

## STUDENTS' PERCEPTIONS OF TRAVEL THROUGH THE LIMINAL SPACE: LESSONS FOR TEACHING

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### Biographical Note

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### KEYWORDS

Threshold concepts, liminal space, analogue electronics, teaching strategies.

### ABSTRACT

This paper presents findings from a study in which educational researchers followed the progress of analogue electronics students over their first two years at university.

In this study, the lecturer's main motivation was to examine how a teaching-focus on threshold concepts might help students grasp troublesome ideas and if those students who grasped the threshold concepts achieved higher scores in the end-of-course examination. The lecturer identified two concepts in the first-year course which students repeatedly found hard to grasp. He focused his teaching on these concepts in the first year, and revisited them, albeit indirectly, throughout the second-year course.

Over the two years, the lecturer utilised a variety of teaching strategies to facilitate students' learning of the troublesome concepts. In order to evaluate the effects of these strategies on student learning, an educational researcher, in collaboration with the lecturer, explored students' perceptions about where they 'got stuck' and what helped them understand the selected threshold concepts. Data from student surveys, individual interviews, and focus groups contributed to insights about their experience of transition through the liminal space. The lecturer and researcher reflected on and analysed the lecturer's teaching strategies using video-stimulated reflective dialogue.

Findings revealed that many students did not fully grasp the two identified threshold concepts in their first year, however, repeated experiences with threshold concepts through varied teaching strategies, and a diversity of learning contexts contributed to students' understanding. In the second year, the continuing students felt that they took the threshold concepts for granted and had ceased to regard them as troublesome. They reported that grasping these threshold concepts was necessary to progress in analogue electronics. Findings of this study indicate that travel through the liminal space can be supported by an explicit and sustained focus on threshold concepts.

### INTRODUCTION

*"I don't know why this is so hard for me! I'm trying so hard to grasp this!" (First-year student)*

In first-year tertiary analogue electronics courses there are threshold concepts (TCs) that students repeatedly find hard to grasp. Over two years we examined if and how a focus on threshold concepts teaching might help students grasp these TCs. The lecturer identified and focused his teaching on two TCs in the first year, and revisited them throughout the second year. He utilised a variety of teaching and assessment strategies to facilitate students' learning. Data from student surveys, interviews, and focus groups revealed that students did not fully grasp the two TCs in their first year. However, repeated experiences with these concepts through varied teaching strategies and a diversity of learning contexts contributed to students' understandings in the second year. Findings indicate that travel through the liminal space can be supported by an explicit and sustained focus on threshold concepts.



## THE STUDY

In 2010, our preliminary study examined first-year electronics students' understanding of two lecturer-identified TCs: Thévenin's theorem<sup>2</sup> and dynamic resistance<sup>3</sup>. Findings revealed that a TC lens was useful for the lecturer to revise the pedagogy (Scott *et al.*, 2010). The study uncovered places where students 'got stuck' as they encountered the two TCs (Harlow *et al.*, 2011). In 2011 student surveys and interview data were correlated with grades in first and second-year courses. This paper focuses on second-year students' perceptions of learning, outlines teaching and assessment strategies, and offers recommendations for teachers.

## TEACHING AND ASSESSMENT STRATEGIES

From our 2010 study, the lecturer knew that students had difficulty understanding the troublesome concept of dynamic resistance. He was aware that analogies could provide learners with new ways of thinking about a phenomenon (Roth, 2006; Bishop, 2006), so to help second-year students understand this threshold concept the lecturer used a *chocolate bar cost* analogy. This threshold concept in the field of economics was employed as a window through which students could view the troublesome concept of dynamic resistance.

*"I wrote on the whiteboard, 'If I pay \$10 for 10 chocolate bars, how much does each bar cost?' I tell them the price depends upon which bar and how you calculate it. I explain that 'marginal' and 'overall' costs are different. This is the same idea as static or dc resistance and dynamic or ac resistance, that we might have called 'marginal resistance'. They seem to get this. Sometime soon after that lots of them get the idea of the two definitions of resistance, and we are on the road through the portal".*

The lecturer also trialled two new assessment approaches – scratch cards and repeated Year 1 questions.

- *Scratch cards:* The use of an *Immediate Feedback Assessment Test* (IFAT<sup>4</sup>) was combined with student collaboration. Namely, several students in collaboration choose answers to ten problems by scratching out a square on a scratch card for each problem. If students do not answer correctly the first time around they have the opportunity to collaborate to choose another answer. The correct answer is worth four points and so on down to zero points for the fifth attempt. Students are encouraged to argue their case when an incorrect answer is selected by the group.
- *Repeated questions:* The TC question on dynamic resistance from the first-year final exam was given to all second-year students (six months after the exam). Students did not do well on this occasion. The lecturer attended to the gaps in their knowledge in a follow-up lecture. At the end of the semester the same question was given to the students again. Table 1 shows results for the fourteen students participating in the research over two years.

Table 1: Threshold Concept question on Dynamic Resistance (DR)

	1 <sup>st</sup> year exam DR question (Dec '10)	2 <sup>nd</sup> year start of semester DR question (Aug '11)	2 <sup>nd</sup> year end of semester DR question (Oct '11)	2 <sup>nd</sup> year exam question requiring an understanding of DR (Dec '11)
Average grade (14 students)	71%	50%	96%	48%

Results indicated that a year after first learning the TC many students were not able to answer the same question. After revisiting the TC within a shorter timeframe, students were more confident in recognising the problem. Applying that same knowledge in a different context, in the final 2011 exam question proved troublesome and the correct response rate was comparable to that from the start of the semester.

<sup>2</sup> Thévenin's theorem is an example of modelling. It is the idea that any circuit can be modelled with a voltage source and a resistor in series.

<sup>3</sup> Dynamic resistance is the ability to substitute a bias-dependent linear component for a non-linear one, subject to the application of only small-signal AC signals.

<sup>4</sup> An Immediate Feedback Assessment Test (IFAT or scratch card) is a card with squares that are scratched away to reveal a star if the chosen multi-choice answer is correct.

The eighteen second-year students' total grades (internal and final exam marks) were categorised into three groups: A (over 69%); B (between 49-69%); and C (under 49%). Figure 1 shows a comparison between 2010 and 2011 average exam marks for the three groups.

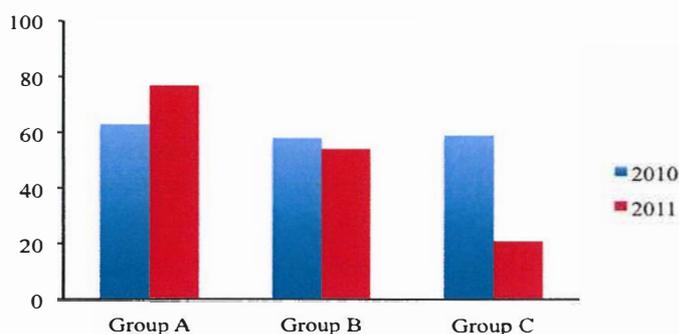


Figure 1: Average exam marks (%) of three categories of 2<sup>nd</sup> year students over two years (N = 18)

On average, the seven group A students improved their exam marks by 14% points over two years. The six group B students' marks declined by 8% points, and five group C students performed significantly less well ( $p < 0.05$ ) in their second year exam than in their first year exam.

Before the second-year final exam, a sample of fourteen students was interviewed about their understanding of the two TCs and what helped their understanding of difficult concepts in electronics. The lecturer graded students' explanations of TCs and these data were compared to their total grade in 2011 (see Table 2). Quotes from these students are denoted by group and number.

Table 2: Second-year students' understandings and grades, 2011

	Explanation of TC (NVivo analysis of interview data)	TC understanding (lecturer's grades for interview TC statements)	What helped TC understanding (2011 student interview data)	2011 Average total grade (%)
Group A	Comprehensive and coherent understanding (2010 and 2011)	A (N = 6)	Worked examples	86
Group B	Confused understanding (2010); developing understanding but unsure (2011)	B (N = 5)	Labs, practical work	53
Group C	Muddled, incomplete understanding (2010 & 2011)	C (N = 3)	Staff support, step-by-step instructions	31

Table 2 shows that both researchers' evaluation of the students' explanation of and the lecturer's grade for TC understandings were a good predictor of students' second-year total grades. An interesting finding was that students in the three categories preferred different ways of learning.

#### WHAT HELPED STUDENTS TO MOVE THROUGH THE LIMINAL SPACE?

Survey responses from the fourteen students showed both differences and similarities between student groups regarding "what helps you learn difficult ideas in electronics?"

In particular, group A emphasised using examples to help them learn:

*"The way I learn is to do as many examples as I can to understand the different forms things can come in and even if the form is unfamiliar to me, I can relate it back to something I have already done". (A5)*

Group B found practical work most valuable to their learning:

*"Being in the lab and doing Thévenin equivalents to simplify your measurements. I normally read through the lab sheet to get the gist of what we're doing – measuring or calculating. Then I start with measuring. I understand from how it is written what to do". (B2)*

Group C found they needed staff support, and step-by-step instructions. One group C student gained a high grade for lab work (75%) in the second year, but failed the exam (19%); in the first year he had passed the exam with 52%:

*"In labs I read through the question, and set up the circuit from the diagram. But I am not sure what to do then. Where to start is hard. They just go "measure this" – they don't say how (it would be good if that was more explicit). I would be in big trouble if there weren't any demonstrators!" (C3)*

### **DISCUSSION: LESSONS FOR TEACHERS**

If travel through the liminal space does indeed mean that students oscillate between old and new understandings (Meyer and Land, 2006), resort to mimicry on occasion (Cousin 2006), and have anxieties about their learning (Eckerdale *et al.*, 2007), teachers need to look for new ways to encourage learners to remain engaged and to move forward. This can be done in several ways as suggested by Land *et al.* (2006). The following recommendations come from our current findings.

### **LISTENING TO STUDENTS**

In order to build on basic understandings find out about students' prior knowledge. A simple pre-test allows the lecturer to identify gaps in students' knowledge and provides opportunity to give immediate feedback to students.

Teachers need to find out how students like to learn. They need to provide varying learning opportunities, including time for students to articulate their understandings and test their own knowledge. Our data show that students appreciate small-group discussions.

We demonstrate that students' TC understandings were a good predictor of their total year grades – those who could articulate their knowledge well achieved the highest grades. These students were not reliant on the materials they had manipulated while working on problems and could give coherent explanations using acquired knowledge. Group B students still needed to manipulate materials to anchor their understanding of TC. Like the students described by Roth (2006), the group C students in our study had a few vague ideas about the TC and required specific instruction from their tutors. The C group's low achievement in Year 2 may be a consequence of poorly structured precursor knowledge and a successful guessing strategy up to Year 2 when the course content prohibited 'educated' guessing.

Teachers may trial different teaching strategies, but unless they realise how their students learn new ideas and transfer knowledge from one situation to another, these may be of no avail. While presenting to students the *chocolate bar* analogy, the lecturer observed that learners must attend to and coordinate different kinds of information in order to perceive the difference between static and dynamic resistance. Teachers need to design formative assessment tasks as *TC learning tasks* – students appreciate immediate feedback. Use short test-questions, and have students discuss questions and answers. A first-year student comments:

*"When you go to a tutorial you discuss problems a lot more easily amongst peers. You have the same kind of level as the other people when you tackle a question – that is SO useful. It means they can understand why you are confused". (First-year student)*

The lecturer was most impressed with the way there was a sense of intense involvement during the second-year scratch-card quizzes. He could move around the class listening to students trying to convince each other that their arguments were valid and could be used to solve the problems in front of them. Additionally, students appreciated an opportunity to practise for the exam.

### **TOLERATING LEARNER CONFUSION**

As students progress in their studies the materials and content become more complex. Consequently, students have to have a firm understanding of less complex concepts in order to assimilate the more complex ones.

One student said he was more confident in his first year as he had a basic physics background, but that in the second year the theories had become more complex (B4 – final grade 56%). Another student (A6 – final grade 97%) agreed that the second year work was harder, and said he was not so confused in the first year as the questions were simple and although he did not really understand the concepts he could “do the question without knowing it”.

Further evidence of confusion came to light in the lab books – some students seemed to have great difficulty in writing complete sentences to explain what they understood (Harlow *et al.*, 2011), had misinterpreted a circuit diagram, did not have a complete understanding of circuit theory, or could not interpret a graph. This revelation has led the lecturer to place an initial focus on ‘holistic current flow’, 2D-3D representation, and graph interpretation as pre-cursor TCs. These ideas have now been included in a concept inventory of analogue electronic TCs (Scott *et al.*, 2012). It is imperative then that teachers devise activities that reveal uncertainties as many students may suffer in silence, continue to be mystified, and resort to mimicry.

To further reduce the likelihood of confusion it is important to plan a coherent course that provides adequate feedback to students about how well they are doing. To keep students moving forward there needs to be continuity in teaching and assessment of TCs. This includes sequencing theoretical and practical work and planning courses end-on-end.

Results demonstrate that the second-year students had moved from a state of conceptual, procedural, and/or technical confusion observed in first-year laboratory sessions (Harlow *et al.*, 2011). However, if there was a significant gap between first encountering the TC and coming across it in a new situation, or some disruption (e.g. change of lecturers) students reverted to a state of confusion as this student commented:

*“This is the worst paper in my whole year. I don’t really understand the lectures. It’s going too fast and not creating the basic knowledge. This year with different lecturers they are jumping from one thing to another – it’s difficult to see the links”. (B5)*

### REVISITING THRESHOLD CONCEPTS

*“If the threshold nature of a certain concept is to be used to refine or revolutionise curricula, we need to identify the concepts”. (Lecturer)*

Thus it is crucial that teachers are able to pinpoint areas where students have trouble getting to grips with the subject. When asked why Thévenin was a TC, the lecturer said it was the first example of circuit-modeling that caused learners an inordinate amount of trouble in electronics and circuit theory although modeling is one of the most uniformly accepted unifying concept/themes in engineering and technology. The lecturer made the TCs explicit from the first time he introduced them to the class, and reiterated their importance each time they surfaced in discussion, lectures, labs and tutorials. A second-year student reported:

*“After the time this year where we did the exam question [dynamic resistance] I got it – before that, no. He recapped and explained it to us after we handed our answers in. If we hadn’t had that chance to recap we would still be lost”. (B4)*

It is important that teachers help students develop a bank of experiences of the TCs in different contexts and support them in extracting similarities and differences across these contexts. High-achieving students emphasised the need to do ‘lots of examples’ before they ‘got’ the TCs. This ‘pattern sniffing’ in order to understand what is the same and what is different about problems, enables transfer of learning and is essential for ‘crossing the threshold’. A second-year student commented:

*“In terms of learning, more assignments and tutorials may have helped especially if we get to go through them after we have had our attempt at them, then different fully worked examples of how to do it”. (A5)*

It is important to notice that students recognised that they were oscillating between old and new understandings and began to gain a clearer idea of the importance of TCs as they met them in different situations:

*“In our first year we only did dynamic resistance for diodes. It’s become much easier this year to figure it out. We do a lot of simulations to do with it. Now we’ve seen it with transistors as well as diodes. This year we’ve done applications and it has been more important to look at dynamic resistance”. (A1)*

### CONCLUSION

Our data demonstrate that the lecturer had refined the curriculum to focus on a limited number of TCs in the first year.



The pedagogy had moved more towards promoting learning through understanding. The lecturer placed more emphasis on formative assessment with immediate feedback. The students became more aware of the TCs and had more opportunities to share their understandings with their peers as they encountered TCs in different contexts.

The comments from the second-year students who grasped the TCs showed evidence of understanding that travelling through the liminal space is about making connections between the different aspects of learning. They highlighted the need for examples to be progressively more complex and varied for the learner to utilise new knowledge in different contexts. Student interviews demonstrated that the liminal space was often one with a long and rocky trajectory, from thinking in concrete forms through to the evolution of forms of talk about abstract entities.

In this study two TCs have provided the focus for changes in teaching and assessment (Scott and Harlow, 2012). We plan to continue to track students through their liminal space to uncover what it is in the process that allows the learner to show continuous success in demonstrating transfer of learning. The trajectory of grasping of difficult ideas could provide a framework for teaching students to learn to think like an expert.

The collaborative research between lecturer and researchers has generated 'lessons for teachers' that will inform a new research study looking at TCs in and across several disciplines. A knowledge of TC theory and collaborative, interactive teaching and assessment strategies can be used effectively to engage students with troublesome concepts. The liminal space can be an uncomfortable place for many students as they overcome their uncertainties. One student's comment illustrates this point vividly:

*"I kind of got it last year but then this year, although it was tough at the start, I actually fully understood what was happening. It's a very difficult subject, but once you get it it's like easy. I don't know why I didn't quite get it before". (C1)*

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