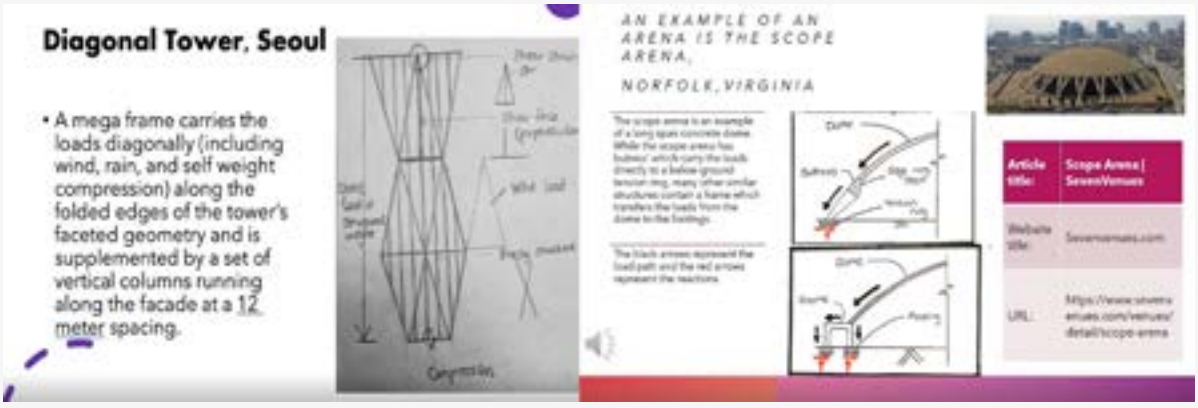

Figure 8. Two screenshots of example of video submissions in Project 3

Activity 9: Spaghetti tower challenge

The final activity was the spaghetti tower challenge, where students had to work in their groups to create a spaghetti tower that supported a marshmallow. This activity was performed online, but is typically done in person and is always very successful. This team exercise is structured, and guidance is provided before the task, following Universal Design Principles. A sample of the submissions are shown in Figure 9. Feedback was given immediately after the challenge by the lecturer in terms of which models worked well and why, and which did not meet the criteria. The student engagement was excellent, even though this took place online.

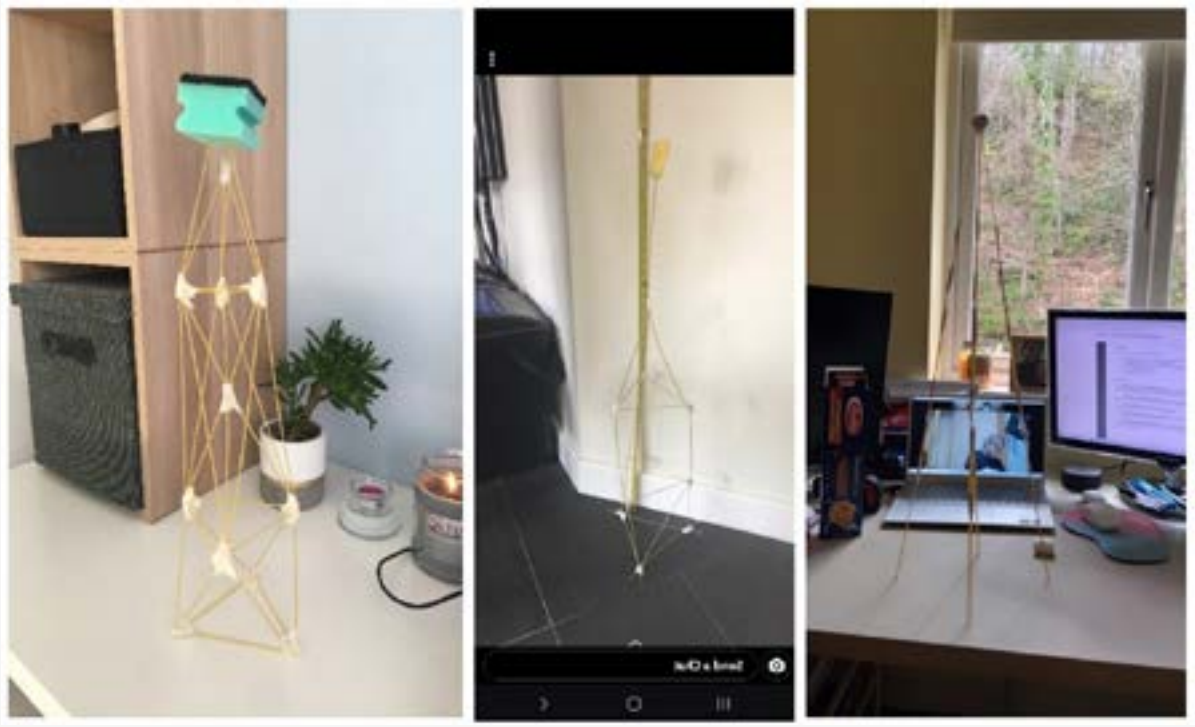

Figure 9. Three samples of spaghetti tower challenge submissions

Project 4:

The final project involves each team designing and physically testing a scaled model of a tower and to demonstrate how the lateral and gravity loads are transferred to the foundations in the structure. Project 4 is submitted at the end of the 12 weeks. The timber model is made using the laser cutter in the Civil Engineering laboratory (see Figure 10). The students must achieve the tallest, lightest and most load resisting structure possible. Students must prepare a report detailing a precedence study for their structure, and details of their design. The report must also include a reflection on how both sets of students communicated with each other and what they thought of the approach of the other discipline. Project 4 is intended to bring together all the learning outcomes of this module and to further reinforce the importance of effective interdisciplinary teamwork and communication between Engineers and Architects. The testing of the towers offers students a way to physically demonstrate their learning in a different way to the previous three projects (a principle of UDL). It also builds on the skills they physical model building skills learned during the spaghetti tower challenge in Activity 9.

Figure 10. Photographs of laser cut model towers being load tested in Week 12 in the Civil Engineering Laboratory (from 2019/20)

Other practical approaches taken:

— The lecturers used breakout rooms as much as possible in order to give groups as much group time as possible.

— The lecturers increased their active learning content on the module from the previous academic year to prevent lecture boredom on Zoom.

— The lecturers provided recorded videos explaining each of the submissions so students could review in their own time.

— The lecturers promoted the use of the chat function in Zoom and found positive levels of student engagement (better than traditional lectures in the past).

— The lecturers provided additional learning material (out of interest) that was not accessible e.g. information of sustainability and the UN Sustainable Development Goals. It appears some students liked to extend their knowledge i.e. not just study the module, but gain an insight into the bigger picture.

— The lecturers introduced the assessment and related rubrics before they covered the content. This meant students knew what was ahead of them in terms of assessment, so could focus on the learning material/activities within this context.

— Recording all the relevant learning material worked well in terms of flexibility for students.

— Activities were all structured and guidance was provided well in advance.

Results and Impact

— Impact of the implemented UDL approaches was assessed through the end of module survey. There were 89 respondents out of 160 students (response rate of 56%) in the survey in 2020/21.

— High attendance was observed throughout with typically 120-130 students every lecture/activity. Engagement was excellent during lectures and activities. This suggests the Universal Design approach was implemented well as students felt there was enough variety and learning approaches used to enable engagement. There was a 91% positive rate from student feedback when asked "did you feel able to participate in class and other learning activities, or were there barriers to engagement?"

— Approaches such as the flipped classroom, team expectations, reflective exercises, spaghetti tower challenge, etc all ensured the students understood the learning outcomes. In the survey, 94% positive response was given to the following question: Were the learning outcomes and rationale for the learning modes (projects, presentations, discussions, labs, etc) and assessments made clear?

— Assessment, in terms of rubrics and how assessment expectations were described for all four projects were almost the same. All assessments had a recorded video from the academic staff explaining the content. It was felt that having two different teaching styles helped to make the delivery more interesting and stimulating for the students. In the survey, 90% positive response was given to the following question: Did the assessment strategy build in flexibility and variety to address different learning styles?

— The learning material and assessment material was kept consistent in style on the VLE throughout the module e.g. step by step approach to the module content to allow flexibility in learning. Both lecturers were very aware of Zoom fatigue and attempted to deliver as many active learning tasks. Student feedback appreciated the live delivery of lectures also as they could interact and ask questions live on the chat function. In the survey, 94% positive response was given to the following question: Was the teaching material and its delivery (lectures, online material, in-class discussions, etc.) sufficiently diverse to support your learning?

— More active learning tasks/exercises and the flipped classroom approach had a positive impact on the module. We also performed live lectures and recorded them, as well as the flipped classroom approach. The use of practical/hands-on activities e.g. sketching, tower building, and bringing an architecture lecturer on to the module to deliver a lecture, all improved the variety of learning modes. In the survey, 89% positive response was given to the following question: Was learning supported by a variety of learning modes (projects, presentations, discussions, labs, etc), or do you feel there were other ways to enable your learning that could be offered as alternatives?

Impact of COVID:

— In some instances, the switching to online during COVID helped engagement. Students could privately ask questions on the chat in Zoom, it was easy to include polls during lectures and then groups could be created in Zoom to perform activities etc by themselves.

— Other aspects, such as Project 4 could not take place during COVID (laser cut tower in the lab) and therefore some of the learning outcomes, from a technical perspective, and enjoyment of the students, was reduced somewhat.

— In the feedback, it was found that some students felt the academic staff did the best they could in relation to COVID and appreciated that some of the activities would have been better in person.

Things that didn't work:

— Both lecturers attempted to use Google Jamboard to create interactive responses to questions live during Zoom sessions and one student kept playing a game using the drawing function (the game was tic tac toe). So, we had to drop this!

— The groups had to be partially added manually in breakout rooms, that was frustrating for the lecturers and time consuming.

Recommendations and Advice for Implementation

The following should be considered by others wanting to implement Universal Design in an interdisciplinary problem-based module. We found these approaches helped improve the learning experience for students and helped them achieve the learning outcomes, which was shown through survey results.

— **Expectations:**

- In group work, it is important for each team to set teammate expectations.
- Describe what is required in each assignment in terms of assessment as early as possible. Preferably before the learning material content is covered.
- All activities had guidance and were discussed well in advance (typically in the previous lecture) to help improve engagement.
- All assessment had video recordings of what was required so that the expectations of the lecturer could be easily referred to by the students in their own time.

— **Consistency**

- Keep the online format of the learning material consistent.
- Keep the assessment criteria consistent.
- Keep the feedback delivery consistent and timely.

— **Flexibility**

- Use as many modes of delivery as possible.
- Provide recorded material describing what is required in assessment.
- As the module was online, all lectures were recorded. Students appreciate being able to review lecture content in their own time. This may not be possible in face to face teaching.
- Students can choose their own assessment weightings.

— **Variety of learning**

- Flipped classroom, active learning tasks, problem-based learning tasks, live lectures, recorded lectures etc. all provided variety for students.
- Bringing in a lecturer from architecture helped to provide a different perspective and variety.
- Having two main lecturers on the module with two different styles 'freshened up' the module when the handover occurred in Week 6.
- Group Work was essential in achieving the learning outcomes for this module.
- Different modes of assessment were used for each of the four assessments in the module; poster, quiz, video and report.

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