Making Structural Analysis fun to learn: challenges and opportunities

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Abstract: A report by Johnson and May prepared for the Ove Arup Foundation in 2008 highlighted some of the problems faced by students studying engineering degrees. Mathematics was found as one of the obstacles. This research project is aimed at critically investigating the problems and challenges arising from teaching engineering students, and how they impact on them achieving their full potential. It proposes some practical solutions in dealing with the problems. What is proposed by this study is to investigate the actual root of the problems encountered, explore new approaches to teaching and learning, and implement these on a carefully selected module on structural analysis at a second year undergraduate level. Questionnaires were distributed to both academic teaching staff and students. Additionally, focus groups were carried out with students and interviews were conducted with academic staff. Three regional universities took part in the surveys. The results indicate that structural analysis is perceived by students as an important topic in their course but that a third of all students who took part in the survey struggled with 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 the students questioned disagreed that too much theory is involved in teaching structural analysis, whereas, just over a third of students found the labs stimulating and rewarding in supporting their learning because they “can see what’s happening”.

Introduction

The delivery of courses to engineering students faces a number of challenges. One of these challenges is the fact that an increasing number of students join a course without having an appropriate understanding of mathematics (Johnson and May, 2008). This hinders the learning and development of the students and impacts on their development and achievement in their chosen course. Evidence witnessed by the proposer suggests this to be a general problem, with varying degrees of severity, across the HE sector in the UK regardless of their position and ranking. Palmquist (2007) highlighted that the root of the problem is many students do not see nor appreciate the relevance of their mathematics courses to their major field of study. Students must be encouraged to learn and appreciate how to apply mathematical concepts to engineering problems, and according to the author, technology is helping to make this a reality.

Lee et al. (2006) investigated the level of knowledge of mechanics which lecturers commonly expect from students entering university and the students’ actual knowledge of the subject upon arrival. The authors found considerable difference between academic expectation and the reality of students’ prior knowledge of mechanics.

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 basis in science and mathematics. The advent of computers and structural analysis computer software have had a huge impact on how
the subject is looked at and taught, there is still a lot of heated debate about whether structural analysis could be taught and made more appealing and accessible to students (Ibell, 2010). The overwhelming feeling is that, unless students are well equipped to input the correct data and are able to validate and interpret computer analysis output, they will not be able to successfully analyse structures, and hence produce sound engineering designs (Brohn, 2009, Mann and May, 2006).

There have been a number of published papers on the teaching of structural analysis and there is ongoing debate in the Institution of Structural Engineers on the topic (e.g. Brohn and Cowan, 1977, MacLeod, 2007, May et. al., 2003), but several important questions remain unanswered, such as: 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 the 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, and in particular the analysis of structures (mechanics). This, in turn, hinders the students’ appreciation and understanding of sound engineering design and design principles.

The present paper is an attempt to answer some of the questions raised above. It aims to critically investigate the problems and challenges arising from teaching engineering students, and how they impact on them achieving their full potential. It proposes some practical solutions in dealing with the problems. What is proposed by this study is to investigate the actual root of the problems encountered, explore new approaches to teaching and learning, and implement these on a carefully selected module on structural analysis at a second year undergraduate level.

Survey

The methodology adopted was to obtain data through questionnaires distributed to both academic staff and students, focus groups of students, and interviews with academic staff. The surveys were based on a second year degree module in structural analysis taught at Coventry University. It consists of formal teaching in addition to a number of lab activities.

The method of collecting adopted was used because it allows gathering information in different ways. Structured questionnaires are good at answering a specific list of topics for the stated aims and objectives of the research. A focus group is used as a technique to explore people’s ideas and attitudes. The disadvantage is that the sample may be small and hence not representative of the student population in general. Personal interviews are a way to get in-depth and comprehensive information. They involve one person interviewing another person for personal or detailed information. In this case, the interviewer asked questions from a written questionnaire and the answers were recorded verbatim.

The survey focused on the West Midlands and specifically on three different Universities, an ex-polytechnic (Coventry University) and two universities from the Russell Group, one old and one fairly new (University of Birmingham and University of Warwick). Consequently, this was deemed a representative sample of universities.

A total of 300 questionnaires were distributed to students from all three local universities that took part in the questionnaires and focus groups. The responses received were: 39 from Birmingham University, 34 from Warwick University and 71 from Coventry University (48% return). The focus groups consisted of groups of 3 and 4 students where the students were asked structured questions and all took part in the answer. Also, teaching staff from the universities took part in structured interviews (4 in total). These were recorded then carefully analysed. The members of staff that were interviewed taught either structural analysis or structural design or both. Staff teaching experience varied from 2 years 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 the answers from questionnaires, focus groups and interviews were then collated and critically analysed. The answers from all three universities were aggregated and are presented herein.

The questionnaire was divided into four sections:

- Structural analysis and the obstacles.
• Teaching of the subject.
• Subject contents.
• Teaching tools/approaches.
Additionally, there were two sections where students were asked how to make structural analysis more fun to learn and what were their preferred subjects (see Table 1 for sample of questions).

The staff interviews consisted of the following structured questions:
• How long have you been teaching structural analysis and what years 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 on 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 the most useful skills 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 by students?
• Do you think that the way structural analysis is taught today does respond to the industry’s needs, why?
• How do you envisage structural analysis teaching will evolve in the future?

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<tr>
<th>Strongly agree</th>
<th>Agree</th>
<th>Disagree</th>
<th>Strongly disagree</th>
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<tr>
<td><strong>SECTION A: STRUCTURAL ANALYSIS AND THE OBSTACLES</strong></td>
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<td>I think my previous studies have prepared me well for this subject</td>
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<td>Structural analysis is important because it feeds into other civil engineering subjects I study</td>
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<td>I find structural analysis a very challenging and demanding subject</td>
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<td>I have problems understanding concepts and find the subject very abstract</td>
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<td>My mathematical background from pre-university education is an obstacle to my understanding of the subject</td>
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<td>I have strong mathematical background, but I struggle when mathematical concepts are used to solve a particular structural engineering problem</td>
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<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 1. Sample of student questionnaire.
Discussion

Main findings

The outcomes and findings from the surveys were critically analysed using a simple Excel spreadsheet with the aim of developing a good understanding of what the problems are, and how best they are addressed. The results for all three universities were aggregated for simplicity.

The results from the surveys 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.

Staffs, however, do feel that mathematics is important in understanding engineering subjects, and that students should possess certain important skills that are necessary for the profession.

Some of the most important findings are summarised here.

• Student see structural analysis as important in their chosen course as it feeds into other subjects.
• 1/3 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 the students questioned disagree that too much theory is involved in teaching structural analysis. This suggests that students are split in the middle as concerns this question. It seems that those students 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 (37% strongly agree and 39% agree) that they find labs stimulating and rewarding in supporting their learning because they “can see what’s happening”
• 80% strongly agree/agree that they find structural analysis a challenging and demanding subject.
• Almost 30% of the students struggle using mathematical concepts in solving structural engineering problems despite their strong mathematical background.
• 20% find it difficult applying boundary conditions
• 30% have difficulty determining bending moment and shear at a section in a structure.
• 32% find it difficult understanding 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.
• Also, staff said that the best delivery approach is to always underpin theory immediately after by worked/practical examples so that it stays fresh in the students’ minds.

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

Assessment

As a result of the findings from the survey, some changes were introduced to the content of the second year module in structural analysis described above, and which is the subject of the case study. Currently, the students carry out a limited number of experiments in small groups of four or five and submit individual reports (see Figure 1 for examples). Feedback is provided on their reports but also in class.
As a result of this study, some topics were removed from the syllabus of the module because they were deemed outdated, with more time devoted to those aspects that the students indicated they were struggling with (as indicated in the next section) 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 taught in class.

More changes are planned in the future. It is planned that assessment of the module will undergo some changes with more emphasis being put on Activity Led Learning (ALL) in the form of practical work (lab-based), group work, computer modelling, and investigative individual mini-projects.

In the future, when the ALL approach is adopted with less emphasis on formal teaching, this will lead to changes in the way students are assessed. It is envisaged that students will still work in small groups, but where skills as well as carrying out the tasks also form part of the assessment.

In this way, students will gain more from the work they carry out and their learning and learning experience are greatly enhanced.

Figure 1. Examples of student activity.

Evaluation

As is evident from the feedback received from both students and staff, the 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 when 76% of students interviewed agreed (37% strongly agreed and 39% agreed) that they find labs stimulating and rewarding in supporting their learning because they “can see what is happening”.

The findings seem to suggest that a third of students surveyed find it difficult to use mathematical concepts previously learned in solving structural analysis problems. The problem is therefore not just of being equipped with the right mathematical tools but also being able to use these tools in solving structural analysis problems.

The authors suggest that students are taught applied engineering mathematics where they can see the link between mathematical concepts and actual structural analysis problems. An ideal situation will be for mathematics in engineering departments to be taught by engineers with a strong mathematical background rather than by pure mathematicians who may not have an understanding and appreciation of engineering problems.
Further evaluation is planned through embedding the proposed delivery approach of Activity Led Learning into the second year module of structural analysis described herein. Students on the course will be asked to complete a questionnaire to give feedback on the approach adopted and how they think it has enhanced their understanding and appreciation of the subject. Lecturers teaching engineering students will also be asked to give feedback of what they think of the proposed approach and how they think it will influence their approach to delivering their own teaching to students.

Conclusions and future developments

Conclusions

This paper surveying civil engineering students to investigate the challenges of teaching structural analysis and the opportunities offered to make the subject more fun to learn by the students. The main conclusions from this investigation are:

• Students perceive structural analysis as an important and challenging subject.
• There was a feeling that too much theory is being taught in learning the subject.
• The survey highlighted the fact that there were concepts that students were finding hard to grasp, such as load paths, boundary conditions, and determinate/indeterminate structures.
• Students find it easier to understand and relate concepts with practical examples.
• Even students with a good mathematical background find it challenging to use mathematical tools in solving structural analysis problems.
• Lecturers believed that the main problem encountered by some students is their inability to visualize things.

It is hoped that the findings from this modest investigation will contribute to institutions and academics to reflect upon current methods used in teaching students, and adopt the necessary changes with the aim of enhancing student learning and development.

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 by the authors in light of the findings from this investigation. An approach centered around ALL is to be adopted whereby students are subjected to less formal teaching with more practical and lab based activity.

Once the changes have been implemented, a post-evaluation questionnaire will be carried out in order to assess the success of the implementation through the adoption of a new approach to teaching the subject of structural analysis (more ALL).

The second year structural mechanics module described in this paper will be used to monitor whether the implemented changes to teaching and assessment will have an impact on the students’ learning experience and progression. Indeed, a number of students have already commented how the teaching of the module has become more enjoyable with the limited amount of activity-led learning approach that has already been put into place. This is something that will be further developed.

Practices learnt from this research, centred around one module, may be transferred and expanded to other modules and disciplines within Coventry University and beyond. Although different disciplines and subjects may experience different challenges and obstacles in the way of efficient student learning and development, nevertheless, it is possible to learn from the current research work in adopting a similar approach to identifying those obstacles and tackling them.

References


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