Using remote laboratory experiments to develop learning outcomes in engineering practice

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Using remote laboratory experiments to develop learning outcomes in engineering practice

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Overview

• Background
• Introduction to the OpenSTEM Labs
• Teaching engineering practice
• Process for developing remote experiments
• Case study
• Lessons learned
Accredited engineering degrees in the UK must meet learning outcomes defined by the Engineering Council Accreditation of Higher Education Programmes (AHEP) framework.

Engineering graduates achieve learning outcomes in six key areas of learning:

1. Science and mathematics
2. Engineering analysis
3. Design
4. Economic, legal, social, ethical and environmental context
5. Engineering practice
6. Additional general skills
The OpenSTEM Labs

• The OpenSTEM Labs provide remote and virtual experiments for our distance learning students

• They cover a range of STEM subjects including engineering, physics, bioscience and chemistry

• Students interact with experiments via a web browser on their laptop or mobile device.
Teaching engineering practice in Engineering qualifications

- Engineering students attend mandatory residential schools at the end of stage 1 and stage 2
- The residential schools are supplemented with remote experiments delivered through the OpenEngineering laboratory

Examples of remote experiments:
- Creep of a material
- Temperature dependence of electrical resistivity
- Strain in a thick-walled pressure vessel
- Electronics
- Heat transfer (under development)
- Wind tunnels (under development)
Development process for remote experiments

- Identify need
- Define learning outcomes
- Describe activity
- Define remote interaction
- Develop and deploy activity
A remote experiment was proposed as part of a stage 2 mandatory module teaching stress analysis (Core Engineering B)

The purpose of the experiment was for students to gain an improved understanding of stress and strain in pressure vessels.

Figure 4.14 A cross-section through a thick-walled cylinder subjected to inner and outer pressures

Lamé’s equations define the hoop stress, radial stress and longitudinal stress in a thick-walled cylinder as:

\[ \sigma_H = A + \frac{B}{r^2} \]  
\[ \sigma_r = A - \frac{B}{r^2} \]  
\[ \sigma_z = A. \]

The two constants \( A \) and \( B \) in these equations are referred to as Lamé constants and are given by:

\[ A = \frac{p_1 r_1^2 - p_2 r_2^2}{r_2^2 - r_1^2} \]  
\[ B = \frac{r_1^2 r_2^2 (p_1 - p_2)}{r_2^2 - r_1^2}. \]
Initial learning outcomes

• Be able to measure experimentally the strain in a thick walled, pressurised cylinder using the provided bench equipment

• Understand the use and positioning of strain gauges to measure engineering strain and consider sources of error

• Be able to compare experimental strain measurements with hand calculations and discuss the reasons for differences
Describe activity

- Off-the-shelf equipment was selected as the basis for the experiment.
- Equipment was tested and key interactions that develop practical knowledge of workshop and laboratory practice were identified:
  - Relationship between force and pressure when using a hand-wheel to control pressure in cylinder.
  - Measuring pressure using a mechanical pressure gauge.
  - Systematically recording data.

![Image of equipment with labeled parts: Pressure vessel, Pressure gauge, Hand wheel, and Strain gauge readings.](Image)
Revised learning outcomes

• Be able to measure experimentally the strain in a thick walled, pressurised cylinder using the provided bench equipment
• Understand the use and positioning of strain gauges for measuring engineering strain and consider sources of error
• Be able to compare experimental strain measurements with hand calculations and discuss the reasons for differences
• Understand the relationship between force and pressure when using pressure equipment
• Be able to measure pressure accurately using a mechanical pressure gauge
• Be able to systematically collect and record experimental data
Define remote interactions

Use electric motor to drive hand-wheel

Students record strain values manually

Early mockup of user interface
The remote experiment was developed by a team of software and hardware developers.

Eight sets of remote equipment were developed.

Experiment was used for the first time in 2019 with a cohort 418 students.

- Submission rate for coursework: 96 %
- Pass rate 80: %.

High level of engagement and student feedback was positive.
Lessons learned

• Need to consider engineering practice learning outcomes as part of experimental design to ensure that the experiment is fit for purpose

• Development of remote experiments is complex and needs a multidisciplinary team

• Assessment increases student engagement