Engineering Thresholds: an approach to curriculum renewal

Sample Workshop Booklet

Facilitators

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Further information and web discussion forum

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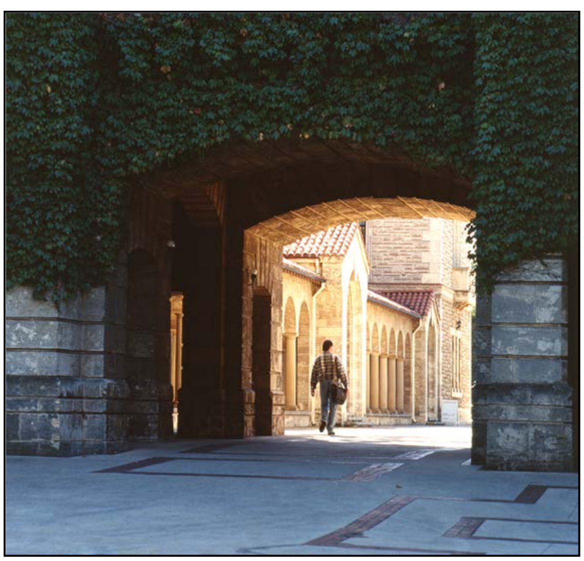
Date: Friday 13 April 2012

Place: University of Technology, Sydney

Time: 10.00am until 2.00pm

Refreshments: Provided

Cost: Free to participants



Support

This workshop is part of the project *Engineering thresholds: an approach to curriculum renewal* supported by the Office for Learning and Teaching.

The workshops are further supported by the Australian Council of Engineering Deans (ACED).

We are grateful to Dr Tim Aubrey and Ms Rosa Tay for supporting the workshop in Sydney.

This workshop will also be held in Brisbane and Darwin in 2012.

AGENDA

10.00am	Opening and Introduction
	Theory
	Identification and Negotiation of Engineering Threshold Concepts
12.00 noon	Lunch
	Improving Engineering Education Using Thresholds Concepts
	Conclusions
2.00pm	Close

INTRODUCTION

PURPOSE OF THE WORKSHOP

In the workshop we will share the approach we have developed and used to help design the engineering units in the first and second year of our new engineering science major. To improve students' learning we identify concepts that are transformative and troublesome, namely 'threshold concepts' (Meyer & Land, 2003). We hope participants will leave with capability to use the approach.

In the morning we will introduce, our methodology for identifying threshold concepts, and our inventories. Participants will think about threshold concepts in their units.

In the afternoon we will discuss ways to help students overcome threshold concepts: curriculum based and pedagogically based. We draw especially on variation theory (Bowden & Marton, 1998). Participants will discuss ways to use this in their units. We will also discuss assessment methods designed to assess transformation rather than ability to mimic transformation.

By identifying threshold concepts can ensure that programs are not over-crowded with too many concepts and insufficient opportunity to develop understanding of the concepts. We also design pedagogy to ensure that students have opportunities to learn identified threshold concepts, and assessments to encourage and check for transformation.

How is this different from usual? We can focus teaching, learning, and assessment on concepts most critical to students' progress and most likely to require extra effort to achieve understanding, rather than steadily working through a syllabus, with too little attention on thresholds and too much time on concepts that students can readily learn independently. Some identified threshold concepts are not normally listed in a syllabus because they are tacit for example, or because they are integrating concepts that are not apparent from within disciplinary silos. These transformative and troublesome concepts are usually left for students to learn incidentally or not at all. Modelling is an example.

THRESHOLD CONCEPT THEORY

Threshold concept theory is a recent development in discipline-based Higher Education research. Meyer, Land and others realised that there were certain concepts, central to the discipline, that would open up required systems and ways of thinking and yet were troublesome for students (Meyer & Land, 2003). It has been discovered that threshold concept theory be used help in focusing students' and teachers' attention, and can also be a curriculum development tool where there is a strong tendency to overcrowd the curriculum (Cousin, 2006, 2010).

Threshold concepts are:

- *transformative*, - opening up new ways of thinking, viewing the world and even changing one's identity by helping a student to identify with the discipline
- almost always *troublesome* - challenging for students e.g. because they are complex, foreign, counter-intuitive, abstract or using new language
- frequently *integrative*- bringing together concepts that otherwise seem unconnected

Students pass through a *liminal space*, the state during which a concept is troublesome to come to understand and accept a threshold concept. In this state students often *mimic* understanding.

THE PROJECT

This workshop is part of the project "Engineering thresholds: an approach to curriculum renewal" supported by the Australian Learning and Teaching Council. In this project an interdisciplinary team at the University of Western Australia (UWA) has identified threshold concepts in an integrated foundation university engineering program. We have designed the four engineering units in the first and second year of the new UWA engineering science major with a focus on the identified threshold concepts (Male & Baillie, forthcoming). A final outcome will be development of a guide to engineering educators on engineering curriculum development using threshold concepts.

IDENTIFICATION AND INVESTIGATION OF THRESHOLD CONCEPTS

Within our methodology we identified potential threshold concepts related to individual units or disciplines of engineering, and negotiated these among diverse participants (Male & Baillie, 2011a, 2011b).

DATA COLLECTION

We used interviews and focus groups with students, tutors, and academics at UWA to identify potential threshold concepts. Participants were asked to identify concepts that they had observed to be transformative and troublesome to students and to explain why they believed them to be transformative and troublesome. These were negotiated, and further concepts identified at workshops: a student workshop, student-staff workshop, and workshops with engineering teachers in Perth, Adelaide, Melbourne, Auckland, Oxford, Birmingham, and Lund in Sweden. Data were collected through notes, transcripts, and completed handouts.

ANALYSIS

Data were analysed for evidence of concepts that are transformative and troublesome and how they are transformative and troublesome. During the analysis we iteratively developed an inventory of threshold concepts. This is presented as a generic engineering threshold concept inventory and an inventory of threshold concepts most relevant to each of our four foundation engineering units: Energy, Global Challenges in Engineering, Materials, and Motion. Concept maps were also developed to provide overviews of threshold concepts identified and their nested structure.

EXERCISE 1. IDENTIFICATION AND INVESTIGATION OF THRESHOLD CONCEPTS

1. Select a concept map appropriate to your group's interests. Each using a different colour, mark the threshold concepts that you consider to be potential threshold concepts in your experience as a teacher and/or student.
2. On the concept map, add any other potential threshold concepts in your teaching.
3. Identify one concept at a time that is of interest to members of the group and discuss the following

    Why do you think this is a threshold? How is it transformative and troublesome? (*Please describe evidence such as student feedback, assessment issues etc.*)

Improving Engineering Education

By identifying engineering threshold concepts and how they are transformative, we can

- design lesson and course plans to focus teaching and learning on threshold concepts
- draw teachers' and students' attention to threshold concepts
- enhance transformative teaching and learning
- assess the transformative aspects of learning, rather than students' ability to emulate understanding

Focusing teaching and learning on transformation through threshold concepts

The structure of a course and of units within a course can be designed to ensure that students have sufficient opportunity to pass through the liminal space for each threshold concept. Threshold concepts should be well separated, with no more than one per week in any unit. Especially tricky threshold concepts should be revisited and further developed throughout a course. Concepts that are not troublesome can be learnt by students outside lesson time. Threshold concepts not usually taught can be included in the curriculum.

Drawing teachers' and students' attention to threshold concepts

Threshold concepts can be identified as such so that teachers and students know to give them extra attention. Appendix A is a summary of the main threshold concepts in the Motion unit. This is in the readers for students in the unit and also used in the training sessions for teachers in the unit.

Enhancing transformative teaching and learning

In variation theory, Bowden and Marton (1998) describe how students learn by experiencing variation in a concept. We provide students with opportunities to experience variation in threshold concepts by replacing lectures with interactive tutorials, both theoretical and practical. Through interaction such as debating, explaining and sketching, students experience variation in features of the concept, manifestation of the concept in a variety of contexts, and possible approaches to understanding or applying the concept among students. Student must *experience* the variation. This can be encouraged through an activity in which they compare and contrast examples with variation. Physically experiencing the variation, through a practical experience is also helpful although not essential.

Our interactive classes are held in a level room with only approximately 25 students per class. Our new foundation engineering units have no lectures – not even mini-lectures during tutorials.

Exercise 2.

Appendix B includes a sample Lesson Plan for facilitators of the Motion unit.

Select a threshold concept and design an interactive lesson plan to help experience variation that will help them develop understanding of the concept. Compare and contrast with others in your group.

Assessing the transformative aspects of learning

Too often students pass units and courses without understanding critical concepts. While in the liminal space, students frequently mimic understanding by following solutions to solve problems. In Capability Theory, Bowden and Marton (1998) propose that students should develop knowledge capability in order to draw on past experiences in unknown futures. A student in the liminal space, with capability only to mimic understanding, does not have sufficiently sophisticated understanding to address unknown problems. Assessments must be designed to encourage and collect evidence of transformation in students. Assessments in which students can pass by plugging numbers into equations using learnt steps are not sufficient. Alternatives and enhancements can ask for an explanation or justification of a method, for example.

Exercise 3

Select a threshold concept and design an assessment to collect evidence of transformation through the threshold concept. Explain and justify to other members of your group.

Resources

Engineering Thresholds Web Discussion Forum
The University of Western Australia
http://engforum.ecm.uwa.edu.au/

Engineering Thresholds Project Website
The University of Western Australia
http://www.ecm.uwa.edu.au/engineeringthresholds

Threshold Concept Bibliography maintained by Dr Michael Flanagan
University College London
http://www.ee.ucl.ac.uk/~mflanaga/thresholds.html

NAIRTL 6th Annual Conference 4th Biennial Threshold Concepts Conference
From personal Practice to Communities of Practice
Trinity College Dublin, Ireland, 27-29 June 2012
www.nairtl.ie

References

Bowden, J. A., & Marton, F. (1998). *The University of Learning: beyond quality and competence*. London: Kogan Page.

Cousin, G. (2006). An introduction to threshold concepts. *Planet, 17*, 4-5.

Cousin, G. (2010). Neither teacher-centred nor student-centred: threshold concepts and research partnerships. *Journal of Learning Development in Higher Education, 1*(2).

Male, S. A., & Baillie, C. A. (2011a). *Engineering Threshold Concepts*. Paper presented at the SEFI Annual Conference. Retrieved 10 February 2012, from http://www.sefi.be/?page_id=24

Male, S. A., & Baillie, C. A. (2011b). *Threshold Concept Methodology*. Paper presented at the Research in Engineering Education Symposium.

Male, S. A., & Baillie, C. A. (forthcoming). Research guided teaching practices: Engineering thresholds; an approach to curriculum renewal. In A. Johri & B. Olds (Eds.), *Cambridge Handbook of Engineering Education Research*: Cambridge University Press.

Meyer, J. H. F., & Land, R. (2003). Enhancing Teaching-Learning Environments in Undergraduate Courses Occasional Report 4. Retrieved 31 May 2010, from http://www.etl.tla.ed.ac.uk/docs/ETLreport4.pdf

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Prepared by Sally Male and Caroline Baillie

The University of Western Australia, 3 April 2012

Appendix A. Sample excerpt from reader, drawing students' and teachers' attention to main threshold concepts in the unit

kindly provided by Dianne Hesterman and Andrew Guzzomi

EXCERPT FROM MOTION READER

Threshold Concepts (www.ecm.uwa.edu.au/engineeringthresholds)

Threshold concepts are concepts that are recognised as being *troublesome*; you will find them, as we did, challenging and difficult to understand. You will need to be persistent in your pursuit of this understanding. However, you will gain great satisfaction when 'it clicks' and you arrive on 'the-other-side' of the hurdle. Threshold concepts are *transformative*. Understanding a threshold concept involves a conceptual shift in your way of thinking about the world and how it works. They are also *integrative*. You will see how different areas of knowledge and experience fit together. In engineering, a threshold concept can be so powerful that complete classes of problems cannot be attempted without first passing through the threshold.

Concepts that may be *threshold* in this unit include*:

- System identification and definition – converting a physical system into a mathematical model. This includes the idea of free body diagrams and control volumes. System identification and definition fall under the more general threshold concepts of abstraction and modelling.
- The conservation laws – nothing is lost. Which properties are conserved and why? We can use this understanding to solve a wide variety of engineering problems.
- Temporal and spatial frames of reference – choosing an appropriate time scale and form of equation to capture the necessary information about a system's behaviour. Temporal and spatial frames of reference also form part of the modelling tool kit.
- Vectors and vector calculus – using a multidimensional mathematical construct to represent a number of system properties in a single variable. For example, velocity $\underline{v}$ is a vector that combines magnitude and direction.
- Thevenin's equivalent for electrical systems – using a simplified model to represent a complex electrical circuit. We can extend this idea beyond electrical circuits.
- Dimensional reasoning – using the idea that equations are dimensionally homogeneous to derive relationships in complex systems. This technique can yield great insight into the system when the underlying equations are too complex to solve.

The above threshold concepts will be acquired within a *threshold framework* that includes:

- Self-driven learning – understanding the value of learning and realising that there are different ways to learn and from different sources (textbooks, online resources etc.)
- Teamwork – teams can achieve more than the sum of the individuals working alone (by leveraging the diverse knowledge and capabilities of members, inspiring each other, developing together and sharing tasks).
- Communication and leadership – two-way, effective communication in many forms is critical to engineering practice. Engineers spend much time working with others and coordinating the work of people over whom they might have no direct authority

* You may identify others. Please let us know!

APPENDIX B. SAMPLE LESSON PLAN, PROVIDING INTERACTIVE EXPERIENCES OF VARIATION

kindly provided by Dianne Hesterman and Andrew Guzzomi

ENSC2001 Motion: Information Session 4

Notes for facilitators

Session Title: Conservation of Charge & Electrical Energy (2)

Paperwork

25 copies of problem sheet and quiz.

Desired learning outcomes

By the end of this topic students should be able to:

1. Analyse more complex circuits;
2. Explain what we mean when we define a voltage or current source as ideal;
3. Explain the difference between a short circuit and open circuit;
4. Apply a range of different analysis techniques to circuits (NTD, Mesh, superposition);
5. Model an electrical circuit as a Thevenin or Norton equivalent circuit.

Compulsory preparation for students

Students should have read through the material provided (Required Reading) and tested their understanding by completing Parts A and B in the course reader. They have been asked to bring this material to class.

Lesson Format

Ask students to introduce themselves to any new members sitting at their table. Return quiz and briefly discuss answers and common misconceptions.

1. <u>Ice Breaker (5 minutes)</u>

Check whether everyone remembers the names of the class members who were introduced in Information Session 3. Choose another table and get each member of the table to introduce him or herself to the class and mention one thing he or she likes. Ask other members of the class to identify each person at this table by their name and like.

2. <u>Review of reading (30 minutes)</u>

Refer students to the questions in Part A of the preparation for this session. Students should have attempted these questions before class.

- Ask students to discuss their answers for A1 to A4 with other students at their table and identify any concepts that are still troubling.
- Facilitate discussion of answers across class, drawing attention to differences and focusing on concepts that are still troubling.

  A1: State under what conditions a circuit element is a consumer of power, and under what conditions it is a supplier of power.

  Prompt question: How do we determine the higher potential side of a resistor?

  A2: When an engine is being cranked, the voltage across a 12V car battery will often be as small as 8V. Why? Conversely, once the car is running, the terminal voltage of the battery may measure 14V. Why?

  A3: Three resistors, with values of 100Ω, 300Ω and 500Ω respectively, are connected in series. Which one gets the largest current? Which one gets the largest voltage?

  Prompt question: what if the resistors were connected in parallel?

  A4: In some apartments, why do the lights dim momentarily when the refrigerator motor comes on? Hint: Thevenin equivalent circuit and voltage divider circuit

  Prompt questions: How does a fuse work? How does a modern circuit breaker work?

3. <u>Equivalent Resistance (20 minutes)</u>

- Ask students to work through Problem 1 in groups of two or three or as a table (~10 minutes).
- Ask tables to discuss solution and then a member of each table to write their group solution on their whiteboard (~5 minutes).
- Discuss similarities and differences in presented solutions (~5 minutes).

Break (10 minutes)

4. <u>Thevenin's Equivalent (30-35 minutes)</u>

- Ask students to work through Problem 2 in groups of two or three or as a table (~15 minutes).
- Give students a few minutes to compare answers with others on their table.
- Ask a member from each table to come up to the whiteboard and explain their table's solution to one part of the problem (~15 minutes).

Prompt question: Can anyone convert the answer to the Norton equivalent circuit?

5. <u>Quiz (5 minutes)</u>

Closed book – ask students to pack up notes, etc.

- Hand out quiz face down, give students 3 minutes to complete and then collect.

End of session

EXERCISE 2.

Appendix B includes a sample Lesson Plan for facilitators of the Motion unit.

Select a threshold concept and design an interactive lesson plan to help experience variation that will help them develop understanding of the concept. Compare and contrast with others in your group.

EXERCISE 3

Select a threshold concept and design an assessment to collect evidence of transformation through the threshold concept. Explain and justify to other members of your group.