Case Study

Structural feeling and conceptual design: an innovative integrated learning framework to promote creativity and engagement.

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Abstract
The Structures team has led the revamp of Conceptual Structural Design for 1st-year Civil and Architectural Engineering students. Design thinking, understanding of structural behaviour and computer modelling are integrated into a unified learning/teaching/assessment (LTA) framework that overcomes the limitations of traditional teaching methods where these skills are developed in separate pedagogical silos, offering a promising alternative to foster creativity in structural engineering learning.

1. Background
A profound modernisation of the long-established Civil Engineering programme and the creation of a new Architectural Engineering programme are two major initiatives currently underway in ABCE. Structural Engineering is core to both programmes and the ideal environment to develop and operationalise new learning paradigms and tools. Accordingly, the Structures team has introduced a new syllabus and new delivery methods for the part-A students who are exposed to the basic concepts of Structural Engineering for the first time. This subject is traditionally perceived as the most challenging within the curriculum.

Structural design can be divided into the two stages of *conceptual* and *detailed* design. The first concerns the formation of a "concept", i.e., an abstract description of the structural system; at this stage, an understanding of the structural behaviour (e.g., load paths and deformed shapes) is required. In the detailed design, the emphasis is on quantitative aspects and the sizing of the load-resisting elements. Traditionally, very little is taught about *conceptual structural design*, even though crucial design choices are made at this early stage. Computer modelling is commonly introduced later, as a separate element of the curriculum and an advanced tool for complex calculations. Challenging this conventional approach, the new LTA framework uses computer analyses as a tool *to foster a feel for structural responses* in 1st-year students. A commercial piece of software is employed as a virtual laboratory for an infinite number of experiments, allowing the *qualitative exploration* of a wide variety of structural problems. In this way, students can be more adventurous and less constrained by time-consuming hand calculations. The new educational model provides the students with practical, transferable skills and *boost confidence in conceptual design choices*. To create an effective learning environment, lecturers with a high level of competency and preparation of design-based learning activities were required.

2. Methodology
In response to the motivations presented above, the new LTA experience has been designed, as outlined below, alongside its scholarly rationale.

<u>Basic structural concepts are introduced using formal lectures</u>. "Students like really good lectures" [1], because in well designed and delivered lectures, it is possible to clarify the ILOs, make sense of the topics covered, help the students to appreciate the practical relevance of what is taught, offer the key to understand new theoretical concepts [2]. These considerations informed our choice of using frontal lectures to introduce basic theoretical concepts (see Appendix A for PowerPoint slides example).

<u>Understanding is developed/consolidated during computer lab tutorials</u>. This is the ideal counterpart of the lectures, where the material is further elaborated and applied to specific examples. Computer based sessions are of utmost importance to promote effective learning, moving the students from a timid understanding of the theory toward a thoughtful application of new concepts and procedures. To facilitate this process, detailed handouts were provided, where a structural system is analysed within a design scenario [3] (Appendix B).

<u>Timely feedback</u>. Tutorials and live discussion during the lectures enabled two-way feedback: we learned where the students were struggling and took actions according to their needs. As a result, the students were either reassured if on track or given targeted guidance to improve.

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Assessment by computer-based projects (group mini-project). This coursework was an excellent way to strengthen students' learning and achieve transferable skills. The freedom to select their case-study structure promoted discussion among the students and exploration of the built environment across the scales, from iconic structures to nanotubes. It encouraged self-directed learning, and the students benefitted from the formative feedback received during the development of their project (See Appendices C and D for a sample of coursework submission).

3. Issues

Students generally perceive Structural Engineering as a complex subject, and traditional educational models based exclusively on calculations do not promote enthusiasm for learning. Further, modern structural analysis programs are inherently complex and include many functions, resulting in a steep learning curve for novices. Our detailed set of step-by-step handouts guided the students through a series of tutorial problems and was instrumental in keeping their focus on structural behaviour rather than on the operational aspects of the program, i.e., not on *how to do it* but on *why we do it*, *what does it mean*, *what's the output* and *how to interpret results*. During the Covid pandemic, the remote connection and the software Impero installed in the computer labs have been of fundamental importance to preserve the interaction with the students. We used dual delivery (half group in person, half remotely connected via Teams) and created a weekly schedule to give all the students the in-person experience and preserve the buzz for learning.

4. Benefits

The computer sessions have been particularly successful. They created an environment where qualitative and quantitative understanding support each other, and students can explore the inseparable relationship between architectural forms and structural performance in an accessible and interactive manner. In terms of knowledge and understanding, the students learn the relevant structural concepts, developing subject-specific cognitive skills (identifying, defining, and solving engineering problems; selecting and applying appropriate mathematical and computing methods for modelling and analysis). Further, the students have subject-specific practical skills and key transferrable skills, i.e., ability to use a specific computer software.

5. Evidence of Success

The Engineering programmes have a clear thread of design running through the levels of study. Skills acquired in part A are transferred in part-B Structural Design modules. Feedback from the students has been very positive; they enjoyed the experience and learning how to use a tool that engineering practitioners normally use. In addition, the students enjoy the possibility to learn from their mistakes. Feedback from students' survey is included in Appendix E.

6. How Can Other Academics Reproduce This?

The pedagogical approach presented can be easily adapted to other Engineering and Design courses where the integrated active-learning environments can facilitate understanding of complex concepts, increase competency, and boost students' enthusiasm. A limiting factor could be the management of large classes and the necessary resources (staff, lab space, software licenses).

7. Reflections

We believe our LTA intervention has been very effective thanks to good design and preparation, our understanding of the learners, where they are when they join the university, and where they need to get to become accomplished professional figures. Our practice will be further enhanced by introducing a new lab for the construction of bench-scale physical models. This will enable considerations of structural complexity, stability, and, importantly, construction sequence.

References

[1] Biggs, J., & Tang, C. (2007). Using Constructive Alignment in Outcomes-Based Teaching and Learning Teaching for Quality Learning at University (3rd ed., pp. 50-63). Maidenhead: Open University Press.
[2] Race, P. (2007) The Lecturer's Toolkit, 3rd. Ed. Routledge: London.
[3] Royal Academy of Engineering, *Contextualising maths resources*, https://bit.ly/3hSfaXO