Understanding of structural behaviour

How can academics make the learning and teaching of structural behaviour more effective? What is the role of academics in better preparing graduates to meet industry expectations?

Taking into considerations the limited resources available and the timelines required to implement substantial changes into curricula, this resource sheet looks at ways to improve existing programmes and focuses on 1 aspect of understanding structural behaviour: **Using qualitative analysis methods**

1. Learning outcomes	
	To be able to sketch Bending Moment (BM), Shear Force (SF) and deflection diagrams without numbers for a diverse range of structural forms, including braced and rigid / moment-resisting frames (and also ideally including some irregular structures in later years).
	To identify patterns and magnitudes in analysis output, and to understand BM and SF diagrams and deflected forms etc. using qualitative analysis methods and/or CSA models.
	To develop an understanding of structural behaviour in order to validate and verify computer software analysis (CSA) models and their output.
	To be able to use approximate analysis methods to check output from a range of 2D and 3D computer models.
	To determine the effects of changing key analysis model parameters (such a support conditions, joint types, member stiffnesses, loading arrangements, stability provision) by experimenting with qualitative analysis methods and/or CSA models.
	To understand common modelling mistakes, and find faults, in analysis models, by experimenting with CSA models. NB: this learning outcome would also be appropriate for quantitative analysis methods.
	To conceptually assess the stability of a range of structures, and whether they are statically determinate or not.
	To determine the structural system, including load-paths, from a set of real construction drawings (NB: this

	item could also be included in section 3 on teaching methods).
	To determine the structural system, including load-paths, relative forces in members (and hence the most critical members) for one or more real structures (including buildings and bridges, for example). (NB: this item could also be included in section 3 on teaching methods).
2. Assessment and feedback	Formative and summative assessment of sketching qualitative BM, SF and deflection diagrams (ideally with explanations / feedback). As a minimum, this should be done with Y1 and Y2 undergraduate students (i.e. in L4 and L5).
	Assess students' ability to understand and explain the structural behaviour of one or more real structures. This could be done via student presentations on existing structures, since a much deeper understanding is required to be able to present information, including critical thinking / reasoning.
	MCQs (multiple choice questions) for both formative and summative assessments (with appropriate explanations and feedback). Again, this should be done with Y1 and Y2 undergraduate students (i.e. in L4 and L5).
	Prediction of expected output (in terms of BM, SF and deflection) for a range of structures / analysis models (starting off with basic structures at L4, and increasing in complexity in L5 and onwards, as appropriate).
	Review and critical analysis of outputs for manual qualitative and/or CSA output.
	Exercises which required students to (qualitatively) imagine potential failure modes for a range of given structures, including strength, serviceability, over-turning, sliding, uplift, and foundation / geotechnical failure etc.
	Assessment should ideally be more project work based, rather than examination based, since this more

	accurately reflects life at work (i.e. in industry), but notwithstanding any JBM requirements.
	It is important to frame the why, using assessments which focus on process as well as outcome.
	NB: Practice, including repetition of the above assessments, should help students to grasp the concepts.
3. Teaching methods: examples of best practice	Ideally include proprietary computer analysis software, with associated computer lab sessions.
	The ‘Brohn Method’, and ‘Understanding Structural Analysis’ book by David Brohn: Understanding Structural Analysis | David Brohn
	‘Modern Structural Analysis’ book by Iain MacLeod, which includes some helpful material on validation and verification: Modern Structural Analysis - Modelling Process and Guidance - Iain A Macleod (imacleod.com)
	Use biomimicry / nature to develop an understanding of structural forms.
	Relate problems / worked examples to real structures (using photographs and drawings, for example) as opposed to just line diagrams, where possible. Refer to ‘Structural Analysis’ by R.C. Hibbeler for an example of how to do this well: Structural Analysis in SI Units (pearson.com)
	Use physical models to reinforce key concepts from qualitative methods.
	Use plenty of worked examples and allow lots of time practice (in tutorial sessions, for example), with detailed explanations and feedback provided to students.

	Incorporate structural analysis software into qualitative analysis methods, particularly comparing diagrams produced in software to ones sketched qualitatively.
	Create links between computer software and more traditional analysis approaches.
	Provide examples of how qualitative analysis is used in industry, so that students can appreciate its relevance.
	Use case studies to consider structural idealisations and approximations.
	Methods which facilitate the sharing of students' expectations of the qualitative analysis results / output, as well as peer explanations.
	Expedition Workshed: https://expeditionworkshed.org/
4. Opportunities and challenges	**Opportunities:** Opportunity to show students the power of qualitive analysis and the link between that, the real world and analysis software. Can give a quick simple method of qualitatively checking analysis software output. Incorporate / link to IStructE structural behaviour quiz, and use this for interview preparation (ideally with support from industry and students who have been through the interview process). Relating structural analysis to the real world. Embed key concepts, and develop an intuitive feel for structural behaviour, prior to considering quantitative analysis. Reinforce qualitative analysis methods using repetition throughout the course. Integrate qualitative analysis methods into design projects throughout all levels. Before creating the model ask students what failure modes they are expecting / should check for.

	Reinforce message that code-based formulae are just a model of a more complex reality, and there are different possible models. Stress importance of hand-calculations to support more sophisticated analysis methods. Link to practical activities, including site visits and Constructionarium., with debriefs after site visits – get students to consider which structural elements were contributing to lateral stability or load carrying (and how), and linking this to other areas of the curriculum.
	Challenges: To compare with software output, staff and students first need to know how to use the software effectively. Avoid pigeon-holing the module (i.e. probably wouldn't want a module entirely on qualitative analysis methods). Marinating and/or developing (as appropriate) the links between structural analysis and structural design (since you can't do one without the other). Avoid didactive teaching methods. Time is generally likely to be a challenge, but including time to set up and run labs / physical demonstrations, and spending time to build student confidence at the start of any project.
5. Strategies for implementation throughout existing curricula	Link back to JBM requirements / criteria. Incorporate qualitative analysis methods in a number modules, and ensure cohesion between lecturers. Study past structures to see how and why they failed. Start with real structures to develop analysis skills. Add qualitative analysis aspects to site visit analysis (see 'Opportunities' for further details). Include other disciplines in activities. Incorporate more group projects and more competitions, ideally.