Making engineering fun to learn: challenges and opportunities

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Abstract

This research project was aimed at critically investigating the problems and challenges arising from teaching engineering students and how these impact on achievement of students’ full potential. It proposes practical solutions to dealing with these problems. This study aimed to investigate the actual root of the problems encountered, explore new approaches to teaching and learning and implement these on a carefully selected module at undergraduate level 5. Questionnaires, focus groups and interviews of academic staff from three regional universities were carried out as part of the investigation. The results indicate that structural analysis is perceived by students as an important topic in their course but that a third of all those who took part in the survey struggled with the mathematical concepts used in solving engineering problems, despite having a strong mathematical background. Some students struggled with basic structural concepts such as shear and bending moments, load paths, etc. Half of those questioned disagreed that too much theory is involved in teaching structural analysis, whereas just over a third found the labs stimulating and rewarding in supporting their learning because they ‘can see what’s happening’.

Keywords: structural engineering, engineering mathematics, activity-led learning

Background/rationale

The delivery of courses to engineering students faces a number of challenges. One of these is the fact that an increasing number of students join a course without having an appropriate understanding of mathematics. This hinders their learning and development and impacts on their achievement in their chosen course. Evidence collected by the author suggests that this is, to varying degrees of severity, a general problem across the UK HE sector.

Over the last five decades, engineering curricula have been largely based on a traditional “engineering science” model in which engineering is taught only after a solid foundation in science and mathematics has been laid. The advent of computers and structural analysis software have had a huge impact on how the subject is viewed and taught, but there is still much debate about whether the teaching of structural analysis could be made more appealing and accessible to students (Ibell, 2010). The overwhelming feeling is that, unless they are well equipped to input the correct data and are able to validate and interpret computer analysis output, students will not be able to successfully analyse structures and produce sound engineering designs (Brohn, 2009).

There have been a number of papers published on the teaching of structural analysis and there is ongoing debate in the Institution of Structural Engineers on the topic, but several important questions remain unanswered:

- What is being taught in university departments?
- How do students perceive structural analysis in terms of its importance?
- How can students be attracted to the subject and helped to overcome the obstacles?
What does the profession require of its new graduates?
Are universities responding to professional demands?
What teaching and learning approaches are currently considered effective by students and staff?

There is evidence from many UK HE institutions suggesting that mathematics remains one of the main obstacles to students’ understanding of structural engineering; in particular, the analysis of structures (mechanics). This, in turn, hinders the students’ appreciation and understanding of sound engineering design and design principles.

The approach

The main objectives and methodology were to:

1. Review the current state of structural engineering education and how it is taught in a sample of UK HE institutions
2. Carry out a survey in the form of questionnaires (about 400), focus groups with students and interviews with staff from Coventry University, the University of Warwick and the University of Birmingham.
3. Based on the findings, propose practical solutions.

Project outcomes include:

1. Highlight the challenges and obstacles in teaching structural engineering to students, with special emphasis on structural analysis.
2. Propose practical solutions to address the problem, leading to the promotion of structural engineering and better ways of teaching it to students.
3. Organise a conference on the challenges and future of teaching engineering.
4. Disseminate the findings through the publication of one or more papers in journals and/or conferences.

Over 300 students from all three local universities (Coventry, Warwick and Birmingham) took part in the questionnaires and focus groups. The focus groups consisted of three or four students who were asked structured questions. Teaching staff from the universities also took part in structured interviews. These were recorded and then carefully transcribed. The members of staff that were interviewed taught structural analysis, structural design or both. Staff teaching experience varied from 2 to 17 years, some with industrial background and some without. This gave a very good cross-section of responses from individuals with different experience and background.

All data from the questionnaires, focus groups and interviews were then collated and critically analysed. The answers from all three universities were aggregated and are presented below.

The questionnaire was divided into four sections:

- Structural analysis and the obstacles
- Teaching of the subject
- Subject contents
- Teaching tools/approaches.

There were two additional sections in which students were asked how to make structural analysis more fun to learn and what subjects they preferred.

The staff interviews consisted of the following structured questions:

- How long have you been teaching structural analysis and at what levels did you teach?
- What do you consider to be the distinctive and/or innovative features of your structural analysis module?
- What is your overall impression of the students’ ability in analysing structures?
- What do you think are the main obstacles encountered by students in understanding and analysing structures?
- What do you consider to be the most helpful means of improving the students’ analytical abilities?
- What, if any, computer structural analysis package do you use for your module and how helpful do you consider it to be in underpinning students’ understanding of the subject?
- What do you consider would be the most useful skills that students need to possess in order to effectively use and interpret computer analysis software?
- What do you consider to be the best ways of making structural analysis more attractive and fun to learn for students?
- Do you think that the way structural analysis is taught today responds to the industry’s needs? Why?
- How do you envisage that structural analysis teaching will evolve in the future?

Table 1. Sample student questionnaire questions

<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
</tr>
</thead>
<tbody>
<tr>
<td>I think my previous studies have prepared me well for this subject</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Structural analysis is important because it feeds into other civil engineering subjects I study</td>
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<tr>
<td>I find structural analysis a very challenging and demanding subject</td>
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<tr>
<td>I have problems understanding concepts and find the subject very abstract</td>
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<tr>
<td>My mathematical background from pre-university education is an obstacle to my understanding of the subject</td>
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<tr>
<td>I have a strong mathematical background, but I struggle when mathematical concepts are used to solve a particular structural engineering problem</td>
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<tr>
<td>I have difficulties transferring the knowledge I gain from example problems treated in class/module teaching to solving other equivalent structural analysis problems independently</td>
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</table>

The outcomes and findings from the surveys were critically analysed, with the aim of developing a good understanding of what the problems are and how best they could be addressed.
Evaluation

The results revealed that students not only experience problems with mathematics and see it as an obstacle to understanding the subject, but also struggle with grasping basic engineering concepts. However, staff feel that mathematics is important to understanding engineering subjects and that students should possess certain key skills that are necessary to the profession.

Some of the most important findings are summarised below:

- Students see structural analysis as important in their chosen course as it feeds into other subjects
- One-third of students struggle with mathematical concepts used in solving engineering problems, despite having a strong mathematical background
- Some students struggle with basic structural concepts, such as shear and bending moments, load paths, etc.
- On average, half of the students questioned disagree that too much theory is involved in teaching structural analysis. This suggests that they are split down the middle regarding this question. It seems that those with a good maths background and who can handle the theory well are comfortable with it, whereas others, because they struggle with the maths, are less comfortable with the theory
- On average, 76% of students agree or strongly agree that they find labs stimulating and rewarding in supporting their learning because they ‘can see what’s happening’
- 80% agree or strongly agree that they find structural analysis a challenging and demanding subject
- Roughly 30% struggle to use mathematical concepts when solving structural engineering problems, despite their strong mathematical background
- 20% find it difficult to apply boundary conditions
- 30% have difficulty determining bending moment and shear at a section in a structure
• 32% find it difficult to understand load paths
• 30% have difficulty understanding the concept of determinate/indeterminate structure
• Staff interviewed believed that the best features of their module are the practical laboratories and computer modelling and said that more of this should be introduced into the teaching
• Staff interviewed thought that the main problem is that students are unable to visualise things
• Staff said that the best delivery approach is to always underpin theory immediately using worked/practical examples so that it stays fresh in the students’ minds.

When students in the focus groups were asked the question “what would you do to make the subject more fun to learn?”, 95% answered “less mathematics and more practical/visual examples”.

Some of the concepts that students are finding hard to grasp (e.g. load paths, boundary conditions, determinate/indeterminate structure, etc.) are already being taught, in a practical environment through small experiments in the laboratory and small group work. Students are finding it easier to understand when relating concepts to practical examples. This needs to be further reinforced next year.

It is hoped that the findings from this modest investigation will encourage institutions and academics to reflect on the current methods used in teaching students and adopt the changes necessary to enhancing student learning and development.

Discussion, summary
As is evident from the feedback received from both students and staff, a common feature is that structural engineering (and in particular structural analysis) is a very challenging subject and that innovative ways of teaching it are needed. There was a general agreement that more practical examples and visualisation are the best approach to helping students appreciate and understand the subject better. This was clearly highlighted by the findings from the questionnaires where 76% of students interviewed agreed or agreed strongly that they find labs stimulating and rewarding in supporting their learning because they ‘can see what’s happening’.

The success of the project will be evaluated next academic year when the proposed delivery approach of activity-led learning (ALL) is embedded into the level 5 structural analysis module. Students on the course will be asked to give feedback on the approach adopted and how they think it has enhanced their understanding and appreciation of the subject via a questionnaire. Lecturers teaching engineering students will also be asked to give feedback on what they think of the proposed approach and how they think it will influence their approach to delivering their own teaching to students.

Further development
A review of the conventional way of teaching (whereby too much theory is taught with limited activity devoted to practical and group work) is currently being reviewed. An approach centred on ALL is to be adopted and students will be subjected to less formal teaching and more practical and laboratory-based activity.

Some changes to the content of a level 5 module in structural mechanics (the subject of this case study) have already been introduced this year. The students currently carry out a limited number of experiments in small groups of four or five and submit individual reports. Feedback is provided on these reports and also in class.
The module in question is for students on the Chartered Civil Engineering BEng course which, in addition to a number of laboratory activities, consists of formal teaching. Some topics were removed from the syllabus because they were deemed outdated, with more time devoted to those aspects with which the students indicated they were struggling (as indicated in Evaluation above), but also to give more time to computer modelling. Students are taught to use computer analysis software to model both continuous beams and portal frames with different support conditions. This learning underpins that which is taught in class.

More changes are planned for next academic year. It is planned that assessment of the module will undergo some changes, with more emphasis being put on ALL in the form of practical work (laboratory-based), group work, computer modelling and individual investigative mini-projects.

Next year, when the ALL approach is adopted and there is less emphasis on formal teaching, there will be changes to the way in which students are assessed. It is envisaged that they will continue to carry out tasks in small groups, but skills as well as task outcomes will form part of the assessment. In this way, students will gain more from the work they carry out and both their learning and learning experience will be greatly enhanced.

The project does not end with the funding but continues beyond and will be sustained. Next academic year, once the changes have been implemented, a post-evaluation questionnaire will be delivered to assess the success of the implementation through the adoption of a new approach (ALL) to teaching the subject of structural analysis.

The level 5 structural mechanics module described above will be used to monitor the impact of the implemented teaching and assessment changes on the students' learning experience and progression. Indeed, a number of students have already commented that the teaching of the module has become more enjoyable, even with the limited amount of ALL (laboratory work and computer modelling) that has been put into place this year. This is something that will be further developed next year.

Practices learnt from this research, centred around one module, may be transferred and expanded to other modules within the department or across other disciplines and departments. Although different disciplines and subjects may experience different challenges and obstacles to efficient student learning and development, it is nevertheless possible to learn from the current research work and adopt a similar approach to identifying and tackling them.

It is the intention to apply for more funding to further continue the project.

References

Further reading/bibliography

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