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

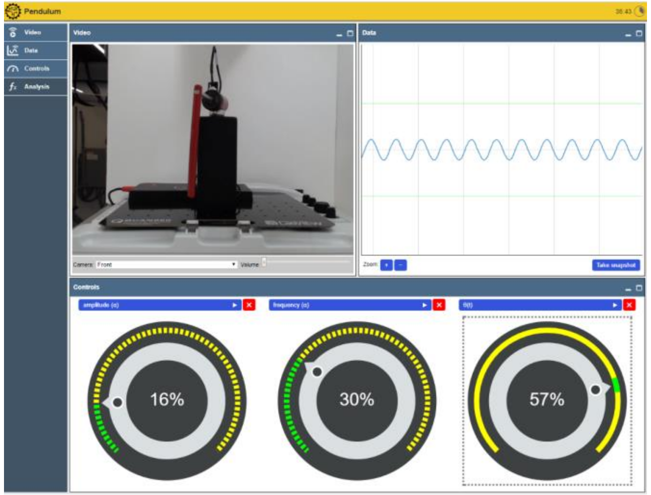
- Accredited engineering degrees in the UK must meet learning outcomes defined by the Engineering Council *Accreditation of Higher Education Programmes* (AHEP) framework
- Engineering graduates achieve learning outcomes in six key areas of learning
- Engineering practice is usually taught through face to face laboratories and workshops

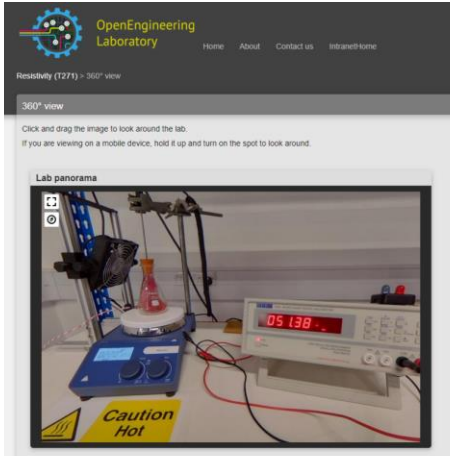
AHEP key areas of learning:

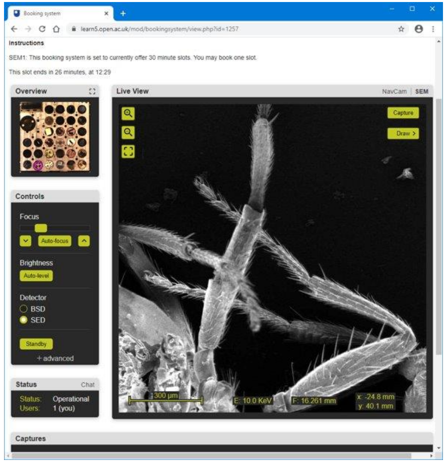
- Science and mathematics
- Engineering analysis
- Design
- Economic, legal, social, ethical and environmental context
- **Engineering practice**
- Additional general skills

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.







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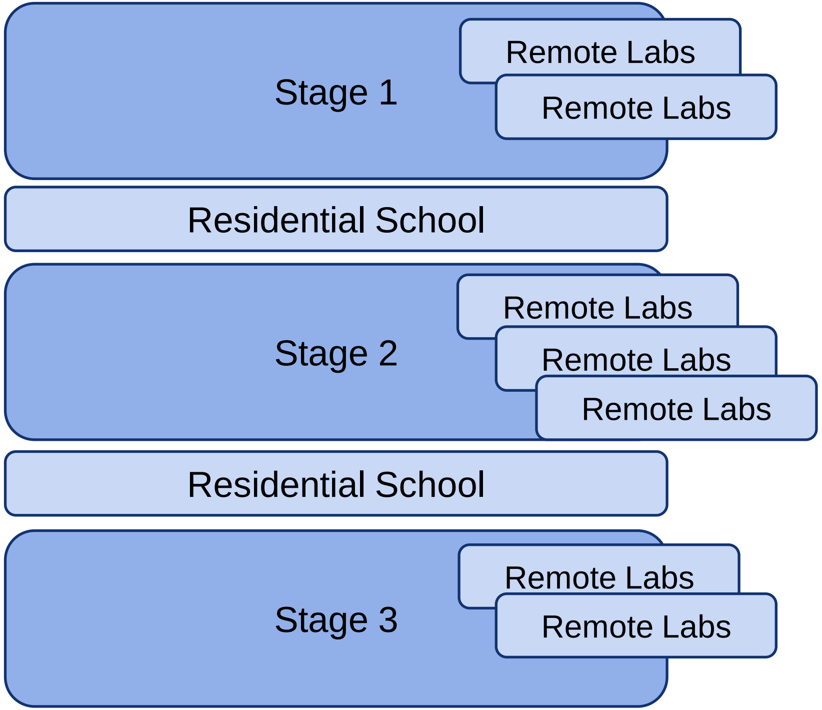
Teaching engineering practice in Engineering qualifications

- 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)

BEng in Engineering



Development process for remote experiments

- Identify need
- Define learning outcomes
- Describe activity
- Define remote interaction
- Develop and deploy activity

Case Study – pressure vessel

- 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

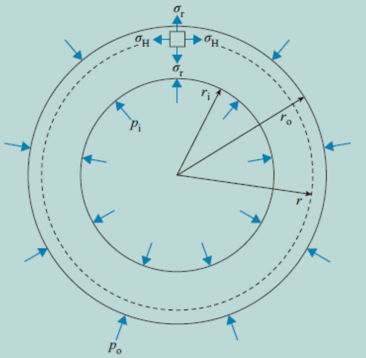


Figure 4.14 A cross-section through a thick-walled cylinder subjected to inner and outer pressures

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

$$\sigma_H = A + \frac{B}{r^2} \qquad (4.5)$$

$$\sigma_r = A - \frac{B}{r^2} \qquad (4.6)$$

$$\sigma_L = A. \qquad (4.7)$$

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

$$A = \frac{p_i r_i^2 - p_o r_o^2}{r_o^2 - r_i^2} \qquad (4.8)$$

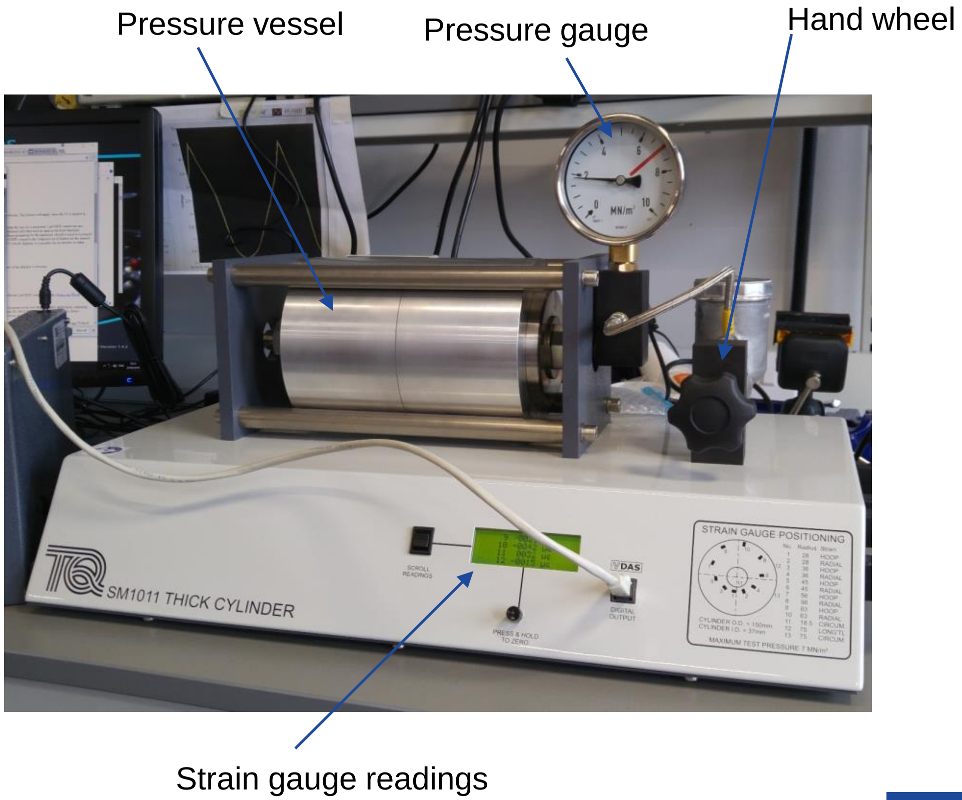
$$B = \frac{r_i^2 r_o^2 (p_i - p_o)}{r_o^2 - r_i^2}. \qquad (4.9)$$

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

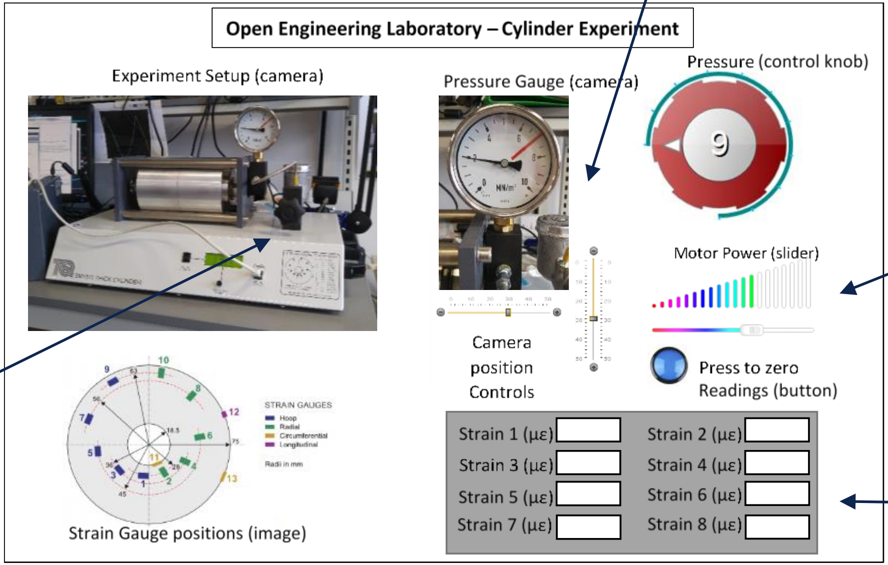
Define remote interactions

Camera position control

Motor power control

Use electric motor to drive hand-wheel

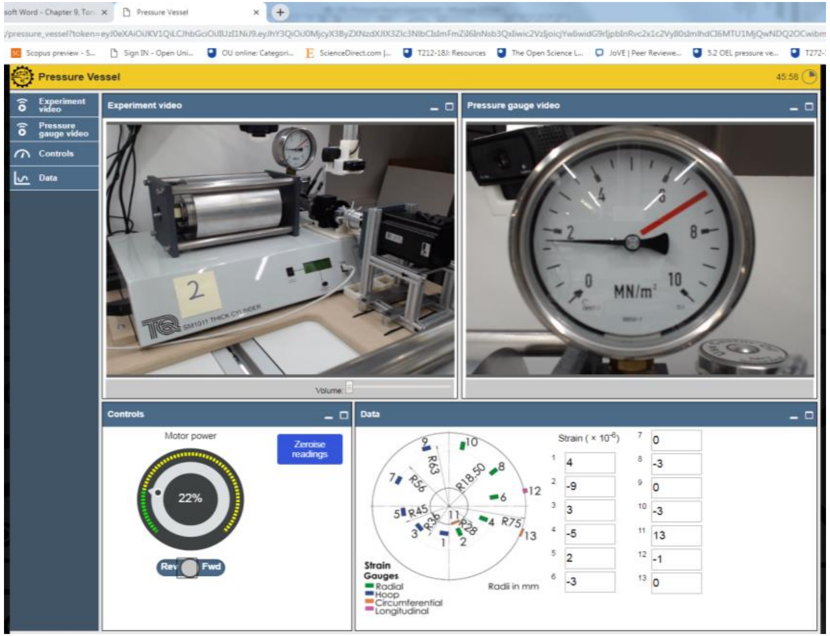
Students record strain values manually



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



Final user interface

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?