Authentic Engineering Assessment:
From formative quizzes to high-stakes examination

Presented by

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I teach 3\textsuperscript{rd} yr, 4\textsuperscript{th} yr and PG courses in Mechanical and Aerospace Engineering:

- Aerospace Structures (~10 yr)
- Finite Element Methods (~5 yr)

The courses skew toward engineering analysis and build on fundamental knowledge in previous years. These are not \textit{coding} classes.

There is a diverse cohort in the classes, with between 40-60\% international students. For many PG students, FEM is their first UNSW course.
Local Stiffness Matrices

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Global Stiffness Matrix

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Authenticity

- Solve “real world” problems
- Align teaching with practice

With software:
  - Decouple algorithms from mathematics
  - Improve efficiency of work and learning
  - Assess the whole “toolbox” of skills
  - Align student incentives
Engineers Australia Competencies

2.1: Application of established engineering methods to complex engineering problem solving.

2.2: Fluent application of engineering techniques, tools and resources.

2.3: Application of systematic engineering synthesis and design processes.

There is a gap here. Some of our assessment encourages being good at solving instances of problems (i.e. traditional exams). Instead, we want students to learn methods to solve whole classes of problem.
Embedding Software in Coursework

• Three step approach:
  1. Augment class theory with code and digital counterparts
  2. Use student code and software for authentic projects
  3. Assess skills using complex problems under software-friendly exam conditions
Augment Theory with Code

• Every theoretical concept has a complimentary MATLAB Live Script
• Live Scripts allow native embedding course theory, pictures, code, widget, graphical output, etc
• These simulations allow students to decouple the algorithm from the implementation of the algorithm
  • leading to better mental models and heuristics
• Seamless desktop and online code storage through MATLAB Drive is a HUGE benefit.

Solve class example
Replicate in MATLAB
Generalise with different variables
Extrapolate to a class of similar problems
Simulation

• Widgets and live scripts offer opportunities to make simple system simulations (without Simulink)

• Some evidence suggests that exposing students to guided simulations before theoretical analysis enhances the learning experience
Section properties and bending stress for thin-walled sections

In this demonstration we are going to solve for the section properties of a thin-walled beam using the thin-walled assumption. We'll use the C-section shown. Our reference coordinate system will have its origin at point 3, with positive x to the right and positive y upwards.

First, we'll need to define some symbols. We'll break the section into three separate pieces (1-2, 2-3, 3-4) for our calculation.

```matlab
syms h w t % Section dimensions
syms s_1 s_2 s_3 % Path length parameters
syms x_12 x_23 x_34 % x as a function of path length
syms y_12 y_23 y_34 % y as a function of path length
```

**Section 1-2**

We'll start at the top and go anti-clockwise. The path parameter for the first section will be $s_1$. 

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Use Code in Authentic Projects

Example

Students work in groups to analyse stress in the wing of a plane (that they eventually get to fly!)

Code built up through classes is progressively applied to solve the different challenges

Students synthesise and adapt the code they have been given and build their own “toolbox”
Software-Friendly Exams

• High-stakes examination in open-web, open-software computer lab
• Students have access to all the tools in their software arsenal

Learn theoretical concepts using code

Synthesise and adapt code to solve deeper problems

Apply code to solve problems in exam setting

Pre-COVID invigilated exam
MATLAB Changes Exams

• Questions can be more authentic and address deeper concepts

• Fewer limits on question scope (e.g. asking students to solve systems of linear equations or complex integrals)

• More efficient solves mean more questions can be asked in the same period.
  • greater coverage of course topics
  • encourages students to study broadly
Concern

Learning concepts with code undermines theoretical understanding.

Code is easy to share and copy. Students will just share code with a full worked solution.

Response

Separating concepts and algorithms from mathematical implementation creates deeper intuition.

Copying is a feature, not a bug. Leverage sharing to help everyone. Ask high level questions to ensure students understand and can use the software.
Summary

- Software skills are a necessary requirement of authentic learning and assessment for engineers

- Coding can augment theoretical concepts with rapid simulation and visualisation

- Integration of software into classes, projects and exams is critical to align student incentives and motivation

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Student Feedback

The way the course strongly emphasized the use of MATLAB and other calculation softwares felt very relevant for employment in the future.

Garth's MATLAB code proved to be the aspect of the course I found the most useful.

... the use of Matlab, it really shows how Matlab is usefully in real life