A novel approach to the use of spreadsheets in structural design

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This case study has been developed from data gathered through observations of the teaching component; interviews with the tutor and a student focus group.

Background
The Software for Engineering Module in the second year of the Civil Engineering BEng and MEng courses at Dundee University invites students to tackle a real-world, open-ended structural modelling problem in the design of complex, non-standard structures. The aim is to enhance students’ problem solving, team work, planning and IT skills, including introducing them to a novel approach for the parametric generation of data sets for use in structural modelling packages using Excel spreadsheets. This use of Excel to generate structural input data for nodes, elements and loadings, which can then be copied and pasted into the modelling software rather keying them in by hand, allows the students to model structures with multiple repetitive or curved members, for example the helical footbridge over the M8. With sufficient thought and planning on the part of the students it is possible for them to construct a spreadsheet that will generate the input data to model complex structures in such a way that different design data sets can be created by changing the values of just a few cells, allowing exploration of problems in a “what-if” manner that would be impossible otherwise. The formulae for doing this are often non-trivial, so students are encouraged to start from pencil and paper drawings, listing the factors they know, what they can generate and how. They work in pairs to help to develop team-working skills and are required to keep time sheets and produce technical reports and presentations to the highest possible quality, with an emphasis on professionalism.

The module is taken by approximately 50 students, most of whom are from the UK, with a significant number having entered directly into the second year of the course with A level, HNC or HND qualifications. This is the students’ first experience of being set an open-ended problem as part of their course and, while most students will have used spreadsheets before (they are used in a first year IT module), the direct entry students will not have had the same introduction as those who took the first year.

The module lasts eleven weeks. For the first eight weeks the students undertake four practical spreadsheet exercises, each lasting two weeks, for which there is a three-hour timetabled slot each week. The aim of these is to introduce the students to the spreadsheet techniques they will need for parametric data generation which involves the tutor explaining how to do some task which the students then undertake. There is another three hour per week slot where the students learn about 3D Autocad. The main modelling task is set as coursework at the beginning of the module. Throughout the eleven
weeks there is a one-hour session each week for discussing problems arising from the coursework and possible solutions, but these sessions are structured so that students cannot do the coursework in them, encouraging them to work out of class. The tutor's approach is to help the students formulate the right questions to which they can find answers themselves, rather than presenting them with solutions to their problems. The last three weeks of the module are scheduled for coursework only. Students work in pairs; changing partners for each of the exercises and the coursework. Each week they have to submit a timesheet describing what they have done, how this compares to what they hoped to achieve and what they plan to do in the coming week. They also have to present reports on how and why they chose their design solution for the coursework (the best reports are made available as exemplars to the following year's students). Each two-week exercise carries 5% of the module mark, with the remaining 80% being on the coursework; students are threatened with a 2% deduction should they fail to submit a timesheet. Aggregate marks are awarded to the pairs and it is up to them whether they split this 50:50 or give some other weighting.

**Reasons for introducing this teaching method**

The original idea of using a spreadsheet to generate the input data for structural modelling came from work on bridge design that the tutor was doing several years ago with the civil engineering company Arup. Its use in teaching and learning was prompted by requests from students to reform the existing Engineering Software module from a focus on generic engineering based on C++ to something more relevant to real life civil engineering. In doing so the tutor wanted to help the students develop a range of professional skills, such as problem solving, team work and time keeping and motivate them by showing them that they are capable of solving real engineering problems.

**Lecturer perspective**

While the actual method of parametrically generating the input data for structural modelling using a spreadsheet was one with which the lecturer was familiar and comfortable from his own professional practice, there was the problem of trying to judge what scale of problem to give to the students. Starting cautiously, with a relatively simple problem, he has monitored what the students are capable of in order to devise problems of suitable complexity. His aim is to come up with a problem that is sufficiently complex so that students will struggle initially but will still be able to solve it, thus allowing them a sense that they have achieved something on a par with what would be required from a practising civil engineer (feedback from former students suggests that this sense is reinforced when students enter practice). Allied with this, the emphasis on a professional approach to timekeeping, teamwork and reporting and a systematic approach to problem-solving shows in the quality of the work submitted by students, which the lecturer describes as showing them "growing up": "the way they tackle things after is just so different from what it used to be."

The lecturer feels the overall approach instils in many of his students "total competence and confidence to get on and use it [...] There are odd people who don't get it quite as well as the rest but in general they'll still be an awful lot better at the end of this module than when they came into it."

**Students’ perspective**

The questionnaire results show that they do not find this an easy module - only four agreed that they found it easy to follow the module content and in the interview they said that it was "really hard" or "a bit overwhelming", especially at the beginning. However they recognise that the level of challenge is appropriate and intentional and, by the end of the module, they are able to cope. They agree that they have learnt how to use a valuable tool (spreadsheets) and technique (the application of spreadsheets to generating modelling data parametrically). In interviews and other feedback provided by the lecturer,

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1 14 students currently filled in a questionnaire in the last week of the module; two groups of students were interviewed, one group currently at the end of the module and one group who had taken it in previous years.
past students have affirmed that they continue to use both the tool and the technique (which "gives a competitive advantage over others not fortunate enough to have taken the course") in other courses and in their own practice.

Perhaps more interesting is that many students reported an improvement in more generic skills; in the questionnaire the vast majority agreed that they had improved their problem solving, time management and team working skills. This came over very strongly in comments, for example they say that "I have significantly improved the way in which I approach a complex problem", "developing a keen sense of problem solving is one of the clearer benefits of the module" and "I have also learnt how to organise and delegate workload within a team." They show awareness of some of the more subtle aspects of professional team work - for example, the importance of "laying out your [work] so that someone checking your solutions knows where to go. There's no point having a big spreadsheet if no one has a clue what it is apart from you" and "[this module aims to] help you become an engineer. I mean not just someone who can just ask [for the answer to a problem] and write it down [...] helping you to be able to work like you will be required to in the real world." They also recognise the benefit of the tutor's approach to helping them when they are stuck, agreeing that the tutor's "never answering a question" except with another question is the right approach.

Issues
It is important and difficult get the level of challenge right for the students. In this case this has been achieved through an adaptive, iterative approach, though students still need reassurance at the beginning of the module when many feel out of their depth.

Several students reported frustration with the amount of time they could spend stuck, i.e. they had reached a point where their calculations weren't working, couldn't see a solution, but had to wait for time in the tutorial to get help. This is a simple consequence of having many more students than lecturers, rather than a reflection on the effort put in by the lecturer.

Benefits
On the basis of feedback received from former students, the method proves useful to the students in future courses and when they enter engineering practice themselves. It instills in students what one described as "professionalism that you can carry forward to what we are going to do in the future", improves their problem solving skills (they recognise the importance of a systematic approach to solving complex problems) and builds their confidence so that they can solve the sort of problems that they will be asked to undertake in engineering practice.

Reflections
This is an example of professional/research practice informing teaching, but it also shows the importance of the consideration given to implementing it in such a way as to maximise the opportunity for learning about problem solving, team work, professionalism and time management (e.g. setting problems at an appropriate level, how working in groups for team work also gives opportunities for peer-learning, thinking through the implications of assessing group work). More than one student described it as the "most important module" they had taken.