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
Background

• 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

• Engineering practice is usually taught through face to face laboratories and workshops

AHEP key areas of learning:
• Science and mathematics
• Engineering analysis
• Design
• Economic, legal, social, ethical and environmental context
• **Engineering practice**
• 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, bio-science 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.

Case Study – pressure vessel

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:

\[ A = \frac{p \left( r_2^2 - r_1^2 \right)}{r_2^2 - r_1^2} \]  
\[ B = \frac{r_1^2 r_2^2 (p_2 - p_1)}{r_2^2 - r_1^2}. \]
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
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

Camera position control

Motor power control

Students record strain values manually

Early mockup of user interface
Develop and deploy activity

- 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
Questions?