

Developing skills to navigate uncertainty and complexity in an uncertain future: lessons from engineering education

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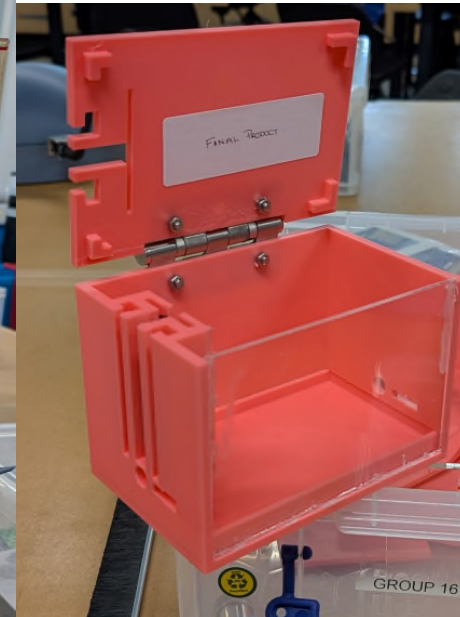
Uncertainty & Complexity

- Uncertainty and Complexity is in all fields especially in engineering, examples include:
 - Limited specifications
 - Incomplete information
 - Assumptions used for calculations
 - The real world is more complex than models
- Developing skills to successfully navigate Uncertainty and Complexity in student engineers is essential to ensure they can be successfully employed



A practice based education

- Traditional engineering education, equations and theoretical
- Engineering design is a practice based discipline
- Substantial theory (1st year) but students need to practice low stakes design at university before undertaking engineering in the real world
- Students who have not practiced design and manufacturing produce designs that meet theory but are inefficient or not able to be manufactured



Accreditation

- Engineering Degrees are accredited by the respective institutions (IMechE, IET...)
- This now requires meeting the AHEP 4 reference standards to meet UK SPEC requirements for engineer professional registration

CEng (MEng)		Level
M1.	Apply a comprehensive knowledge of mathematics, statistics, natural science and engineering principles to the solution of complex problems. Much of the knowledge will be at the forefront of the particular subject of study and informed by a critical awareness of new developments and the wider context of engineering	7
M2.	Formulate and analyse complex problems to reach substantiated conclusions. This will involve evaluating available data using first principles of mathematics, statistics, natural science and engineering principles, and using engineering judgment to work with information that may be uncertain or incomplete, discussing the limitations of the techniques employed	7

Complexity

“**Complex problems** have no obvious solution and may involve wide-ranging or conflicting technical issues and/or user needs that can be addressed through creativity and the resourceful application of engineering science.”

- Complexity is an essential part of accreditation expressed in M2 previously
- Developing the skills to address complexity is undertaken over 3-4 years of engineering education
- Revised Bloom’s Taxonomy underlies the themes in AHEP4 when compared to AHEP3
 - AHEP4 places much greater emphasis on the higher level cognitive processes ‘to evaluate’ and ‘to create’ as shown in defining complex problems

Design Teaching ES2D2

- ES2D2 Mechanical Engineering Design
- A group project based module for students to practice existing design knowledge and develop practical design theory and prototype production skills
- Term 2 & 3
 - Week 24 design portfolio assessment
 - Week 39 final presentation with prototype showcase



Uncertainty

- Setting problems for students to complete will deliberately include vague or uncertain components such that the research and methodological skills are developed
- Specifications that have inaccuracies/ made by management and not what is needed
- How do they develop skills to define a project scope and specifications?

Fistula Arm for Nurse Training to access a fistula.

This project is with the Renal, Respiratory, Cardio-Vascular clinical management group at the Glenfield hospital in Leicester is one of the largest renal units in the country. A fistula is a man-made tube which is placed into the arm between a vein and artery through surgery to enable renal dialysis. This is for people with kidney failure while awaiting a kidney transplant. It is to enable the cleaning of their blood. The fistula provides an access point for large needles to drain and replace the blood in the patient. This procedure takes around four hours for a complete process.

If a fistula is not accessed properly the patient can bleed to death in 15 minutes. This necessitates that the nurses who access fistulas are well trained on model arms and require refresher assessment to ensure that their skills remain safe.

This project is for you to produce a model arm for practicing fistula access. This needs to have a blood analogue running through it at arterial / venous pressure. It also requires a semi sealable hole post fistula access. The blood analogue needs to flow through a circuit for this practice to be realistic. A flesh analogue is required to cover the fistula area to provide a realistic entry point. There are 90 nurses who require this training and assessment so the ability to change the fistula and other tubing will provide longevity to the project increasing the sustainability of the arm.

Outputs

- Design Portfolios
- Posters
- Prototypes



PROTOTYPING :

Following the initial sketches, prototyping was carried out to visualise and refine the concepts. The next pages document this process for three specific attachments, demonstrating how the prototyping phase helped to refine the most user-centred design. Additional prototypes can be found in Appendix D.

Pole Holder: Concept 1

The initial prototype was made entirely from cardboard to quickly visualise the concept. Two models were developed, with the second incorporating a Velcro strip for added support and improved functionality.

Poles too close together as handles will clash into each other.

Would be manufactured from a silicone-based material

Velcro strap for added support to ensure poles can't fall

Hikers may not need a double pole holder as some only use one.

Poles may not be securely fastened to the bag with this design, causing them to swing while walking.



Pole Holder: Concept 2

Constructed from cardboard to replicate a commonly used pre-existing holder

3D printed from two components using an adjustable ratchet style design.

Made from one component which could be easily manufactured

A ratchet style design ensures the holder is compatible with multiple pole diameters

The design doesn't secure the poles well as external forces can push poles out

This design requires equal force on each side of the holder to adjust the inner diameter which may be difficult for some users.



Pole Holder: Concept 3

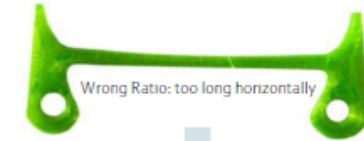


The final design was inspired by compliant mechanisms, which use the flexibility within a material to create motion without the need for traditional hinges or joints [27]. Due to its high sensitivity, multiple iterations were necessary to achieve optimal functionality and ensure a secure grip on the pole, as seen to the right. To minimise material waste, each prototype was scaled down, using approximately 3.0 grams of flexible TPU per design. The final design successfully grips poles ranging from 17mm to 25mm in diameter, making it the chosen model for the final version.

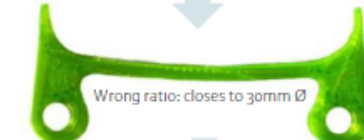
This design is 3D printed from flexible TPU.

The user simply pushes the pole into the opening and the clip will fold around the pole tightly.

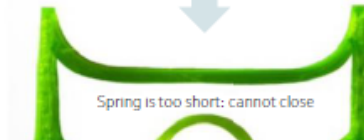
This design can suit a range of pole diameters due to the design's flexibility (17 – 25mm)



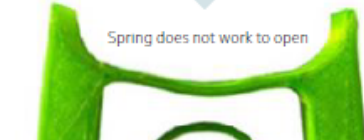
Wrong Ratio: too long horizontally



Wrong ratio: closes to 30mm Ø



Spring is too short: cannot close



Spring does not work to open



Correct size but does not hold shut



New parts allow system to hold shut

Take it back to practice

THE CORE IDEA

Learning to deal with uncertainty and complexity is a skill which requires practice.

Including this in projects and assessment provides this opportunity for students to develop these skills.

A FIRST STEP TO TRY

Identify what are the uncertainties students need to address in your field?

Identify the complexities of your field that students need to develop skills to address?

How could you develop practice in identifying, defining and reducing uncertainties to build skills?

ADAPT IT FOR YOUR CONTEXT

What practical activities could you use to develop projects/ assessments / exercises that build in complexity and uncertainty for students to practice directly.

What existing skills have your students started to develop?

● Contact me for further discussion: Richard Watson, School of Engineering, r.watson.2@warwick.ac.uk.