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Final Report

A threshold concepts focus to curriculum design: supporting student learning through application of variation theory

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List of Abbreviations

ANU	The Australian National University
ALTC	The Australian Learning and Teaching Council Limited
DBI	Disciplinary-Based Initiatives
(H)IRAC	(Heading),Issue, Rule, Application, Conclusion
ISAAC	Issues, Statement, Authority, Application, Conclusion
QUT	Queensland University of Technology
Sydney	The University of Sydney
UTS	University of Technology, Sydney

Acknowledgements

This was an ambitious and complex project, in terms of its theoretical scope and the number of participants involved. In addition, the work commitment required to achieve an outcome within the two-year timeframe was considerable.

Although the project participants have been acknowledged in the report, we would like to express our thanks more personally here for their enthusiasm and commitment over the two year time period, despite numerous changes in their institutional and personal circumstances.

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Executive Summary

This project develops and evaluates a model of curriculum design that aims to assist student learning of foundational disciplinary 'Threshold Concepts'. The project uses phenomenographic action research, cross-institutional peer collaboration and the Variation Theory of Learning to develop and trial the model. Two contrasting disciplines (Physics and Law) and four institutions (two research-intensive and two universities of technology) were involved in the project, to ensure broad applicability of the model across different disciplines and contexts. The Threshold Concepts that were selected for curriculum design attention were *measurement uncertainty* in Physics and *legal reasoning* in Law.

Threshold Concepts are key disciplinary concepts that are inherently troublesome, transformative and integrative in nature. Once understood, such concepts transform students' views of the discipline because they enable students to coherently integrate what were previously seen as unrelated aspects of the subject, providing new ways of thinking about it (Meyer & Land 2003, 2005, 2006; Land et al. 2008). However, the integrative and transformative nature of such threshold concepts make them inherently difficult for students to learn, with resulting misunderstandings of concepts being prevalent.

According to Variation Theory, misunderstandings (or less sophisticated understandings) of a disciplinary concept may be explained in terms of students' lack of awareness of key features or aspects of the concept. Learning is thus seen as occurring through a shift in awareness, where a student becomes aware of aspects of a concept that they had not previously noticed. It is argued that awareness of a conceptual feature is best facilitated by drawing students' attention to variation in that feature. Therefore, student learning of a concept is best facilitated by introducing variation in each of the critical features of the concept into teaching and learning activities. This draws students' attention to different aspects of the concept, by varying some aspects whilst keeping others invariant.

Following creation of the two cross-institutional disciplinary peer groups in Physics and Law, the project involved four primary stages:

1. supporting each disciplinary group in the identification of an appropriate Threshold Concept for the project
2. supporting each group in the conduct of phenomenographic action research into variation in students' understandings of that concept
3. group curriculum design of a set of learning activities to address the misunderstandings identified in step two, using Variation Theory as a guiding framework
4. implementation of the new curriculum design and assessment of student learning outcomes.

In this model, the phenomenographic action research served to identify the critical features that needed to be highlighted for students when learning the Threshold Concept, and Variation Theory provided guidance as to the most effective ways of highlighting these features during curriculum design.

Participant reports of the teaching and learning impact of the project were profound, with substantial changes to lecturers' understanding of student difficulties in learning the concepts, and to their sense of how best to teach the concepts. Direct assessment of student learning outcomes was more difficult to measure, given the complex real-world contexts in which the curriculum designs were implemented.

1. Introduction

1.1 Project rationale and relevant literature

"…oh it's changed the way I think about how I'm going to teach this subject and how I think of it myself, which in itself is surprising because I've taught this thing for many years" (project participant)

This project develops and evaluates a model of curriculum design that aims to assist student learning of particularly difficult but foundational disciplinary concepts, *Threshold Concepts* as defined by Meyer and Land (2003, 2005, 2006; Land et al. 2008). The claim is that, within each discipline, there are a limited number of concepts that are 'threshold' in nature, so-called because they act as 'conceptual gateways' to disciplinary ways of thinking about a subject area. Threshold Concepts are conceived as inherently transformative and integrative in nature. Once understood, such concepts transform students' views of the subject area; because they enable students to coherently integrate what were previously seen as unrelated aspects of the subject, providing a new way of thinking about it.

Threshold Concepts are thus vital for students' learning in a discipline because they provide "a transformed internal view of subject matter, subject landscape, or even world view" (Meyer & Land 2005 p. 373), leading not only to new ways of understanding a subject area, but a shift in the learner's sense of professional or disciplinary identity. It is only through coming to understand the Threshold Concepts in a discipline that students can come to think like a subject specialist and adopt a disciplinary way of thinking about the world. "When an individual acquires a Threshold Concept the ideas and procedures of the subject makes sense to them when before they seemed alien" (Davies 2006 p. 74). In this sense, in coming to understand Threshold Concepts, students also come to see the subject, the world and themselves differently.

However, the transformative and integrative nature of these concepts makes them commonly troublesome for students to learn (Perkins 2006), and so they are often not fully understood by students. Meanwhile, due to the threshold nature of these concepts, such misunderstandings have long-lasting implications for students' learning in the subject area, and their ability to apply that learning in professional practice. This makes Threshold Concepts a particularly valuable area on which to focus extra curriculum design attention.

Threshold Concepts have been referred to as the 'jewels in the curriculum' because they can be used to identify transformative points in students' learning. They help explain why many students 'get stuck' at common points in the curriculum and why some students can pass a course exam, but not necessarily be able to apply their learning when in a professional setting. A focus on Threshold Concepts in curriculum design helps play a diagnostic role, highlighting for teachers areas of the curriculum that deserve special attention, not only because they represent transformative learning points for students, but because they are areas where students are most likely to experience difficulties in their learning. In addition, the integrative nature of Threshold Concepts means that a good understanding of these foundational concepts facilitates understanding of a host of related concepts, leading to an impact on student learning far beyond the individual concept in isolation.

While the potential power of a curriculum focus on Threshold Concepts is becoming increasingly recognised, ways of identifying and teaching Threshold Concepts are not yet clear. This project addresses that gap by developing a model for identifying and teaching Threshold Concepts based on the *Variation Theory of Learning,* developed by Marton and colleagues (Marton & Booth 1997; Bowden & Marton

1998; Marton & Tsui 2004) as an outcome of the phenomenographic research approach (Marton 1986, 1994; Marton & Booth 1997).

In bringing Variation Theory into the project, we build on work done in Hong Kong in particular, where the potential value of using Variation Theory to help address common misunderstandings amongst students of difficult disciplinary concepts has been well tested through a series of government-funded educational initiatives (Lo et al. 2004). Although these initiatives are focused on pre-tertiary education, there are obvious implications for higher education. The initiatives build on the Japanese concept of a 'lesson study', in which teachers with overlapping curriculum content meet to jointly plan a lesson addressing that content, teach the lesson separately, then meet again to compare learning outcomes and revise future lessons on the same content area. The potential benefits of the lesson study approach include not only improved student learning, but also ongoing professional development for the teachers, through peer review and practitioner-based action research, leading to evidence-based improvements in teaching and learning.

The Hong Kong initiative takes all the benefits of the Japanese lesson study approach, but builds on it through introduction of a theoretical basis for joint lesson planning, based on Variation Theory. In what is described as 'learning studies' or 'research lessons', the teachers are introduced to Variation Theory, then jointly plan a lesson based on that theory. Empirical research into the benefits of this approach, comparing the learning outcomes for students in theory-based 'research lesson' classes with those in a theoretical 'lesson study' class show dramatic results from the introduction of Variation Theory into curriculum design — 70 per cent versus 30 per cent success in post-tests of students' understanding of economic concepts, for example (Pang & Marton 2003, 2005). The impact on development of the teachers involved is also substantial (Pang 2006).

According to Variation Theory, misunderstandings (or less sophisticated understandings) of a disciplinary concept or practice may be explained in terms of students' lack of awareness of key features or aspects of the concept/practice. Learning is thus seen as occurring through a shift in awareness, where a student becomes aware of aspects of a concept/practice that they had not previously noticed. For instance, with the concept of 'price' in economics, a sophisticated understanding involves awareness of the ways in which the features of 'supply' and 'demand' can vary in relationship to each other. Common misunderstandings include awareness of the impact of variation in supply, but not demand; of variation in demand, but not supply; and of variation in demand and supply operating independently, but not in relationship to each other.

Curriculum design based on Variation Theory enables students to progressively expand their awareness of different aspects of a concept and of the relations between these aspects. This expanding awareness of different aspects of a Threshold Concept may also be understood in terms of Land's (2008) progressive stages of a students' conceptual journey towards full understanding of the concept. Such curriculum design is usefully informed by a preceding exploration of variation in students' understandings (or awareness) of the Threshold Concepts to be learned. This is the traditional focus of phenomenographic research (Marton 1986, 1994; Marton & Booth 1997), which will be used to guide the approach to action research used in this project.

Although the particular concepts that would be regarded as threshold must necessarily differ between disciplines, the existence of such Threshold Concepts and the model we are trialing for addressing them through curriculum design is believed to apply to all disciplines. Thus, this project aims to provide a curriculum design process and curriculum examples and resources of broad disciplinary value. To assist with the breadth of applicability of the project outcomes, the project

focused on two very different disciplines, Physics and Law, across different university types (research-intensive and universities of technology) and locations (ACT, NSW and QLD).

In brief, this project aims to test the potential value to curriculum design of a focus on disciplinary *Threshold Concepts*, using the *Variation Theory of Learning* as a framework to guide the design of curricula to address the Threshold Concepts, and *phenomenographic action research* into students' (mis)understandings of the Threshold Concepts to provide empirically-derived insights into the features of the concepts that create greatest difficulty for students. In this sense, the curriculum design is inherently theory-informed, research–led and evidence-based. The project is also marked by cross-institutional peer collaboration between disciplinary teachers, plus collaboration between educational researchers/developers and disciplinary teachers, with associated impacts on the professional development of the teachers involved.

The relatively resource-intensive nature of this approach to curriculum design is mitigated by the focus on Threshold Concepts, representing a limited number of disciplinary concepts worthy of this degree of attention. Furthermore, given the transformative and integrative nature of Threshold Concepts, improved student learning of these concepts is expected to have a widespread impact on student learning across the discipline, beyond the specific concepts focused on in this curriculum design process.

The project had three principal aims, to develop and trial a model of curriculum designs that:

1. focuses extra teaching and learning attention on the most significant parts of the curriculum (using Threshold Concepts)
2. enhances teaching and learning of particularly difficult concepts (using phenomenographic action research and Variation Theory)
3. is readily transportable across different disciplinary and institutional contexts.

1.2 Project team

1.2.1 Project leaders

Professor Gerlese Åkerlind, Director, Teaching and Learning Centre, University of Canberra (formerly Director, Centre for Educational Development and Academic Methods, The Australian National University - ANU), *Project Leader*

Associate Professor Jo McKenzie, Director, Institute for Interactive Media & Learning, University of Technology, Sydney (UTS)

Dr Mandy Lupton, Faculty of Education, Queensland University of Technology (QUT)

Professor Keith Trigwell, Professor of Higher Education, Institute for Teaching and Learning, The University of Sydney (Sydney)

1.2.2 Project participants

Physics:
Associate Professor Paul Francis, Physics, ANU
Associate Professor Les Kirkup, Physics, UTS
Mr Darren Pearce, Physics, QUT
Dr Craig Savage, Physics, ANU (2008 only)
Associate Professor Manjula Sharma, Physics, Sydney

Law:
Ms Susan Carr-Gregg, Law, UTS
Ms Rachael Field, Law, QUT
Ms Leanne Houston, Law, UTS
Ms Judith Jones, Law, ANU

In addition, a number of Law tutors (seven) and Physics demonstrators (four) from the participating universities have been involved with the project (see Acknowledgements).

1.2.3 Project support

Ms Chris Kertesz, The Australian National University, Project officer.

1.2.4 Reference group

An international reference group of disciplinary and theoretical specialists provided advice and guidance on the project.

Specialists in Threshold Concepts:
Professor Ray Land, University of Strathclyde;
Dr Charlotte Taylor, The University of Sydney.

Specialists in Variation Theory:
Professor Ference Marton, Gothenburg University;
Dr Ming Fai Pang, Hong Kong University.

Disciplinary specialists:
Professor Michael Coper, Law, ANU;
Professor Sally Kift, Law, QUT;
Associate Professor Anna Wilson, Physics, ANU.

2. Project processes

"So this [erroneous] sense of there is one way, we've got it in our heads and if only the students understood what we understood they'd be fine. It's not that way at all. We each have our own understanding of it. There may be some commonality. Hopefully there is. But also some quite important and profound differences". (project participant)

At the most basic level of description, this project involved groups of disciplinary teachers and educational developers working together to select a disciplinary Threshold Concept, investigate student (mis)understanding of the concept using phenomenographic action research, and redesign of the part of their curriculum addressing the Threshold Concept using the Variation Theory of Learning.

The disciplinary teachers were convenors and lecturers of first-year Law and Physics courses in The Australian National University, The University of Sydney, the University of Technology, Sydney, and the Queensland University of Technology. This led to a total of nine project participants, consisting of four-to-five convenors from each discipline; one-to-three from each institution. To enhance disciplinary dissemination and reduce the project-related workload for each participant, they were assisted by one-to-two tutors and demonstrators from each course, using a train-the-trainer approach, with a total of 11 tutors/demonstrators involved over time (four-to-seven per discipline; two-to-three per institution). The project team acted as the educational developers in the project, with one from each institution, each of whom was also actively engaged in educational research and theory, involving Phenomenography for all, and Variation Theory and Threshold Concepts for some. The Threshold Concepts selected by the disciplinary teachers for the project were 'measurement uncertainty' in Physics and 'legal reasoning' in Law.

2.1 The role of Phenomenography and Variation Theory

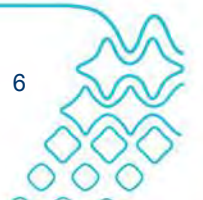
The relationship between Phenomenography and Variation Theory in the project is that Variation Theory can most effectively be used to inform curriculum design decisions when it is combined with phenomenographic research in the following two-stage approach:

1. Phenomenographic investigation of variation in students' understandings (or conceptions) of a key concept to be learned. This involves the identification of key features of the concepts that students discern or do not discern in their understanding of it.
2. Use of the principles of Variation Theory to design a curriculum that maximises students' opportunities for discerning the full range of key features of the concept identified in the previous investigation.

Phenomenography and Variation Theory share common epistemological assumptions, as Variation Theory was derived from Phenomenography. Both argue that individuals experience the world differently because experience is always partial. At any one point in time and context, people discern and experience different aspects of any concept or phenomenon to different degrees. This applies as much in the classroom as in the larger world. Thus, student understandings and misunderstandings of a disciplinary concept may be understood in terms of which aspects or features of the concept are discerned, and *not* discerned, in students' awareness of it. Awareness of an aspect is indicated by the perception of the *potential for variation* in that aspect; lack of awareness is indicated by an implicit, taken-for-granted assumption of uniformity in that feature of the concept.

For example, with the Law Threshold Concept of 'legal reasoning' addressed in this project, students' understanding of 'the nature of legal rules' was identified as a critical feature or aspect of their overall understanding of legal reasoning (see Table 1). The least sophisticated way of understanding legal reasoning, as "a formulaic process for predicting a legal outcome", involves an understanding of legal rules as rigid, unchangeable and completely clear (i.e., an implicit assumption of uniformity in interpretation of a legal rule; in other words, the potential for variation in interpretation of legal rules has *not* been discerned). In contrast, a more sophisticated understanding of legal reasoning, as "an interpretive process of arguing for an outcome that serves your client", includes awareness of legal rules as manipulable, interpretable and ambiguous (i.e., the potential for variation in that critical feature of legal reasoning *has* been discerned).

Because Phenomenography explains different understandings of a concept in terms of more and less complete awareness of the critical features of the concept, what is commonly understood as 'misunderstandings' of a concept are regarded



phenomenographically not so much as wrong, but as partial, including awareness of some aspects but lacking awareness of other aspects of the concept. This leads to an unusual approach to curriculum design, which aims to expand students' awareness of different aspects of the concept, rather than remove their current 'incorrect' understanding and replace it with the 'correct' one.

Phenomenographically, different individual understandings of the same concept may be understood as part of a larger whole, the *collective sum* of ways of understanding. It is assumed that different understandings of a concept would typically be related, in a part-whole manner, through shared discernment of some of the same aspects of the concept. Thus, the interviews with students undertaken during the action research stage of this project enabled a sampling of different individual understandings of the Threshold Concept, which were then grouped and related during the analysis stage. The grouping of student interviews into different categories of understanding is based on the student interview transcripts *within* any one category showing shared awareness of particular features of the concept and shared lack of awareness of others. Meanwhile, the student interview transcripts *across* different categories show shared awareness (and lack of awareness) of some aspects of the concept, but not others. In other words, each category of understanding is marked by a different pattern of awareness and non-awareness of the critical features of the concept.

The different categories of understanding are commonly ordered in terms of inclusivity of awareness of these different features, indicated by an *expanding awareness* of different aspects of the concept. More inclusive understandings inherently represent more sophisticated or complete understandings of the concept, because an increasing number of critical features of the concept are discerned as potentially varying, and thus problematised rather than taken-for-granted when thinking about the concept. For example, in this project, the phenomenographic analysis of students' understandings of the concept of 'measurement uncertainty' in Physics identified (mis)understandings that derived from an awareness of the importance of searching for patterns in measurement data, *but without awareness* of the importance of applying error calculation formulae; and an awareness of the importance of applying error calculation formulae, *but without awareness* of the importance of thinking through the real-world implications of measurement error. What is needed for a disciplinary-like understanding is for students to be aware of and integrate all three aspects of uncertainty: (1) searching for patterns in data; (2) applying error calculations; and (3) thinking through the implications.

On this basis, conceptual development is not seen as requiring the rejection of students' existing understanding of a concept, but to expand their current awareness through helping them to discern additional aspects of the concept that they currently don't discern. This has led to the Variation Theory of Learning, based on the argument that attempts to facilitate students' conceptual development should focus on optimising opportunities for them to experience variation in aspects of disciplinary concepts that they currently take for granted. In brief, the relationship between Phenomenography and Variation Theory is that phenomenographic research serves to *identify* the critical features that need to be highlighted for students when teaching and learning a concept, whilst Variation Theory provides guidance as to the most effective *ways of highlighting* these features for students, thus helping students to discern the critical features required to achieve a sophisticated understanding of the concept.

According to Variation Theory, student learning of a concept is best facilitated in any teaching and learning activity by introducing variation in each of the critical features of the concept into the activity. This draws students' attention to different aspects of the concept by varying some aspects whilst keeping others invariant. For example, continuing the Physics example from above, what is needed to draw students'

attention to the real-world implications of error calculations is to expose students to situations in which the patterns of data scatter and the error calculation formulae are both held constant, whilst the real-world implications are varied (by varying the context). For instance, the real-world implications may be varied, and thus highlighted for students, by asking them to consider the same data and error calculation in the different contexts of measuring a bolt hole for a bridge vs. the mass of a subatomic particle.

Whilst it is common for teachers to vary different features of disciplinary concepts in an intuitive manner when teaching, this is typically done implicitly rather than explicitly. As a consequence, multiple features of a concept are commonly varied simultaneously, in an ad hoc rather than structured way. This creates confusing patterns of variation for students in which it is much easier to miss noticing variation in some of the critical features than if each is varied separately while the others are held constant.

Whilst all of the critical features need to be varied simultaneously at some point in students' learning, to ensure an integrated understanding of the whole and of how the different features can interact, doing this before they have discerned each of the critical features separately may impede rather than help their conceptual development. For example, it will be more difficult for students to notice the real-world implications of measurement uncertainty when teachers vary data, formulae and real world context simultaneously, than when only the context (and thus implications) are varied, whilst data scatter and error calculation formulae are held constant.

Whilst the need for variation of the different features of a concept is intuitive for teachers, what is much less intuitive is the simultaneous need for *invariance*; the recognition that what is *not* varied is as significant for students' learning as what is varied.

2.2 Stages of the project

Following creation of the two cross-institutional disciplinary peer groups in Physics and Law, the project involved four primary stages:

1. Introducing each disciplinary peer group to the idea of *Threshold Concepts*, and supporting them in the identification of an appropriate Threshold Concept on which to focus curriculum design attention for first-year students in their discipline.
2. Supporting each group in the conduct of *action research* into variation in students' (mis)understandings of that concept, to inform future curriculum design. This involved guided use of phenomenographic research methods at each stage of: (1) design of interviews with students; (2) conduct of interviews; and (3) interview analysis.
3. Group *curriculum design* of a set of learning activities to address the misunderstandings identified in step two, using Variation Theory as a guiding framework.
4. Implementing the new curriculum design, *assessing student learning* outcomes and revising the next iteration of curriculum design in response to the outcomes for students.

Although this approach to curriculum design could be undertaken by individual academics acting on their own, the power and dissemination of the approach is increased, and the associated workload reduced, by the involvement of disciplinary peer groups. In all, this project involved:

- *24 individuals*, consisting of four educational researchers/developers (one per institution) acting as institutional project leaders; nine disciplinary lecturers (four-to-five per discipline) and 11 tutors/demonstrators (four-to-seven per discipline), to ensure disciplinary dissemination.
- *four institutions* of varying types and geographical locations (The Australian National University, The University of Sydney, University of Technology, Sydney and Queensland University of Technology), to test the applicability of the model in different institutional contexts.
- *two disciplines* of very different types (Physics and Law), to test the broad disciplinary value of the model.

2.2.1 Stage 1: Identification of an appropriate Threshold Concept

The two disciplinary peer groups were supported in identifying an appropriate Threshold Concept for the project through provision of selected readings, followed by a face-to-face workshop consisting of expert presentations, discussion, exercises, and questions (see Appendix 1: Workshop 1 meeting agenda for an outline of the one and half day meeting). The pre-readings, expert presentations, questions and whole-group discussions were designed to introduce participants to the theoretical nature of Threshold Concepts. The disciplinary group exercises and discussion during the workshop were designed to guide participants in the selection of a Threshold Concept.

Participants were introduced to the following five criteria for identifying Threshold Concepts:

1. *Troublesome* – Threshold Concepts are often difficult to understand because a disciplinary understanding is alien or counter-intuitive to novices.
2. *Transformative* – understanding the concept results in a qualitative shift in individuals' perspective on the subject, and possibly their sense of identity and world view.
3. *Integrative* – full understanding of the concept exposes hidden inter-relatedness in the subject/discipline.
4. *Irreversible* – Threshold Concepts are unlikely to be forgotten, indeed, students may 'forget' what it was like not to understand.
5. *Bounded* – Threshold Concepts may constitute a boundary between conceptual areas or disciplines.

This was followed by a whole group exercise in applying the five criteria to the concept of 'ethics' and a case study exercise based on potential Threshold Concepts in health, to make application of the criteria more meaningful to participants.

Participants were then separated into disciplinary groups and asked to brainstorm key concepts for first-year students in their discipline (see below). From this set of key concepts, they were then asked to identify potential Threshold Concepts to be addressed in the project using the five criteria specified above. There is often confusion between the idea of a 'threshold' concept versus a 'key' concept amongst those newly introduced to the notion of Threshold Concepts; it was hoped that this method of asking participants to first identify key concepts, from which a subset of Threshold Concepts is identified, would help with this confusion. Threshold Concepts will inevitably be key concepts in a discipline, but not all key concepts will be threshold in nature.

After identifying a small set of potential Threshold Concepts, each group was asked to write a brief description of how each of these concepts met the five criteria. This activity was also intended to help them distinguish key from threshold concepts. Interestingly, both groups had difficulty applying the concept of 'boundedness', so their final justifications (see below) included the first four criteria only.

The workshop was held in December 2008, and followed by electronic communication and videoconferencing between the project leaders and disciplinary lecturers to finalise agreement on the Threshold Concept selected for the project before the start of the 2009 academic year. As will be described below, the Physics group decided on 'measurement uncertainty' and the Law group on 'legal reasoning' as the Threshold Concepts to be investigated during the project.

An internal project website was also set up at this time using the Moodle learning management system. It was hoped that this would serve as both a resource repository and discussion forum for participants and project leaders, but it eventuated that most participants, especially in Law, preferred to wait for the videoconferencing meetings for discussion. These were then held on an 'as needed' basis throughout the project to stimulate progress and help in meeting timelines. The internal website was nevertheless invaluable as a resource repository and record of project processes that was readily available to all members of the project when needed, for instance, when preparing conference presentations.

2.2.2 Stage 2: Action research into student (mis)understandings of Threshold Concepts

The purpose of the action research component of the project was to identify what it is about the Threshold Concepts selected that students experience particular difficulty in understanding. To introduce participants to the complexity of phenomenographic research methods in a way that would be as manageable as possible for them, this stage of the project was addressed in three steps: interview design, conduct of interviews and interview analysis.

Interview design:

Participants were first introduced to Phenomenography as a whole group at the end of the December 2008 workshop meeting. Videoconference style meetings were then organised for each disciplinary group separately between February and April, 2009. The focus of the videoconference meetings was to support each disciplinary group in the design of an appropriate interview schedule for phenomenographically investigating student understandings of the selected Threshold Concept. Readings and interview design guidelines (see Appendix 2: Guidelines for designing phenomenographic interviews) were provided on the Moodle site and discussed during the videoconference meetings.

Both the Physics and Law interview schedules used the approach of semi-structured questions oriented around a trigger scenario (see Appendices 3 and 4: Law and Physics interview schedule). The intention was to give students a disciplinary-relevant scenario in which they needed to apply the Threshold Concept, then interview them about their thinking. The aim was to enable different understandings of the concept to emerge. The semi-structured interview questions explored how students came to their conclusions about the scenario, and in particular *why* they thought and said what they did about it.

Conduct of interviews:

Guidance in phenomenographic interviewing was provided through readings and written guidelines (see Appendix 5: Guidelines for conducting phenomenographic

interviews), modeling of interviewing by project leaders conducting mock interviews during the videoconferencing meetings, and the conduct of pilot interviews – transcripts of which were then shared and discussed by each disciplinary group.

It was at this stage of the project that each course convenor recruited one or two tutors/demonstrators. The original intention was that they assist with both the conduct and analysis of interviews. However, their role in the project varied with each course convenor. Some convenors preferred to conduct all the interviews themselves, some conducted just the initial interviews, and some left the conduct of interviews entirely to their tutors/demonstrators. Nevertheless, all of the tutors/demonstrators as well as all of the course convenors were involved in the interview analysis, as described below.

An induction pack for tutors/demonstrators was prepared by the project leaders, consisting of: a background to the project; discussion notes from the initial workshop brainstorming potential Threshold Concepts; the interview schedule and interview guidelines; a sample interview; and the interview information sheet and consent form. Institutional project leaders helped to brief the tutors and demonstrators, but course convenors were expected to take primary responsibility for introducing their tutors and demonstrators to Threshold Concepts, Phenomenography, and the purpose of the project as a whole, in line with a train-the-trainer approach to dissemination of the project methods.

The aim was to conduct a minimum number of interviews that might be expected to capture the range of key variation in students' understanding of the Threshold Concept. Following pilot interviews, each convenor was asked to ensure that six of their first-year students were interviewed, aiming for a total of 24 interviews for each discipline across the four institutions as a whole. (With the Law group, eight interviews were sought from each convenor because only three institutions were represented, with no Law participant from the The University of Sydney.) Final numbers were 21 interviews for Law and 23 for Physics.

The interviews were conducted between May-July 2009, to allow time for data analysis and curriculum redesign during the second half of 2009.

Interview analysis:

Interviews were transcribed verbatim and analysed in two steps:

1. a preliminary analysis of the six-to-eight interviews for each discipline in each institution; followed by
2. a final analysis of the total set of 21-23 interviews for each discipline across each of the institutions involved in the project.

The preliminary analysis involved an institutional meeting for each discipline, which included the institutional project leader, institutional course convenor, and associated tutors/demonstrators. Each person was expected to start analysing the interview transcripts in advance of the meeting (see Appendix 6: Guidelines for analysing phenomenographic interviews), then the institutional project leader led them through a discussion of the variation in understandings that were emerging from the transcripts.

A one and half day whole group workshop meeting was held in September 2009 with the primary aim of combining the interviews across institutions and progressing the interview analysis to a stage that was adequate to inform the curriculum design (see Appendix 7: Workshop 2 meeting agenda). A fully fledged phenomenographic analysis was not possible nor anticipated within the timelines of the project.

The workshop started with further guidance to participants on how to analyse interviews phenomenographically. Participants then broke into disciplinary groups, each accompanied by two project leaders who helped the groups to develop their analyses as far as possible within the time available. Participants were encouraged to compare and contrast student interviews in an iterative manner, looking for key similarities and differences in their responses. This process helps to highlight different aspects of the concept that some students may be aware of and others not, with this varying awareness of key aspects associated with different understandings of the concept.

2.2.3 Stage 3: Design of curriculum and student assessment

The aim of the curriculum redesigns was to improve students' understandings of the Threshold Concepts by applying Variation Theory and the findings from the student interviews to the design of the part of the curriculum where the Threshold Concept was addressed. The lecturers were introduced to Variation Theory at the end of the second workshop and some readings were made available.

Discussion of the actual curriculum redesigns and the use of Variation Theory to guide the designs was initiated towards the end of the workshop meeting (September 2009), following the interview analysis. Discussions continued through a series of access grid or videoconference meetings held between November 2009 and April/May 2010, as well as through e-mail interchanges between participants. The meetings were held separately for each disciplinary group. Tutors and demonstrators were invited to participate, although only one from each discipline participated on a regular basis.

Curriculum and assessment design in the Law group:

Discussions in the Law group began with a focus on the understanding of legal reasoning that the group was seeking to achieve with first year students, based on the categories of understanding that they constituted from the analysis of student interviews. All three universities agreed that a Category 2 level of understanding (see Table 1, below) was desirable, although some also aimed for a Category 3level of understanding. It was agreed to have a common curriculum design that would focus on achieving the minimum common desired outcomes (Category 2 understanding), but would also leave open the possibility of additional interventions in different universities intended to achieve higher levels of understanding.

The Law group then sought to develop common curriculum materials that could be used across all three universities (see Appendix 8: Law curriculum design), although they were implemented in slightly different ways to suit institutional differences in circumstances. At ANU the design was implemented as a 90 minute tutorial, forming an integral part of the *Foundations of Australian Law* course. At UTS and QUT, the 90 minute session was offered as an optional tutorial, attached to the *Legal Method and Research* course at UTS, but not attached to any one course in particular at QUT.

Participants recognised that, in the usual Law curriculum, the teaching of legal reasoning was intertwined with the teaching of many other aspects of the Law, including statutes and significant cases. They therefore decided to base the curriculum change on a series of scenarios that varied different aspects of legal reasoning, while holding the other aspects of the Law constant as far as possible. The lecturer from one university took the lead in developing scenarios based on a simple statute involving speeding on a public road, and the tutor from another university undertook research into appropriate cases to support the scenarios as they became more complex and the number of varied aspects increased. Materials

were shared by email, and their relation to the interview findings was discussed in further videoconferencing meetings.

The Law group also sought to use common modes of assessment of the learning outcomes. Two forms of assessment were developed. One was to ask students to provide a short written answer to a single question: “What is the purpose of legal reasoning?”; the second was a problem exercise that required students to use legal reasoning in a context similar to the scenarios (see Appendix 9: Law assessment design). However, the design was implemented a little differently in each university, depending on the context. At ANU and UTS, both the short answer question and problem exercise were used in the final course exam, but at UTS the short answer question was an optional question in the exam. At QUT and UTS, the short answer question was used on its own immediately following the curriculum design intervention. (Thus, UTS used the short answer question both at the end the intervention and in the course exam.)

Curriculum and assessment design in the Physics group:

Discussions of curriculum redesign in the Physics group differed from those in the Law group. The lecturers began by agreeing on common intended learning outcomes, on the basis of the student interview analysis and their prior experiences of teaching. However rather than developing a common curriculum design as with the Law group, each of the lecturers designed a different intervention, but based on the common intended outcomes.

The lecturer from The University of Sydney was unable to implement the curriculum design in her course, due to her university's requirement for early specification of course design and materials, however, she continued to be fully involved in the curriculum design discussions. Each of the remaining three lecturers was able to implement a curriculum redesign, but the ANU and UTS participants had more flexibility to change aspects of the curriculum at relatively short notice than did the QUT participant, which impacted on the final designs.

The group discussed existing approaches and materials that could continue to be used, along with new ideas. As with the Law group, one lecturer took an initial lead in posting some existing materials on the project Moodle site, then others followed. The aim of all of the materials was for the lecturers and/or students to intentionally vary each of the critical aspects of understanding of the Threshold Concept that were identified from the interviews, whilst holding the other aspects constant, then to try to vary them simultaneously so that they would be integrated into a holistic understanding (see Appendices 10-12: ANU, QUT, UTS curriculum design).

Given the common intended learning outcomes across the institutions, even though their curriculum design for achieving those outcomes varied, the Physics group agreed to use one common mode of assessment (see Appendix 13: Physics assessment design). This was a problem-based short answer question posed in the final exam. The question was designed to assess whether students had achieved the intended learning outcomes, and required both a quantitative and qualitative response. Two of the lecturers also agreed to use an additional common multiple-choice question.

2.2.4 Stage 4: Implementation and evaluation of student learning outcomes

In Law, all three universities used the same scenario-based curriculum design, although they varied slightly between institutions. At ANU, the intervention was embedded as a tutorial component in the course curriculum for first-year students. It

was presented early in semester one 2010 and followed up with additional discussion of legal reasoning over a number of weeks. At UTS, where the first-year curriculum was already set for the beginning of 2010, and at QUT, where the most relevant subject was not taught at the relevant time, the scenarios were implemented as a stand-alone intervention in optional 90 minute workshops for students. At UTS, the workshop was offered only to students in the lecturer's course, and held shortly before the first semester course exams. Students were told that the workshop would help them with exam preparation. Two (repeated) workshops were offered and over 30 students came to each one. At QUT, the workshops were not as obviously connected to exams or to one particular course, and were offered between teaching semesters. Two (repeated) workshops were offered, and eight students came to one workshop and 12 to the other.

The actual presentation of the workshops was undertaken by the 2009-10 project tutor at QUT and two new project tutors at UTS, who had not been involved in the project the previous year and so had not participated in the action research component. At ANU, where the course had a large enrolment, eight tutors and lecturers were involved in presenting the (repeated) tutorials, including the project participant and project tutor. Hence, the teachers enacting the curriculum design did not necessarily have an awareness of the project background, or an understanding of Threshold Concepts and Variation Theory.

In Physics, implementations of the curriculum redesign differed across the three universities. At ANU, measurement uncertainty was addressed over three lectures, two laboratories and one tutorial – though only the tutorial was explicitly designed using Variation Theory. At UTS, the curriculum design involved modifying a lecture and a related tutorial and laboratory that had previously focused on the Threshold Concept to be more explicit in enabling students to notice and then integrate the critical aspects of uncertainty. At QUT, a single lecture session was designed to achieve this, as the lecturer did not control the laboratory program.

The actual presentation of the curriculum redesigns was undertaken by varying individuals. Lectures were presented by the project participants, tutorials by either the project participant or project tutor, and laboratories by the project demonstrator and additional demonstrators not otherwise involved in the project. As with Law, this meant that the teachers enacting the curriculum design did not necessarily have an awareness of the project background, or an understanding of Threshold Concepts and Variation Theory.

3. Project outcomes

"Did illustrate to me that a lesson [curriculum design intervention] that is designed to take into account a particular theory of learning can have an impact both on the person teaching it and the students who are there." (project participant)

3.1 Identification of Threshold Concepts in first-year Physics and Law

3.1.1 Law Threshold Concept: legal reasoning

The Law group participants identified the following as key concepts in first-year Law: precedent, statutory interpretation, separation of powers, *ratio/obiter*, legal reasoning, legal systems, legal institutions, legal method, legal history, issues of fact

vs. issues of Law, difference between substantive/procedural/remedial, sources of Law, minority/majority judgments, Law-making process, democratic system.

After some debate, they selected *legal reasoning* as the Threshold Concept for the project, justified against the following four criteria:

1. *Transformative:* Looking at the other side; accepting there isn't a right answer; knowing that you have to think carefully about meaning and argument and be persuasive. Makes you problematise things, question things, test the facts, test the boundaries and limits of things. Involves a sense of self-identity as a lawyer. For example, given a criminal scenario where the students think that a person is guilty, but after learning about legal argument and weighing up all the evidence, working with the wording of a statute and using the case law, and other authorities they might then take a different view.
2. *Integrative:* Understand what lawyers, barristers and judges are doing, why you have multiple judgments. Understand the culture of argument and the uses of argument, recognising the importance of authority.
3. *Troublesome:* Not an inherent skill for students. Involves taking responsibility for your position and your argument; it's easier to just make assertions rather than backing them up. Students want to know what they have to do to get good marks in the exam and assume that's by finding the 'right' answer. Contradicts some of their learning (way of knowing things) up to this point; takes them out of their comfort zone. The students don't always understand why they need to have authority and evidence behind assertions. Challenges some of their fundamental assumptions about society and justice. Students have to change their preconceptions about what Law is and what Law can achieve.
4. *Irreversible:* The way of thinking becomes irreversible in that once you are able to argue like a lawyer and use authority and provide evidence for a position and assertions, you can't undo that skill.

3.1.2 Physics Threshold Concept: measurement uncertainty

The Physics group identified the following as key concepts in the teaching of first year students, with the underlined concepts potential Threshold Concepts: field, astronomy flux, induction, significance, PDF time, approximation, orders of magnitude, wave particle duality, conservation law, uncertainty, acceleration, first principles, diagrams, modelling, force, vectors, momentum, gravity, entropy, relativity, space-time, frames of reference, idealisation-reality, quantum, impulse, energy, potential, equilibrium, dynamic & static, measurement, temperature.

After some debate, they selected *measurement uncertainty* as the Threshold Concept for the project, and identified the following as related concepts: significance, first principles, diagrams, modelling, approximation, orders of magnitude, measurement, system, idealisation-reality.

Justifications against the Threshold Concept criteria (finalised with help from the Physics disciplinary representative on the reference group) included:

1. *Transformative*: There are several symptoms of students' behaviour which suggest that a good understanding of the role of measurement uncertainty results in transformation in a student's thinking. Before a student has grasped the role of uncertainty in measurement, they see the outcome of an experiment as a single number. This means that comparisons are made between the values x_1 and x_2 rather than say $x_1 \pm \sigma_1$ and $x_2 \pm \sigma_2$ (where σ_1 and σ_2 are measures of uncertainty on x_1 and x_2 respectively). Uncertainty is seen as a mistake –

something to be eliminated or remedied, or which indicates an experiment has been performed incorrectly. When graphing data, lines are drawn to connect points rather than to show a trend. Once the threshold has been crossed, students experience a radically revised view of many aspects of measurement, including factors contributing to experimental design, the limitations on experiments and inferences from data, and indeed the very nature of experimental results. Uncertainty is seen as an intrinsic part of the result of a measurement and as essential in assessing the quality of the outcomes of an experiment; its target magnitude becomes something that is an important criterion in the design of an experiment; and extrapolations/interpretations are made taking uncertainties into account.

2. *Integrative*: The concept of measurement uncertainty integrates a range of concepts and skills in a way that makes more meaning out of the whole. Concepts such as random and systematic error, calibration, repetition, hypothesis testing, significance, tolerances, populations and samples, experimental design, the limits of what can be discovered, interpolation and extrapolation, modelling, approximation and more are brought together in a complex cluster to form a key element of scientific method.
3. *Irreversible*: Once a student has grasped the role of uncertainty, their views of the interdependency of theory, experiment and data are irreversibly changed. Their ways of reading data change so that, for example, they distinguish between scatter and pattern, and they recognize all data as contestable.
4. *Troublesome*: There is no doubt that uncertainty is frequently a troublesome concept for students to grasp. The mathematical formalism is non-trivial; the idea of quantifying something that by definition you are unsure of and cannot directly measure is deeply challenging; and learning to 'read' data is something that takes practice. In addition, the challenge to the idea of a 'true' or 'exact' value is often at odds with the definite language of theory (and hence lectures and textbooks). The realisation that data (upon which theories depend) are inherently uncertain, and that the process of measurement is imperfect, leads students naturally and compellingly to question the basis of physical knowledge. This can be deeply unsettling for students who crave clarity and certainty.

3.2 Identification of critical features for student understanding of each Threshold Concept

3.2.1 Critical features of legal reasoning

The Law group identified four different ways of understanding legal reasoning (though there was not enough time to develop the fourth category in detail). Each understanding was marked by varying awareness of four critical aspects of the concept (see Table 1 below):

1. nature of the rule / Law in legal reasoning
2. purpose of legal reasoning
3. value of the logical and consistent nature of legal reasoning
4. role of HIRAC / ISAAC in legal reasoning.

The group also identified varying awareness of the purpose of reading the law, but this aspect of the legal reasoning may not be *critical* in distinguishing between different understandings.

Table 1: Critical features and different understandings of legal reasoning

	1. A formulaic process for predicting a legal outcome	2. An interpretive process of arguing for an outcome that suits your client	3. A dynamic, responsive and innovative process for developing the Law to reflect changing society	4. Law as a tool for change. Recommendation to Parliament
Nature of the rule/Law in legal reasoning	Rigid; completely clear (Accept the rule. Only the facts can be in dispute / argued)	Manipulable / Flexible / Interpretable (Challenges the rule) Facts & rules can be argued	Changeable – Dissents, exceptions; [Change the rule]	
Purpose of legal reasoning	To correctly predict the outcome (Adjudicate)	To produce the best outcome for your client (Advocate)	To produce the best outcome for society [Change agent]	
Value of the logical and consistent nature of legal reasoning	[Comfort with predictability of Law] To be able to predict accurately	[Discomfort-will outcome be just; will I do the best/right thing] To treat people equitably	Greatest good for greatest number	[Comfort with unpredictability of Law] Imperfect
Role of HIRAC / ISAAC	It is legal reasoning	It is a tool for aiding legal reasoning	It is implicit / evident in legal reasoning	
Purpose of reading Law (for students)	To learn the rules (See example of LR)	To look for ambiguity and use it for your argument	To observe legal reasoning in action [?]	

3.2.2 Critical features of measurement uncertainty

The Physics group identified three critical aspects of the concept:

1. a *pattern-recognition* aspect that allows students to distinguish between trends, measurement variability and potential anomalies in data scatter
2. a *formal*, procedural aspect that allows them to apply appropriate error calculation formulae to quantify different elements of uncertainty
3. a "*meaning*" aspect that invests uncertainty with real-world consequences.

A sophisticated understanding of uncertainty involved the integration of all three aspects, whilst a less sophisticated understanding emphasised only one or two of these aspects.

The disciplinary group did not reach the stage of agreeing on different understandings of the Threshold Concept associated with student awareness and lack of awareness of each of these critical features, but identification of the critical features and their integration or lack of integration was all that was required in order to move onto curriculum design using Variation Theory.

3.3 Redesigned curricula and assessment

Both the Law group and the Physics group developed renewed curriculum and assessment materials for the initial implementations, which are available to be modified and reused in the future.

In Law, one outcome of the curriculum redesign was a set of legal scenarios (see Appendix 8: Law curriculum design) that were designed to focus students' attention on particular aspects of legal reasoning by varying these aspects while holding other aspects constant. The scenarios referred to a common statute, with the most complex scenario including two legal cases. They included some instructions to tutors on using them with students. There were two approaches to using these in the Law curriculum. One approach involved using the scenarios as in-class exercises early in the semester in a first-year Law subject. The second approach used the scenarios in workshops that could be linked to a particular subject or offered separately to Law students in any subject. More detail on how the workshops were enacted can be found in Section 4.2.2. The Law materials have already been reused in later workshops at UTS.

In addition to the curriculum materials, the Law group also developed a common post-test question for class activities or the workshops, and a common examination question. These are included in Appendix 9: Law assessment design. The examination question included a problem question and a case extract.

In Physics, outcomes of the curriculum design were different across the three universities, resulting in a suite of possible materials that could be used by others. The materials and approaches to using them were designed to encourage students to separate the critical aspects of noticing patterns in data, using formulae to calculate uncertainties and focusing on the meaning or consequences of uncertainties, then integrating these three aspects. Examples are included in Appendices 10-12 and further material is available on the project website. The materials included sample tutorial questions (Appendix 10: Physics curriculum design, ANU), a practical exercise for students with instructions for demonstrators (Appendix 11: Physics curriculum design, QUT), and a lecture, tutorial outline, and laboratory experiment instructions (Appendix 12: Physics curriculum design, UTS).

The common Physics assessment designs consisted of a post-test question, which presented students with a set of data and required them to integrate calculation of uncertainties with making an assessment of the consequences of these uncertainties. Two multiple choice exam questions were also developed (see Appendix 13: Physics assessment design).

4. Project impact

"I guess two impacts...firstly… using [Phenomenography] to spot the differences - so to work out what are students' different understandings of this Threshold Concept? That was a good way of really analysing students' existing knowledge … then the second way … we've used Variation Theory to say well, we can teach this better because students may be able to grab a concept better if we can show - if they can see variations." (project participant)

4.1 Participant perceptions of the benefit to their teaching

Participants' impression of the benefits of the project to their teaching were gathered at regular stages throughout the project, but in particular through a confidential interview with lecturers, tutors and demonstrators conducted by the external evaluator towards the end of the project (see Appendix 15: Changes in participants' understandings as an outcome of the project).

Although there was variation between individual participants, overall the perceived benefits were profound, far exceeding the project leaders' initial expectations at the commencement of the project. Participants reported benefits, sometimes of a transformational nature, in the following areas:

- Improved understanding of what it is that students find difficult when learning the Threshold Concept.

  Physics: …a lot of rather simplistic ideas about your students and their misconceptions that has to be confronted … and you realise that in fact it's a little bit more complicated - what's going on in the students' minds than that (P2)

  Law: So it really brings home to you the diversity of understanding, and the students can hear the same thing but experience it very differently (L5)

- Improved understanding of how best to teach the Threshold Concept, as well as other disciplinary concepts.

  Physics: …certainly it was informative … and changes how I think about what I'll do in my own Physics teaching (P7)

  Law …the way that we worked out the methodology will certainly be effective and will definitely be used in all future introductory Law subjects (L4)

- An expansion in participants' *own* understanding of the Threshold Concept.

  Physics: …it's certainly triggered a new cycle of thinking about it and possibly a different order of thinking about it (P7)

  Law: I think I have a more sophisticated understanding of what legal reasoning is than before I started the project … So I think it's expanded, I guess, my view of what legal reasoning is (L2)

Given that project participants were disciplinary academics with many years experience, one who had even authored a book about the Threshold Concept being investigated, this last benefit is particularly pleasing, and exceeds the outcomes anticipated by the project.

4.1.1 Triggers for change

The aspects of the project that participants found particularly beneficial in triggering these insights included:

- Conducting and analysing student interviews, as part of the phenomenographic action research process.

  Physics: Ah, the interview data, reading the transcripts actually showed up different features, different aspects which, hearing it … the student voice, was enlightening (P4)

  Law: … came about when we really actually analysed the interviews and we were able to - we built a grid, almost, of, I guess, levels of understanding, levels of sophistication... (L2)

- Designing the curriculum intervention and observing student reactions when teaching it, as part of the implementation stage of the project.

  Law: Really watching them in class, listening to them in class and seeing them absorb what we were teaching them, or what I was teaching them… (L5)

- Engaging in focused discussion about teaching and learning issues with disciplinary colleagues, as part of the peer collaboration process built into the project.

  Physics: getting together and talking with other people from the same discipline and trying to come up with shared ways of doing things has been a really - for me a very useful process (P7)

  Law:… to have discussions with other colleagues: more fruitful discussions than the quick five minute discussion you might have in the lunch room (L2)

- Collaborating with educational developers/researchers, as project leaders.

  Physics: … given me the opportunity to actually work in a meaningful way with educational developers rather than just my discipline specific peers (P7)

  Law: It was a combination of explaining or discussing aspects of our teaching with some of the things that the project leaders were saying (L6)

- Taking time to reflect on curriculum design in a focused way, which was both required and legitimated by their involvement in the project.

  Physics: So when you give this extra emphasis, this extra thought about things, it's amazing what emerges that you didn't expect (P7)

  Law: I think it's the luxury of time, doing a project like this, to sit and think about what we're teaching, what they're learning… It's the ability to look at something in a bit more depth and to have some more thinking time about why we're doing what we're doing and how can we do it better (L2)

- The new frameworks for thinking about teaching and curriculum design provided by educational theory, including Threshold Concepts, Phenomenography and Variation Theory.

  Physics: The Threshold Concept aspect of it, trying to work out what the nature of the threshold is. I think that can be a useful way of making a discussion happen (P7)

  Law: … that different theoretical framework, in addition to practically implementing it, gave me the chance [to change my understanding of the concept] … I'd say that there was a theoretical framework but also the experience of working on the redesign of a course. So both as important as the other (L5)

Of course, not all aspects of the project impacted on each participant in the same way, and the lecturers, who were full participants in the project, tended to experience more substantial impacts than the tutors and demonstrators, who were only partial participants. Nevertheless, all participants found some aspect of the project beneficial in gaining insights into teaching, learning or curriculum design.

It is also interesting to note the powerful impact that came simply from engaging in focused discussion with colleagues and making dedicated time to reflect on teaching. A sophisticated curriculum design process supported by external funding is in principle not required to enable such activity, but as some participants commented, they could not legitimate such activities without it.

4.2 Learning outcomes for students

Precise tests of student learning outcomes were not possible within the project design, which placed a greater priority on the educational development aspects than the educational research aspects of the project. Simple comparisons of pre- and post-tests of learning were not seen as valid, because they would not enable identification of the impact of this particular curriculum design approach compared to other approaches. Introduction of a control group of students was seen as unethical, given the anticipated benefits of the project-based curriculum design. Comparison of current year student outcomes with the outcomes of the previous year's students, who completed the course prior to the curriculum intervention, was also not valid. This is because the approach to course assessment was changed at the same time as the intervention, in line with the curriculum design. In addition, a number of the lecturers varied other aspects of their course design at the same time as introducing the project-based intervention, making it impossible to distinguish the impact of the project-based curriculum design from other curriculum changes. For instance, one of the physics lecturers reported a striking increase in student learning:

> *Well we looked at - monitored how much the students knew about the concepts of uncertainty at the end and probably about 90 per cent of our students, at the end of this year, were at the level which mainly about 10 per cent of students the previous year. So, I think we've [... made a dramatic] improvement in how much the students know and understand about these things. We still don't know how long lived that's going to be and whether it can be applied to different contexts, but insofar as we can measure at this point the improvement has been stunning.*

However, because he had been experimenting with a number of curriculum changes simultaneously, he then added the proviso that he couldn't tell which interventions, or combination of interventions, had been helpful to students.

This had been anticipated in advance of the project, and an unusual approach to assessing the learning impact planned. The plan was to video record each implementation in action, on the assumption that each teacher would inevitably vary critical features of the threshold concepts differently during the implementation, even though working to the same curriculum design. The video recordings enabled an analysis of each implementation in practice, using variation theory to examine how the critical features of the concepts were *actually* varied (as opposed to how they were *planned* to be varied in the curriculum design). This would enable a prediction of different learning outcomes for students as a result of variation in the different implementations of the same curriculum design. If the outcomes of the assessment of student learning were in accord with the predictions, then the potential of using variation theory to improve teaching and learning outcomes would be demonstrated.

Employing this plan in the Physics implementations became difficult because each lecturer employed a different curriculum design. However, the Law implementations did facilitate this approach to assessing learning outcomes. In four instances of the Law interventions (there could be more than one instance per course due to multiple tutorials) at two of the institutions, the contextual curriculum circumstances surrounding the intervention were similar, in that the intervention was introduced as a stand-alone workshop separate from the rest of the course. In addition, the short answer question, "What is the purpose of legal reasoning?",that was subsequently used in final exams was completed by students at the end of the workshops, creating a comparable test of immediate learning outcomes across the four interventions. This created the possibility of conducting valid comparisons between these four interventions in particular that would allow an indicative test of learning outcomes based on the application of Variation Theory to the teaching of Threshold Concepts.

This section will describe the student learning outcomes that we were able to identify most directly following the four workshops. As described above, the workshops were designed using Variation Theory, to try to help students to become more aware of the critical aspects of legal reasoning identified through the phenomenographic action research. The workshops were videoed in implementation, to record how the intended curriculum was actually enacted in the workshops, including what the tutors actually presented and how their interactions with students affected what was planned. To test the curriculum design value of Variation Theory, we were particularly interested in identifying the aspects of legal reasoning that were varied and held constant during the class. At the end of the class, students were asked to respond in writing to the question, "What is the purpose of legal reasoning?". This design allowed a comparative analysis of the relation between what happened in the workshops and what students learned.

The videos of the workshops were analysed by two of the project team leaders and the students' learning outcomes (as evidenced by their written responses to the end of workshop question) were analysed independently by the other two team leaders. In this way, the observations and conclusions made by each pair could not influence those of the other pair. The broad patterns of variation that were evident in the workshop videos were then compared with the patterns of student learning evident in the written responses. This outcomes of this Variation Theory based analysis of how the workshops were conducted and how this related to the learning outcomes observed through students' written responses is described in detail below.

4.2.1 The intended curriculum design

The workshops were based on a series of three-to-four legal scenarios based around the potential offence of speeding in a vehicle. The scenarios were intended to vary different aspects of legal reasoning. In the intended design, the first scenarios were designed to be very simple, to draw students' attention to the legal reasoning process, but without raising the possibility of varying arguments and conclusions. The third scenario then opened the possibility of varying the legal argument for each side of the case, and the fourth scenario focused on varying interpretations of legal rules, varying the use of cases to support legal argument and the possibility of a varying the legal argument for each side of the case. The overall intention of the workshop design was to enable students to notice the critical features of legal reasoning that distinguished the understanding described in category 2 of the phenomenographic analysis of legal reasoning with the understanding described in category 1. A category 1 understanding is marked by an awareness of legal reasoning as a formulaic process for predicting a legal outcome, but without the understanding that legal rules are ambiguous and may be interpreted differently to achieve different legal outcomes in the interests of a client (see Table 1, above).

4.2.2 How the intended curriculum was enacted: what actually happened in the interventions

Analysis of the workshop videos focused on what the tutors and students did and on the main aspects of legal reasoning that were varied (usually by contrast) or held constant in the class. In all four workshops, the tutors followed the overall pattern of the intended curriculum, but there were differences in how the curriculum was enacted, due to inevitable differences in the different styles and intentions of the tutors and their interactions with the students. To avoid identifying tutors and universities, we will call the workshops one through to four.

An analysis of the intended curriculum for the workshops (see Appendix 8: Law curriculum design) based on the pattern of critical aspects of legal reasoning that were varied and held constant is outlined below in Table 2.

Table 2: Law workshops - intended curriculum

Scenario 1 – Fred driving at 60 kms in a 40 zone • apply formula, no argument • conclusion constant
Scenario 2 – Fred driving at 30 kms in a 60 zone • facts vary, rule invariant – apply formula, no argument • conclusion constant
Scenario 3 – Fred driving travelling at 45 kms in a 40 zone • facts vary, rule invariant • facts in dispute – apply formula, awareness of alternative argument • conclusion varies - will depend on arguments
Scenario 4 – Fred in passenger seat, accidently causes car to move, travels at 50 kms in a 40 zone • facts vary, rule varies (definition of driver) • case law introduced – create argument (interpretation of 'driver') • conclusion varies - will depend on arguments

To illustrate the video analysis process, a summary for one of the workshops (workshop 1) of how the curriculum was intended versus enacted with regard to variation of features of legal reasoning is shown in Table 3.

Table 3: Law workshops - intended vs. enacted curriculum

Intended pattern of variation	Enacted pattern of variation
Scenario 1 – Fred driving at 60 kms in a 40 zone • apply formula, no argument • conclusion constant *Write up with fluid expression*	Presentation of the different methods (formula) for legal reasoning (different acronyms/abbreviations are used e.g. IRAC, ISSACS) – acronym varies, but they are all tools for legal reasoning **Student activity - apply formula – issue, rule, facts, conclusion (Cat 1)** Tutor statement - relationship between law and facts – correct application is discussion of law and facts together (Cat 2a) **Student activity – write up in prose (applying legal reasoning formula, and expressing it are different aspects)** Tutor statement – need fluid expression
Scenario 2 – Fred driving at 30kms in a 60 zone • facts vary, rule invariant – apply formula, no argument • conclusion constant *Need a dispute for case to go to court*	**Student Activity - apply formula – issue, rule, facts, conclusion (Cat 1)** Tutor Statement – a case only goes to court if there is an argument, a need for interpretation (Cat2b)
Scenario 3 – Fred driving travelling at 45 kms in a 40 zone • facts vary, rule invariant • facts in dispute – apply formula, awareness of alternative argument • conclusion varies - will depend on arguments *What will Fred argue? What will the Prosecutor argue?* *Does not create new rule of law*	**Student Activity - apply formula – issue, rule, facts, conclusion (Cat 1)** Tutor Statement – creating an argument, awareness of two arguments – Fred's and Prosecutor's (Cat 2b) Tutor Statement – role of regulatory body (court) (Cat 2b) Tutor Statement – applying established principle vs. making precedent through argument (contrast, separation) (Cat 2b)
Scenario 4 – Fred in passenger seat, accidently causes car to move, travels at 50 kms in a 40 zone • facts vary, rule varies (definition of driver) • case Law introduced – create argument (interpretation of 'driver') • conclusion varies - will depend on arguments *Don't write using headings for exams. Rewrite in prose and keep expression fluid* *What are the two arguments?* *Is there such thing as a right or wrong answer?* *Is there such a thing as good/bad legal advice* *How comfortable are you with making a prediction?*	**Student Activity – apply formula – issue, rule, facts, conclusion (Cat 1)** **Student Activity – use case Law to create an argument to determine whether Fred is the driver (Cat 2b)** Tutor Statement – Right answer, better answer, comfort with making a prediction? (Cat 2b) Tutor Statement – difference in the type of legal reasoning and the different people who do it (Cat 2b) (introduction of variation in actors and purpose) Tutor Statement – stretch, extend a principle (Cat 2b) Tutor Statement – policy reasons for conclusion/outcome e.g. transfer of loss (introduction of acknowledgement of policy, Cat 3)

In all four workshops, the tutors emphasised the importance of following the steps of a legal reasoning process. The process was referred to by an acronym (IRAC or ISAAC) that differed between institutions but involved the same steps. Students were first expected to identify the legal issue, then decide the elements of the legal 'rule' that were involved, then apply the facts of the case to the rule and use this application to come to a conclusion. In teaching these scenarios, the tutors in all four classes frequently contrasted following the steps in this process with jumping straight to a conclusion.

By varying only the facts, whilst keeping the other aspects of the scenario constant between scenarios one and two, the curriculum design intended students to notice the different application of the rule to the facts and the different conclusions arising from different applications. In most workshops, the students responded by raising a wide range of other possibilities that might open up a legal argument but that were not in the statement of facts for the case. In terms of Variation Theory, this meant that many more features were varied than was intended. Noticeably, particularly in workshops 3 and 4, several students also jumped straight to the conclusion in scenario two. In all workshops, the tutors re-emphasised the contrast (variation) between reaching an outcome by jumping to a conclusion versus following the process or steps.

In scenario three, the tutors in all four workshops contrasted, or encouraged the students to contrast, the 'alleged' speed measured by the speed camera with the statement of a fixed speed. This opened the possibility of having varying arguments, one for Fred and one for the prosecution. This contrast was made in all workshops, but with differing degrees of clarity and emphasis. In workshop 1, the tutor contrasted this aspect of scenario three with scenarios one and two, by emphasising that this was different to the preceding scenarios and involved turning what was previously just an application of the rule into an argument. Likewise, in workshop 4, the tutor noted that the 'alleged' speed introduced an element of contention and contrasted two ways of approaching it.

The treatment of scenario four varied the most between workshops. The tutors in workshops 1 and 4 spent the most time on this scenario, and were clear and explicit in inviting students to contrast the two different arguments that could be made. The tutors in workshops 2 and 3 also made this contrast, but the workshop 3 tutor spent more time contrasting other issues, such as the level of authority of the cases used, the level of court involved and the ways that cases could be matched to or distinguished from the facts. The tutor in workshop 1 also spent some time contrasting ideas such as whether there was a 'right' compared with a 'best' answer and the students' level of comfort in making a prediction.

Conclusions about the four enactments:

Overall, the two team leaders who analysed the videos agreed that workshop 1 offered the greatest potential for students to notice the critical features of the desired (category 2) understanding, because the intervention had varied these features whilst holding others constant (i.e., varied interpretations of the same fact/rule scenario). It also provided some opportunity for students to notice some features related to a category 3 understanding (i.e., that legal rules may be changed to produce the best outcome for society).

Workshop 1 was followed in learning potential by workshop 4. This workshop was expected to be less effective than workshop 1 because, although the tutor varied interpretations of the same fact/rule scenario, as in one, she also more frequently contrasted a good exam answer that followed the formulaic steps, with a poor answer that jumped straight to application and conclusion. This served to emphasise

the structured process of legal reasoning as a critical feature, but not the ability to develop contrasting arguments leading to different conclusions.

In workshop 3, there was variation in the desired features, but fewer aspects were held constant and many more other features of the Law were varied simultaneously. Whilst this offered the *possibility* of students developing more complex understandings through discerning the variation in desired features presented, this was less likely than in workshops 1 and 4 because the degree of simultaneous variation would reduce students' chances of discerning variation in any one particular feature. In workshop 2, the desired features were varied, but less clearly, with less time placed on comparing the different arguments in scenario four. Consequently, it was anticipated that fewer students in this workshop would achieve the desired learning outcomes.

4.2.3 Student learning outcomes from the workshop

The students' written responses to the post-workshop question, 'what is the purpose of legal reasoning', were analysed phenomenographically and compared with the categories created from the original Law action research analysis. This revealed a distinction within category 2 (see below) that appeared to be a consequence of the revised curriculum design. Hence the categories used for classifying students' responses were expanded to include subcategories 2a and 2b (see Table 3 for an analysis of how the critical features relevant to categories 2a and 2b were enacted in one).

Brief descriptions and examples of student responses seen as representing a category 1-3 understanding of legal reasoning are presented below.

***Category 1**: The purpose of legal reasoning is to follow a formulaic process for predicting a legal outcome.*
Responses allocated to this category highlighted the structured process of legal reasoning but without reference to the possibility of developing different arguments or different conclusions from the legal reasoning process.

"Legal reasoning is important in deconstructing legal problems. In identifying the legal issues / rules which arise in the course of problem solving, legal reasoning provides a framework. This framework must be applied to the facts at hand sequentially and logically to reach a conclusion."

***Category 2a**: The purpose of legal reasoning is to make a reasoned argument for predicting a legal outcome.*
Responses allocated to this category also highlighted the structured process of legal reasoning (as with category 1) but in addition highlighted the importance of using the process to make an argument, not just reach a conclusion.

"To be able to formulate an argument, apply relevant Law and broad principles to arrive at the most probable conclusion or solution. To solve issues using the Law and its application. To apply a methodical approach to solving issues using the Law applying to the issues to come to a solution or conclusion."

***Category 2b**: The purpose of legal reasoning is to engage in an interpretive process of considering different possible arguments and legal outcomes.*
Responses highlighted the importance of using a structured process to make an argument (as in category 2a), but also showed awareness of the possibility of preparing different arguments leading to different conclusions.

"The purpose of legal reasoning is to argue the facts of the case in different directions. There may be two or more similar cases with facts that have been decided and the issues / facts could be distinguished or have an analogy formed in relation to the outcome wanted. There may not be one particular right answer, however in terms of Law exams etc it is essential that you apply / argue your view."

Category 3: *The purpose of legal reasoning is to engage in a responsive process for developing the Law to reflect changing society.*
This category of understanding went beyond the official goals of the curriculum design, but was still achieved by some students. Responses highlighted similar aspects to category 2b, but also went beyond them to show awareness of wider issues or impacts of the Law.

"The purpose of legal reasoning is to help comprehend, interpret and develop areas of Law. An understanding of legal reasoning is vital when determining possible outcomes and questions in Law, and also when predicting the development of specific areas of Law."

Conclusions about the learning outcomes:

It was noticeable from the videos of the workshops that all tutors placed emphasis on comparing the use of the steps in legal reasoning (IRAC/ISAAC) with jumping to a conclusion, which we saw as having aspects of a pre-category 1 understanding. By the end of the workshop, no students were observed on the video to be jumping to a conclusion or failing to consider the legal rules and cases provided. Also, no student responses failed to mention the need to follow a process or use certain steps in reaching a conclusion. The tutors were evidently successful in ensuring that all students at minimum had noticed that there was a structured process to legal reasoning that was to be worked through before reaching a conclusion.

In addition to this observation of common outcomes, there were differences in outcomes between the workshops (see Table 4) that seemed broadly in line with the predictions made from the video analysis. The lecturers' desired outcome was that student learning from the curriculum design would reach category 2. Although this was often achieved, a category 1 outcome was also common. Observations of the videoed implementations of the design explain this, because in practice, the implementations often emphasised variation in elements of legal reasoning that related to category 1 more than category 2.

Table 4: Categorisation of student responses to the short-answer question

Learning outcomes	Workshop 1	Workshop 2	Workshop 3	Workshop 4
Category 1	3	7	16	16
Category 2a	1	4	5	10
Category 2b	2		2	3
Category 3	1		2	2

The number of students in workshop 1 was low, but it was noted that 57 per cent of students gave responses above category 1, with 43 per cent of the students allocated to categories 2b and 3. In workshop 4, which we predicted as the next most likely to bring about the desired (at least category 2) understanding, 48 per

cent of students gave responses above category 1, with 16 per cent in categories 2b and 3. In workshop 3, which we saw as affording desired understandings but also creating possible confusion, 36 per cent of responses were above category 1 with 16 per cent in categories 2b and 3. In workshop 2, which we saw as affording the least opportunity for students to notice variation relevant to category 2, 33 per cent of responses were in category 2a but none were above this.

The pattern of responses was broadly in line with our predictions of the relative effectiveness of the workshops based on the analysis of what was varied and held constant, although the small numbers of responses from workshop 1 make it difficult to draw firm conclusions. From this point of view, the results were encouraging for demonstrating the value of Variation Theory for improving student learning. It is clear, however, that more than one iteration of curriculum design and implementation would be needed to optimise use of Variation Theory.

4.2.4 Suggested revisions to the curriculum design and guidelines to tutors for future iterations

It was apparent from the videos of the workshops that student *activity* was frequently directed only at applying the legal reasoning formula, not at creating varying arguments, even though tutor *statements* may have highlighted the development of varying arguments (see for example, Table 3 above). This meant that student activity primarily emphasised only a category 1 or 2a understanding of legal reasoning.

To increase opportunities for students to notice variation in the features of legal reasoning required to achieve a category 2b level of understanding, we suggest that future curriculum revisions aim to involve the students more strongly in actively creating alternative arguments (ideally in writing) for the same fact/rule scenario. We suggest that these arguments be presented from the perspective of the different legal practitioners, i.e. defence, prosecution and judge. Awareness of the combined perspective of defence and prosecution would target category 2b understanding. Introduction of the perspective of the judge would provide the opportunity to target category 3 understanding, by introducing the role of policy in legal reasoning.

4.3 Potential for ongoing uptake of the project approach to curriculum design

All participants were keen to continue using what they had learned from the project in their own teaching and curriculum design. They were equally keen to continue disseminating project outcomes and personal insights to colleagues, both formally, through presentations and publications, and informally. There have already been eight conference presentations by participants and project leaders; one of which has led to a refereed publication, with more in train. One outcome of the final project meeting in November 2010 was the development of a publication plan by both disciplinary groups. The Law group is also keen to edit a book on Threshold Concepts in Law, to extend the impact on Law teaching in the sector following publication of their action research and curriculum design outcomes.

Disciplinary dissemination was also inherent in the project design, with 20 disciplinary teachers involved: nine as project participants and 11 as tutors and demonstrators. This is in addition to the three Physics and Law disciplinary specialists on the reference group, one of whom, Anna Wilson, is now actively engaged with the Physics participants in further analysis and dissemination of project outcomes.

Three of the project participants and two members of the reference group hold or have held positions of significant disciplinary influence at a national level that facilitates disciplinary dissemination:

- leadership of the Carrick Disciplinary-Based Initiatives in Physics (Les Kirkup and Manjula Sharma, project participants) and Law (Michael Coper, reference group)
- appointment as an ALTC Senior Teaching Fellow (Sally Kift, reference group) or Teaching Fellow (Rachael Field, project participant)
- leadership of other ALTC projects (Charlotte Taylor, reference group, and Les Kirkup, project participant).

Dissemination will be supported by the public website of resources and outcomes developed as part of the project: http://www.thresholdvariation.edu.au
This website is designed to be of value to all stakeholders, including education developers seeking to trial the approach in their institution, teachers in Physics and Law looking to experiment with their own curriculum design, as well as teachers from other disciplines. The site includes curriculum design examples, case studies of implementation, curriculum resources, and implementation guidelines.

Transportability of the project processes across different disciplinary and institutional contexts was tested and demonstrated during the project through the equally successful involvement of different disciplinary and institutional types. In all, the project trialled the curriculum design approach in seven contexts, involving two disciplines in four universities. Further, the substantial difference in the nature of the two disciplines (Physics and Law) and the four institutions (research-intensive and universities of technology) provided a test of transportability.

Participants' perceptions of the potential for ongoing uptake of the project approach to curriculum design was explicitly sought through a confidential interview with lecturers, tutors and demonstrators conducted by the external evaluator towards the end of the project (see Appendix 15: Changes in participants' understandings as an outcome of the project). This interview sought participants' views on:

- aspects of the project that they would continue to use in the future
- whether there were any aspects that they would avoid using or processes that they would use differently
- whether they would recommend the approach to colleagues in their own discipline and other disciplines.

Although the extent of enthusiasm varied between individual participants, overall, participants (especially full project participants) were keen to continue using the approach and happy to recommend it to colleagues. The greatest concern in both their own continuing use and in recommending it to colleagues was due to the resource-intensive nature of the approach. However, when less time-intensive approaches were discussed, the general reaction was that there would be a substantial reduction in the learning and teaching gains from such abbreviations.

Another way of looking at this issue is that such a resource-intensive process can be justified, but only for aspects of the curriculum that are of a particularly foundational and troublesome nature, and of broad disciplinary value, i.e., Threshold Concepts. Given the integrative and foundational nature of such concepts, a small number of projects such as this one could lead to a broad disciplinary impact.

5. Project dissemination

Project processes and outcomes have been disseminated in Australia and overseas in a variety of ways, including:

- presentations at national and international conferences and symposia
- presentations at departmental seminars
- preparation of refereed publications
- preparation of a public website of project resources and outcomes.

Disciplinary dissemination was also embedded within the project design through the train-the-trainer approach, in which lecturers disseminated their understandings of disciplinary Threshold Concepts, action research using a phenomenographic approach, and curriculum design using Variation Theory to tutors or demonstrators in their courses. Furthermore, the involvement of tutors/demonstrators in the action research and curriculum implementation stages of the project provides additional dissemination advantages. Because first-year tutor/demonstrators are often PhD students entering the discipline, this approach has helped to disseminate the curriculum design model and outcomes to future academics entering the disciplines. In addition, the experience of training and involving their tutors/demonstrators in the project has enhanced participants' ability to explain and disseminate the model to disciplinary colleagues in other situations.

5.1 Presentations and publications

Built into the project has been the expectation that lecturers and tutors/demonstrators, as well as project leaders, would present seminars and conference papers on the curriculum design model within departments and at disciplinary conferences. The project included conference funding for participants, who presented papers at the following conferences (presenters underlined):

Åkerlind, G., Carr-Gregg, S., Field, R., Houston, L., Jones, J., Lupton, M., McKenzie, J., & Treloar, C. (2010, June). *A Threshold Concepts focus to first year Law curriculum design: Supporting student learning using Variation Theory.* Presentation at 13th Pacific Rim First Year in Higher Education (FYHE) Conference, Adelaide, South Australia.

Åkerlind, G., Wilson, A., McMahon, C., McKenzie, J., & Lupton, M. (2010, December). *Adapting educational theory to discipline pedagogy: Integrating research, teaching and scholarship*. Presentation at Society for Research into Higher Education (SRHE) Annual Research Conference, Newport, Wales.

Kirkup, L., McKenzie, J., Francis, P., Sharma, M., Pearce, D., Wilson, A., & Åkerlind, G. (2010, October).*Enhancing student understanding of uncertainty in measurement through the application of phenomenographic analysis and Variation Theory*. Presentation at International Society for the Scholarship of Teaching and Learning (ISSOTL) 2010 Conference, Liverpool, United Kingdom.

Lupton, M., Åkerlind, G., & McKenzie, J. (2010, December) *Phenomenography and Variation Theory applied to teaching and learning legal reasoning*. Preseentation at Phenomenography & Variation Theory Symposium, University of Technology, Sydney (UTS), Sydney, New South Wales.

McKenzie, J., Åkerlind, G., Lupton, M., & Trigwell, K. (2010, July). *Spaces of variation in understanding uncertainty and legal reasoning: Extending*

understandings of transformation, irreversibility and liminality in coming to understand Threshold Concepts. Presentation at the 3rd Biennial Threshold Concepts Symposium, The University of New South Wales (UNSW), Sydney, New South Wales.

Pearce, D., & Markwell, T. (2010, September). *ALTC Threshold Concepts and Variation Theory project: The Physics focus and preliminary results*. Presentation at the National Uniserve Science Conference (Physics Discipline Day), The University of Sydney, Sydney, New South Wales.

Sharma, M., McKenzie, J., Francis, P., Kirkup, L., & Pearce, D. (2010, July). *Student understanding of uncertainty*. Presentation at American Association of Physics Teachers (AAPT) Conference, Portland, Oregon.

Wilson, A., Åkerlind, G., Francis, P., Kirkup, L., McKenzie, J., Pearce, D., & Sharma, M. (2010, September). *Measurement uncertainty as a Threshold Concept in Physics*. Paper presented at the National Uniserve Science Conference, The University of Sydney, Sydney, New South Wales. [Accepted for publication in refereed conference proceedings]

5.2 Public website of project resources

The public project website http://www.thresholdvariation.edu.au provides a major and long-lasting resource to support dissemination of the model, and has been linked to the disciplinary sections of the ALTC Exchange. The website provides a set of curriculum design resources based on the project model, including case study examples, video clips of implementation, copies of seminar and conference papers, and links to relevant resources on disciplinary sites, such as Physclips and the Merlot repository.

6. Project evaluation and linkages

6.1 External evaluation

There have been two external evaluators associated with the project. The first evaluator, Dr Mia O'Brien, The University of Queensland, acted as an external evaluator during 2008-2009. In this role she attended the first two project workshop meetings, as a participant observer, in December 2008 and September 2009. The focus of her evaluation was on the project processes (see Appendix 14: Evaluation and Observations, December 2008-September 2009).

The second external evaluator, Camille McMahon, acted as evaluator in 2010, with a focus on evaluating project outcomes. She also attended the third and final project workshop meeting as an observer in November 2010 (see Appendix 15: Changes in participants' understandings as an outcome of the project).

6.2 Internal evaluation

The project had three principal aims, to develop and trial a model of curriculum design that:

1. focuses extra teaching and learning attention on the most significant parts of the curriculum (using Threshold Concepts)
2. enhances teaching and learning of particularly difficult concepts (using phenomenographic action research and Variation Theory)

3. is readily transportable across different disciplinary and institutional contexts.

Evaluation of each aim was embedded in the project design. Transportability across different disciplinary and institutional contexts is indicated by the equal success of the project in each context. In all, the project trialed the model in seven contexts, involving two disciplines in three-to-four universities. Further, the substantial difference in the nature of the institutions and the Physics and Law disciplines provides a test of transportability across different disciplinary and insititutional types.

Teaching and learning outcomes from the curriculum design model are indicated by the reported impact of the project on participants' professional development as teachers, and the analysis of learning outcomes from different curriculum implementations described in the Project Impact section.

There was also ongoing formative evaluation of the project processes throughout the project. Each meeting/workshop included a formative evaluation component, seeking lecturer perceptions of the value of the meeting and between-meeting processes, and consequent understanding of the learning theory, action research methodology and curriculum design processes involved. Feedback from each meeting was used to inform the design of subsequent meetings as well as contributing to the overall project assessment.

6.3 Related ALTC projects

The disciplinary focus of this project provided an opportunity to build on past ALTC initiatives such as the Carrick Disciplinary-Based Initiatives (DBI) in Physics and Law, with Les Kirkup and Manjula Sharma (Physics) and Michael Coper (Law) involved in this project as previous DBI project leaders, (the first two as a team members and the second on the reference group).

The focus on Threshold Concepts has also allowed us to link to another recent ALTC project, 'Using Threshold Concepts to Generate a New Understanding of Teaching and Learning Biology'. The team leader for that project, Dr Charlotte Taylor, has been a member of this project's reference group.

Another related project is the 'Engineering thresholds: an approach to curriculum renewal' project, which is being led by The University of Western Australia's Professor Caroline Baillie. The project is focusing on those essential and critical foundational concepts that substantively define the thresholds or portals for engineering students of any discipline. Professor Baillie attended a session at which this project was presented at the Third Biennial Threshold Concepts Symposium held in Sydney in July 2010.

Two of the disciplinary lecturers involved in the project, Associate Professor Les Kirkup and Rachael Field, are ALTC Fellows. Les's project focused on service teaching, which was also the context for the curriculum redesign in Physics at some universities involved in the project. Rachael's current project has a focus on first year Law students, and she has shared some of her fellowship ideas with her Law colleagues in meetings in this project. ALTC Senior Fellow Professor Sally Kift was on the project reference group.

7. Factors that contributed to and impeded project success

A number of factors contributed to the successes of the project. These include the theoretical grounding of the project, the engagement of team members and the approaches to project communication and management.

The theoretical grounding of the project in the ideas of Threshold Concepts, Phenomenography and Variation Theory made it intellectually appealing to the project team and to disciplinary academics. Interviews conducted with disciplinary team members showed that they perceived value in focusing on a Threshold Concept in their discipline and discussing it with disciplinary colleagues. This was the case even if they were not entirely convinced of differences between 'threshold' and 'key' or important concepts. Most team members valued the phenomenographic interviews with students and felt that they had learned a great deal about students from the process, although noting that interviews were time consuming. Although several team members noted that they did not feel that they had a good understanding of Variation Theory, several did comment on the value of thinking more explicitly about variation in the curriculum. The theoretical ideas also contributed, in various ways, to changes in many team members' understandings of teaching, their students' learning or even the disciplinary concepts themselves. A second iteration of curriculum design would have done much to further cement these changes.

The theoretical grounding was also a necessary requirement for disciplinary academics who sought to both improve their students' learning through the curriculum and have the potential of achieving disciplinary research and scholarship outcomes. This was particularly the case for the Physics academics, who chose measurement uncertainty as their Threshold Concept in part because student learning of this concept had not been researched very much previously, and thus had greater potential for research and publication outcomes.

The second broad factor that contributed to project success was the ongoing involvement of the group members. All of the initial project leaders and disciplinary academics were involved throughout the project, even though the role of one disciplinary academic changed. A member of the Physics reference group, Dr Anna Wilson, also became very closely involved, including in the interview analysis and advising on curriculum redesign. We perceive this to be a function of both their personal commitment and the project focus. The group members were all committed to improving students' learning and strongly valued the opportunity that the project provided for peer collaboration and discussion of important disciplinary concepts.

A third factor was the project design that included three face-to-face meetings and a budget allocation for disciplinary academics to present aspects of the project at conferences. This supported extended conversations that were important for analysing interviews, exploring curriculum design options and encouraging group reflection, as noted in the interviews with disciplinary academics. Communication was also facilitated by the use of multiple strategies including a project Moodle site, which was used by some participants but not others, access grid and videoconference meetings and email.

The major factor impeding the maximisation of project outcomes in both disciplinary groups was the timeframe for the project. Within a two year period, it was possible to complete all of the planned steps in the action research approach: identifying a Threshold Concept, interviewing students, redesigning curriculum and implementing aspects of the redesign. However, it was not possible to learn from and refine the process. This meant that the assessment of improved learning outcomes needed to be carried out on the first curriculum implementation, rather than there being a chance to pilot, formatively evaluate and refine the approach. This limited the extent

to which the model and associated improvements in learning outcomes could be adequately assessed across both disciplines and the range of contexts. (The inherent challenges in achieving rigorous assessment of improvement in learning outcomes across different contexts with different enabling and constraining features are also worth noting.)

Another factor that increased the level of challenge for the project was the level of control that the disciplinary academics had over the first year curriculum, especially in relation to making changes over a short timeframe. At the time of project initiation, we invited team members who had teaching responsibility for core first year subjects. However, some academics' roles changed such that they were no longer convening the target subject by the second year of the project. Others worked in institutional contexts where a longer process is needed in order to make changes to the curriculum. Despite this challenge, all disciplinary team members did continue to participate in the project and all but one were able to implement curriculum changes that used Variation Theory to improve students' learning of the Threshold Concept.

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9. Appendices

Appendix 1: Workshop 1 meeting agenda

Identification of Threshold Concepts

Preliminary workshop outline
December 16-17, 2008

Location: University of Technology, Sydney
IML seminar room, Room 1.2715, Level 27, UTS Tower Building, Broadway

Day 1 -- Tuesday, December 16

12.00 Open with lunch

1. 30 Introduction to project and workshop (Gerlese Åkerlind)

2.00 Introduction to Threshold Concepts (Mia O'Brien)

2.30 Identifying Threshold Concepts in participants' own course (Mandy Lupton)
(includes afternoon tea/coffee break)

5.00 Close -- check into hotel (Mercure)

6.00 Dinner

Day 2 -- Wednesday, December 17

9.00 Question/answer session re project and Threshold Concepts (Gerlese Åkerlind)

9.30 Selecting a Threshold Concept for the action research project (Keith Trigwell) *(includes morning tea/coffee break)*

12.00 Lunch

1.00 Discussion (Jo McKenzie):
(1) how participants currently address the selected Threshold Concept in their courses;
(2) what variation in students' understanding of the Threshold Concept participants currently experience.

3.30 Close -- where to from here (Gerlese Åkerlind)

4.00 Transport to airport

Appendix 2: Guidelines for designing phenomenographic interviews

Student Interviews

Often, a good way to elicit rich information about the variety of student conceptions is to conduct loosely structured interviews where the questions are not just directed at finding out about what the students do or think, but why they do or think those things. There are many examples of such interviews in the literature, and the examples given here are intended to give a flavour of the process, rather than a prescription for what to do. One thing common to the interview examples given here is that they are all drawn from the discipline of Phenomenography.

Interview Structure

Interviews which aim to uncover a range of perceptions of approaches are characterised by their loose structure and the open-ended nature of the questions.

Typically, the interviewer might start by asking the interviewee about what they do in a particular situation, or how they would go about approaching a particular activity. That is, each interview starts with the same (or similar) questions or scenarios.

The remainder of the interview is likely to be governed strongly by the responses of the interviewee. Initial responses may be followed up with questions such as
"Can you tell me more about that?"
"Why do you think (or do) that?" or
"Why do you think you do it that way?"
As the interview progresses, the interviewer may need to lead the interviewee into providing more detail, or considering something in a new light, but in general leading questions are avoided. Typical questions asking for more depth or information might include
"Why did you say that?"
"You have talked about X, but what does X mean to you?"
"You have talked about X and Y - how do you think these two things relate to each other?"

Green, in the second chapter of *Doing developmental Phenomenography* (Bowden & Green 2005), described types of questions she had found herself asking in pilot interviews at the start of a project:

- Clarification questions:
  - Tell me more about that ...
  - Describe that to me from start to end.
  - Tell me how you felt about that ...
- Playing the naive:
  - What do you mean? I'm not clear ...
  - Your substantive area is not my own and so there are some things here I am not clear about (e.g. You used the term XXX, can you define it for me?)
- Exploring contradictions:
  - It is interesting to me that earlier you noted that X was significant, but later you talked about Y. These seem to contradict each other. Can you tell me about that?

Examples

In chapter 8 of the same book (Bowden & Green 2005), Akerlind describes how she designed, conducted and analysed interviews for her doctoral thesis. The primary aim of her interviews was "to encourage participants to reveal their ways of understanding of their own growth and development as an academic." She outlines the first part of her adopted interview structure as follows:

1. First, by way of context, can you tell me what your current appointment is and a little about your history as an academic?
2. Based on your experiences so far, what does it mean to you to bean academic?
3. Can you give me a concrete example of something you do as an academic?
    - Why do you do that?
    - What were you hoping to achieve?
    - Why did you do it that way?
4. Do you envisage what you're doing as an academic changing over time?
5. This raises the issue of academic growth or professional development - can you tell me, what does growing and developing mean to you, as an academic?
6. Can you give me a concrete example of something you've done to help you develop or grow as an academic?
    - How did you go about that?
    - Why did you do it that way?
    - What did you gain or hope to gain from it?

While these questions are not the ones you will want to ask your students, they provide a good illustration of how an interview can be designed which, while following a path likely to lead to the researcher obtaining data of interest, allows the interviewee to choose to focus on examples and experiences that he or she feels to be key parts of answering the questions.

The phenomenographic approach has been used widely in the past two decades, and examples of phenomenographic research based on interview data can be found in many fields.

Reference

Bowden, J A & Green, P 2005, Doing developmental phenomenography, RMIT University Press, Melbourne.

Appendix 3: Law interview schedule

Interview questions

- Primary questions:
  1. How would you describe 'legal reasoning'?
  2. How does legal reasoning differ from other forms of reasoning?
  3. How does this (trigger scenario) evidence legal reasoning?

- Follow-up Probes:
  (Probe on the *purpose* of the different aspects of legal reasoning that students describe)
  - What is the purpose of that?
  - Why is that important?
  - Why would you do that? / why do you think they did that?
  - What would happen if you didn't do that?
  - What do you mean by that?
  - Can you tell me more about that?
  - Can you give me an example in practice?
  - How could you do it differently?

- Summary question:
  - Before we finish, could you please summarise for me again what you think constitutes legal reasoning and why we need legal reasoning.

Trigger scenario

grant and hurley solicitors

MEMORANDUM OF ADVICE

To:	JENNY BANISTON, Supervising Partner
From:	STUDENT DE QUT, Articled Clerk
Date:	26 JUNE 2009
Re:	ANGELA SMITT – PRIVACY
File No:	JB2006/231

1. STATEMENT OF RELEVANT FACTS

Angela Smitt recently contacted our firm seeking advice regarding a range of issues including divorce, post-separation parenting issues, and a possible action for invasion of privacy. This memorandum relates to the privacy matter.
Angela was married to Bradley six months ago in Australia. They are both well known actors, are Australian citizens, and currently reside in Australia. They have an infant child, Brangela, who is five months old. Brangela is currently residing with Angela. Angela wishes to divorce Bradley and exclude him from the future parenting of Brangela.

Angela is concerned to protect Brangela's privacy as she grows up, and to keep her out of the public eye. Despite her efforts, the paparazzi have taken a photo of Brangela. The photo was taken in a public place, and has been sold to Celebrity Gossip magazine. It is due to be published next week. Angela is seeking advice regarding the possibility of a cause of action for breach of privacy.

2. SUMMARY OF ADVICE

Angela does not have a cause of action in this matter for breach of Brangela's privacy.

3. PRIVACY

3.1 Is there a right to privacy in Australia?

The case of *Victoria Park Racing and Recreation Grounds Co Ltd v Taylor*[1] has traditionally supported the view that Australia **does not recognise a tort of invasion of privacy**.[2] However, in *Australian Broadcasting Corporation v Lenah Game Meats Pty Ltd*,[3] the **High Court rejected the authority** of that case,[4] opening the door for a future High Court to recognise such a right.

3.2 Has Brangela's privacy been invaded?

To date, *Grosse v Purvis*[5] is the only case that has **explicitly recognised** a right to privacy. In that case, the Queensland District Court found that in order to prove an invasion of privacy, four elements must be satisfied:

The first element - there must be a willed act by the defendant.[6] In this instance, the taking of the photo of Brangela would be considered a willed act.

The second element – the act must intrude upon the privacy or seclusion of the plaintiff.[7] The photo was taken in a public place. Therefore, it does not intrude upon the privacy of Brangela.

The third element – the act must occur in a manner which a reasonable person of ordinary sensibilities would consider highly offensive.[8] In this matter there is no indication that the photo was taken in a manner which would be considered highly offensive by a reasonable person.

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[1] (1937) 58 CLR 479 at 496.

[2] D Butler, 'A Tort of Invasion of Privacy in Australia?' (2005) 11 *Melbourne University Law Review* <http://www.austlii.edu.au//cgi-bin/disp.pl/au/journals/MULR/2005/11.html?query=abc%20v%20lenah%20game%20meats#fn15> at 26 June 2009. See also, for example, *Cruise v Southdown Press Pty Ltd* (1993) 26 IPR 125, 125; *Australian Consolidated Press Ltd v Ettingshausen* (Unreported, New South Wales Court of Appeal, Gleeson CJ, Kirby P and Clarke JA, 13 October 1993).

[3] (2001) 208 CLR 199.

[4] *Australian Broadcasting Authority v Lenah Game Meats Pty Ltd* (2001) 208 CLR 199 at 248

[5] [2003] QDC 151.

[6] *Grosse v Purvis* [2003] QDC 151 at [444].

[7] *Grosse v Purvis* [2003] QDC 151 at [444].

[8] *Grosse v Purvis* [2003] QDC 151 at [444].

The fourth element - the act must cause the plaintiff detriment in the form of mental, psychological or emotional harm or distress, or prevent or hinder the plaintiff from doing an act which they are Lawfully entitled to do.[9] There is no evidence to suggest that any harm or distress has been experienced by Brangela as a result of the paparazzi taking the photo.

Therefore, as there is no recognised tort of invasion of privacy in Australia, and as the circumstances around the taking of the photograph of Brangela do not satisfy the threshold test established in *Grosse v Purvis*, there is no cause of action in this matter for breach of privacy.

3.4 Recommendation

It is recommended that Angela **should not pursue an action** for invasion of Brangela's privacy.

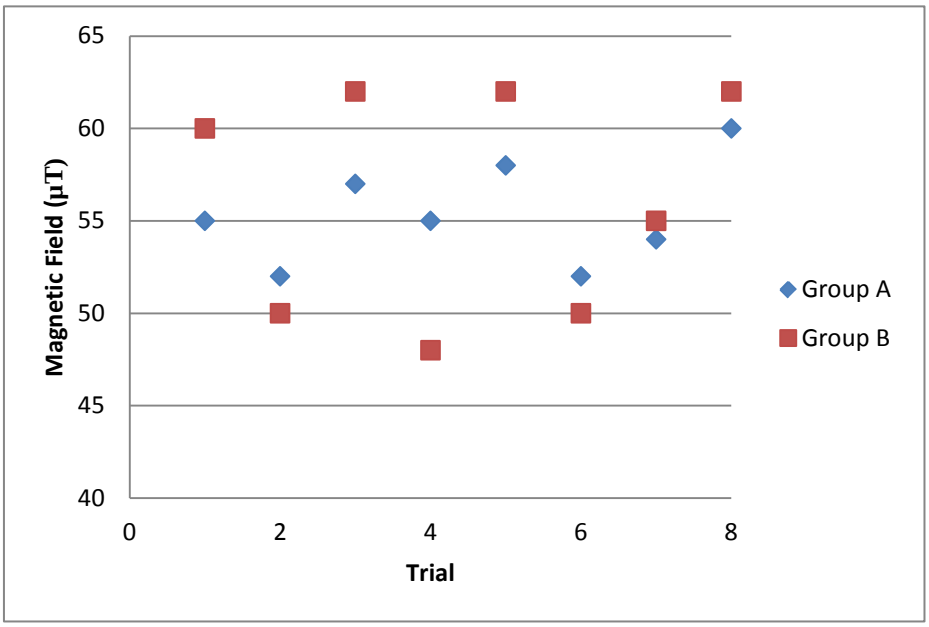
[9] *Grosse v Purvis* [2003] QDC 151 at [444].

Appendix 4: Physics Interview schedule

Students were shown each trigger scenario, accompanied by the questions below.

Scenario 1: Magnetic Field Measurement Comparison

You go to a Magnetic Observatory where scientists are making sensitive measurements of the Earth's magnetic field and they wish to compare these measurements with theories about the composition of the Earth.
You go into a laboratory where two groups of scientists (group A and group B) are each busy with their own experiment to measure the magnetic field in the laboratory on that day. The table and graph below show the data gathered by each group.



Trial	Group A Magnetic field (μT)	Group B Magnetic field (μT)
1	55	60
2	52	50
3	57	62
4	55	48
5	58	62
6	52	50
7	54	55
8	60	62
average	55.4	56.1

Questions

1 What do you make of these data?

2 Would you say one of the two groups' data were better than the other? [Follow up: If so, which one and explain your choice]

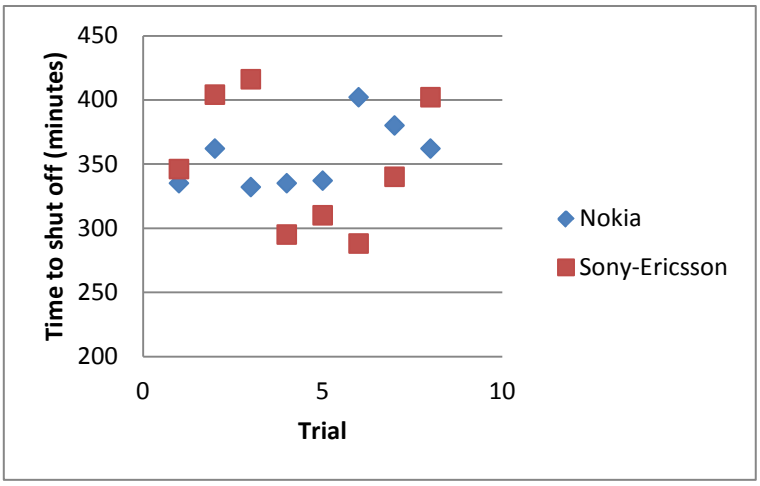
3 Given these data, what value would YOU give for the strength of the Earth's magnetic field as measured in the laboratory?

4 Is there any more information you would like before committing yourself to giving a value for the magnetic field?

5 Do you believe that the true value for the Earth's magnetic field can be found? [follow up: If yes, how would you find the true value?; if no, what would prevent you from discovering the true value?]

Scenario 2: Mobile Phone Battery Life Comparison

Battery life is a big factor that customers take into account when deciding which mobile phone to purchase.
A consumer group wishes to advise potential purchasers of competing Sony-Ericsson and Nokia phones about the battery life of phones available from each manufacturer.
The consumer group devise a standard test in which each phone is initially charged fully. For each phone, the display brightness is set to 50% and backlight is illuminated for 10s. used
A landline is called with each phone. The call continues until the battery drains, and the phone shuts itself off.
The consumer group test the Sony Ericsson K610i and the Nokia N72.
The time for each phone to shut off is shown in the table and graph below (each mobile phone is recharged between trials).



Trial	Nokia time to shut off (minutes)	Sony-Ericsson time to shut off (minutes)
1	335	346
2	362	404
3	332	416
4	335	295
5	337	310
6	402	288
7	380	340
8	362	402
average	355.6	350.1

Questions

1 What do you make of these data?

2 Given these data, would you advise someone to buy one of these phones? [Follow up: If so, which one and explain your choice]

3 Is there any more information you would like before giving your advice?

4 Do you believe that the true value for the shut-off time for each phone can be found? [follow up: If yes, how would you find the true value?; if no, what would prevent you from discovering the true value?]

Final round-up questions

If a student mentions uncertainty during the discussion then we can move on to the round-up questions below. If they don't mention uncertainty perhaps we could say, *Scientists often talk about uncertainty in their results.* (now move onto round up questions]

Final round-up questions:
Why does uncertainty matter? [Probe: Can you give an example in which knowing the uncertainty matters?]

Appendix 5: Guidelines for conducting phenomenographic interviews

Interview guidelines

The way you start the interview is very important, because this is your opportunity to create a comfortable atmosphere in which the students will talk *freely* without any sense that what they say is being judged by you or is likely to be repeated to others (other than within the project). Choose a relaxed setting, offer them a drink or biscuit.... Reassure them that this isn't about finding the right answers, you are interested in how they think about the issues presented. Indeed, what you're looking for is *differences* in how students think about the issues rather than finding a one right way.

Assure them of confidentiality and reassure them that their responses to the interview will *not* influence your evaluation of their work in any way. (In this respect, it is easier if you are interviewing previous students rather than current students, or if the tutor/demonstrator working with you is interviewing current students in someone else's tutorial/lab rather than in their own.)

The interviews will take a variable amount of time, because some students will spontaneously talk at length, while for others, getting them to elaborate on their responses will feel like pulling teeth. Ideally, I would be hoping the interviews will take about 30 minutes, + or -10 minutes, but longer interviews would not be a major problem.

As already indicated, some students will respond to your initial questions at length (though not necessarily on the topic), others only briefly. Sometimes, they will simply say that they don't know what you mean by the question you have asked, or be silent. So you need to be ready to make the trigger question more meaningful to them by phrasing it in an alternative way.

Because students will often give only a brief reply to the initial trigger question, or give a reply where you can't be sure what they mean, the follow-up probes often end up being more important than the trigger question. It is in the probes that you ask students to elaborate on their initial response, eg, to explain what they mean by particular terms that they use. *A common pitfall* is to assume that you know what the interviewee means by particular words and phrases that they use. No matter how obvious the meaning may seem to you on the surface, it is important that you always explore key words or phrases that seem significant to the student you are interviewing, for example,

- "What do you mean by that?"
- "Why do you think that is significant/ important?"
- "What would happen if you didn't take that into account?"

Keep your probes short. *A common pitfall* when interviewing is for the interviewer to say too much. Try to ask brief, guiding questions and encourage your students to do most of the talking. You need to encourage your students to talk at a detailed and concrete level about how they are thinking about the data you have given them, and *why* they are reaching particular conclusions. In your probes, place an emphasis on asking them to provide:

- Specific, *concrete examples* and illustrations, more than generic aims and principles (e.g., Can you give me an example of that?);
- Their *way of thinking* more than their actions (e.g., Why would you do that? Why do you think that is an important/useful thing to do?);and
- What *they actually* think or would do, not what they think they should do or what they think other people would do (e.g., What would *you* do here?).

Another common pitfall is to accidentally lead the student in a particular direction with your questions. You will note how open-ended the sample probes above are. I would recommend memorising some of these in advance so that you can pull them out easily when on the spot.

Appendix 6: Guidelines for analysing phenomenographic interviews

Suggested approach to analysis
(for the institutional analyses prior to the cross- institutional analysis at the Sept 2009 workshop)

On your own --

1. First, read though ALL the transcripts without marking anything – this is to get a sense of the group of interviews as a whole and not prejudge too early what is important/not important.

2. Then re-read each transcript, highlighting significant paragraphs and crossing out irrelevant paragraphs -- to reduce future reading load while continuing to become familiar with the transcripts.

3. Then organise the transcripts spatially (probably involving yet another reading), putting similar ones closer together and dissimilar ones further apart -- to help highlight the similarities and differences.

4. Then take each group of similar transcripts, and just read through those one group at a time, looking again for any that are more similar and more different within that sub-group -- this is to increase your sensitivity to similarities and differences.

5. What is it that marks these various groups and subgroups as similar and different? In other words, what are some students noticing about legal reasoning that others are not?

As a group --

I suggest that you and each of your tutors move through steps 1-5 independently -- you will each need to allow several hours for this, though it doesn't need to be done all in one sitting. Then meet up as a group (with your institutional contact) to discuss and compare observations. Allow about 90 minutes for this. Please briefly write up the outcomes of your discussion to bring to the September meeting.

Pre-reading: Law group

I attach 2 articles reporting a phenomenographic analysis of 'The experience of becoming a legal professional' by Reid, Nagarajan and Dortins (2006). It is the only phenomenographic research article I know of in the area of legal education, and I attach it simply to give you a better sense of what the outcomes of such an analysis can look like, in the hope that this will help you when doing your own analyses.

The other article, 'A phenomenographic approach to developing academics' understanding of the nature of teaching and learning' by Åkerlind (2008), is intended to give you a sense of how you will be able to use the outcomes of your interview analysis to inform your curriculum re-design around the threshold concept next year, so it is not as urgent to read.

Åkerlind, G. (2008). A phenomenographic approach to developing academics' understanding of the nature of teaching and learning. *Teaching in Higher Education, 13* (6), 633–644.

Reid, A., Nagarajan, V., & Dortins, E. (2006). The experience of becoming a legal professional. *Higher Education Research and Development, 25* (1), 85–99.

Pre-reading: Physics group

Linder et al (2006) 'Using a variation approach to enhance physics learning in a college classroom' and Fraser et al (2009) 'Teaching in higher education through the use of variation' – should give you a sense of what the analysis is for (and thus we hope help clarify what you are looking for in the analysis). Of the two, I think the Fraser article is more important and suggest you read this first. (The Åkerlind (2008) article is an optional extra if you have time.)

Åkerlind, G. (2008) A phenomenographic approach to developing academics' understanding of the nature of teaching and learning. *Teaching in Higher Education, 13* (6), 633–644.

Fraser, D., & Linder, C. (2009). Teaching in higher education through the use of variation: Examples from distillation, physics and pr ocess dynamics. *European Journal of Engineering Education, 34* (4), 369–381.

Linder, C., Fraser. D., & Pang, M.F. (2006). Using a variation approach to enhance physics learning in a college classroom. *The Physics Teacher, 44* (9), 589–592.

Appendix 7: Workshop 2 meeting agenda

Workshop outline
September 28-29, 2009

Location: University of Technology, Sydney
IML Seminar Room 1.2715, Level 27, UTS Tower Building, Broadway

Day 1 – Monday, September 28

12.0 Open with lunch

1.00 Review of progress to date and expectations for the 2 days (Gerlese)

1.30 Introduction to phenomenographic analysis of interview transcripts (Jo)

2.00 Break into disciplinary groups for further analysis
(Includes afternoon tea/coffee break)

5.00 Close – Check into hotel (Mercure)

6.0 Dinner

Day 2 – Tuesday, September 29

9.0 Review of previous day's progress (Gerlese)

9.30 Break into groups for further analysis
(Includes morning tea/coffee break)

11.30 Reporting back

12.0 Lunch

1.0 Introduction to Variation Theory and implications for curriculum design (Keith)

1.30 Break into disciplinary groups for discussion of curriculum redesign to address Threshold Concepts

3.30 Where to next--Close over coffee (Gerlese)

4.0 Transport to airport

Appendix 8: Law curriculum design

Because of individual differences in the circumstances of the three institutions (ANU, QUT, UTS) involved, participants implemented the same redesigned curriculum, but in different ways: in a 90 minute tutorial as an integral part of the *Foundations of Australian Law* course at ANU, as an optional (90 minute) session attached to the *Legal Method and Research* course at UTS, and as an optional (90 minute) stand-alone session at QUT not attached to any one course in particular.

Notes on Threshold Concepts exercise for 2010 teaching
"Driver" example

Fred is visiting the town of Coolah in New South Wales. This town values quiet and orderly conduct of its daily activities. At the entry of the town there is a prominent notice:

Welcome to Coolah! We value safe driving.

Coolah is in New South Wales and is subject to section 20 of the *Road Rules 2008* (NSW) "It is an offence for a driver to drive a vehicle at a speed over the speed limit applying to the driver for the length of road where the driver is driving."

Base Exercise: Legal reasoning using statutory rule

Fred is driving along the main road of Coolah. There is a sign stating that the speed limit is 40 kilometres per hour in a School zone. Fred is sitting behind the wheel of his car, in control of it, going at 60 kph. He passes a speed camera. Is Fred guilty of an offence under section 20.

This gives us an opportunity to demonstrate the way that HIRAC works to guide you through the process of legal reasoning.

Provide the students with this example.

The acronym HIRAC provides you with the steps in order

RUN THROUGH IT VERBALLY

Step one

H/I = Heading/Issue

Is Fred guilty of an offence under section 20 of the *Road Rules 2008* (NSW)?

[This is the legal issue that you are addressing.]

R = Rule
Next we need to give the relevant rule that addressed the legal issue:

To be guilty of this offence all 3 elements in Rule 2 must be satisfied.

Fred must be:
- a driver (element a) **and**

- in a vehicle (element b) and
- over the speed limit applying to the road etc (element c)

The source of the rule is, of course, Section 20 of the Road Rules 2008 (NSW)

A = Application
Element a - We are told that Fred is "sitting behind the wheel of his car, in control of it" so he is a driver.
Element b - Fred is in a "car" so it's clearly a vehicle.
Element c - The vehicle is travelling at 60 kph which clearly is over the displayed speed limit of 40 kph.

Conclusion (relates back to R) – since the three elements of the offence are satisfied then Fred is guilty of the offence.

THAT IS VERY BASIC LEGAL REASONING.

NOW – YOU TRY IT. THIS EXERCISE WILL HELP THEM TO GET IT DOWN ON PAPER.

IN CLASS EXERCISE ONE

Give them the exercise sheet to fill out.

Re-run the same scenario – this time they write an answer down – on the sheet (attached – copies available in the room).

HAND THIS SHEET OUT TO STUDENTS

In-Class Legal Reasoning Exercise 1

Fred is visiting the town of Coolah in New South Wales. This town values quiet and orderly conduct of its daily activities. At the entry of the town there is a prominent notice:

Welcome to Coolah! We value safe driving!
Subject to section 20 of the Road Rules 2008 (NSW)
"It is an offence for a driver to drive a vehicle at a speed over the speed limit applying to the driver for the length of road where the driver is driving."

Fred is driving along the main road of Coolah. There is a sign stating that the speed limit is 40 kilometres per hour in a school zone. Fred is sitting behind the wheel of his car, in control of it, going at 60 kph. He passes a speed camera. Is Fred guilty of an offence under section 20?

Heading/Issue

_____
_____

Rule including Source/Authority.

_____
_____

Application of the rule to the facts of the problem.

_____
_____

Conclusion in relation to the issue.

_____
_____

Please note – this is simply a tool to tease out the structure of your early attempts at HIRAC. You do not **EVER** write down these headings in legal writing for assignments, exams etc.

If you have time re-write this material into a paragraph with no headings and keeping your expression fluid.

In-Class Exercise- ANSWER
HIRAC WorkSheet

Heading/Issue

Is Fred guilty of an offence under section 20 of the *Road Rules 2008* (NSW)?

Rule including Source/Authority.

Section 20 of the *Road Rules 2008* (NSW) states that:
"It is an offence for a driver to drive a vehicle at a speed over the speed limit applying to the driver for the length of road where the driver is driving."

There are three elements to this offence.

Fred must be:
- a driver (element a) **and**
- in a vehicle (element b) **and**

over the speed limit applying to the road etc (element c)

Application of the rule to the facts of the problem.

Element a - We are told that Fred is "sitting behind the wheel of his car, in control of it" so he is a driver.
Element b - Fred is in a "car" so it's clearly a vehicle.
Element c - The vehicle is travelling at 60 kph which clearly is over the displayed speed limit of 40 kph.

Conclusion in relation to the issue.

(relates back to R) – since the three elements of the offence are satisfied then Fred is guilty of the offence.

Please note – this is simply a tool to tease out the structure of your early attempts at HIRAC. You do not **EVER** write down these headings in legal writing for assignments, exams etc.

If you have time re-write this material into a paragraph with no headings and keeping your expression fluid.
Is Fred guilty of an offence under section 20 of the *Road Rules 2008* (NSW)? Section 20 of the *Road Rules 2008* (NSW) states that: "It is an offence for a driver to drive a vehicle at a speed over the speed limit applying to the driver for the length of road where the driver is driving." In order to be guilty of this offence Fred must be: a driver and driving the vehicle over the speed limit applying to the road. Fred clearly is a driver, who is in a vehicle and, since we are told that he is doing 60 kph, this is clearly also over the speed limit of 40 kph. Since all three elements of the offence are satisfied, Fred is guilty of the offence.

When they finish – give them the following to test their comprehension/ability

Take exactly the same fact scenario but now Fred is travelling at 30 kph instead of 60 kph. Speed limit is still 40 kph.

[If they jump to the conclusion – ask the students to reason it out using the elements of HIRAC – verbally or on paper (whichever you prefer)]

What is the issue? Can they state it as a question that might form a heading?

What is the rule? (and source, ie the section)

What is the application?

What is the conclusion?

Does anyone have any questions?

Does everyone understand the application stage?

Pay particular attention to the application stage.
Do they know what they are doing here?

- This is **where they make close reference to the facts of the problem** that they are solving.
- Tell them to check that they have done this on their answer. Thorough application is where they will pick up lots of marks – and its something that is so frequently neglected.
- Sometimes requires the 'statement of the obvious' (but that is OK).

Broader point.
Are there cases likely to go to court?

No dispute about the facts.
No dispute about the Law.
So - unlikely to get to court – and in fact dealt with by issue of a notice and payment of a fine. Simple application of the legal rule to the facts.
Need a dispute as to facts or a dispute as to the scope of the rule to get to court.

Are you ready to try a variation of the same thing?

Variation 2: Rule constant - dispute the facts

Displayed speed limit = 40 kph
Fred is sitting behind the wheel of her car, in control of it, on the main street of Coolah. He passes a speed camera which **allegedly records** his speed at 45 kph.

Heading/Issue – is Fred guilty of an offence under section 20 of the *Road Rules 2008* (NSW)?

Rule –to be guilty of this offence the 3 elements must be satisfied. Fred must be:
- a driver (element a) **and**
- in a vehicle (element b) **and**
- exceeding the speed limit (element c)

Application
Element a - We are told that Fred is "sitting behind the wheel of his car, in control of it" so he is a driver.
Element b - He is in a "car" so it's a vehicle.
Element c - The vehicle is allegedly travelling at 45 kph which does exceed the speed limit but the driver disputes the accuracy of the speed camera.

Arguments for each side of dispute.
What will prosecutor argue? [Speed camera is accurate]
What will defendant (defendant's Lawyer) argue?
[Speed camera is not accurate]

Conclusion – If the court determines that the speed camera is accurate and the driver was driving in excess of the speed limit then the elements of the offence will be satisfied and the driver will be guilty of an offence.

Broader point.

This is a dispute about the facts. Role of the court would be to rule on what happened.
Unlikely to generate a new precedent and unlikely to be reported.
Does not create a new rule of Law.

Teacher's note: The point of the next exercise is to start to get students to realise that even apparently straightforward statutory rules have limits that can be tested – and that some fact scenarios will test those limits and this is when alternative arguments might be raised – ultimately contributing to establishment of new precedent (or a case interpreting the statute).

The HIRAC point of course is that HIRAC can be used as part of the framework to present alternative arguments, ie, arguments raised by each side/party to the dispute.

Hand out the extract *Harvey v Police* and the following problem and ask them to read it in class.

Variation 3: New fact scenario – dispute about the scope of the rule (and in particular, the meaning of 'driving' which is one of the elements in the rule).

Allow the students time to read the extract in class.

Then discuss with them what the case says about interpreting 'driving'.
Get students to put it into their own words – or to identify key phrases which explain the reasons given.

Commissioner of State Motor Car Insurance Office v Pullin
This case says that intention to drive is irrelevant. Did the person perform an act that made the car move?

Harvey v Police considers degree of control. Whether the person driving was seated in the passenger seat and able to operate the controls was important.
"It would be more natural to regard him as having interfered with the driving of the vehicle during the friend's temporary absence from the vehicle."
Subjective intention is relevant.

Once they are happy that they understand the rules in the case – ask them to apply it to the problem.

HAND THIS SHEET OUT TO STUDENTS

In-Class Legal Reasoning Exercise 2

Extract from statute.

Road Rules 2008 (NSW)

"Rule 20 Obeying the speed limit

A driver must not drive at a speed over the speed limit applying to the driver for the length of road where the driver is driving.

Penalty and disqualification: a driver who contravenes this rule is guilty of an offence and is liable to a maximum penalty and a period of disqualification …"

Week 2 – in class exercise 2

Fred is sitting in a car in the passenger's front seat on a summer's day. The car is parked outside some shops on the top of a steep hill and there is a school zone (speed limit 40 kph) at the bottom of the hill. Fred's girlfriend, who had driven the car as far as the shops, has just got out of the driver's seat to run into a shop for 5 minutes to buy some milk. Fred is hot waiting in the car so he puts the car out of gear, with the handbrake on and then turns the ignition on so that the car engine is running with the air-conditioning operating.

Fred then reaches across the car to get a map from the pocket in the driver's door. He accidentally bumps the end of the handbrake which releases the brake and the car begins to roll down the steep hill. Fred tries to re-engage the handbrake but the car has too much momentum and he cannot stop it using the hand-brake. He tries but cannot reach the foot pedals with his hands. From the passenger's seat he does manage to steer the car until the road levels out and the car comes to a stop on its own. Fortunately there was no collision, no pedestrians about and nobody was injured. However, before the car rolled to a stop it was caught by a speed camera doing 50 kph in the 40 kph school zone at the bottom of the hill. His hands were on the steering wheel at the time that the camera operated and his head and upper torso were leaning towards the driver's side of the car peering over the dashboard. However, his lower torso was seat-belted into the passenger's seat and he was not able to operate any of the foot pedals with his feet.

Is Fred guilty of an offence guilty of an offence under section 20 of the Road Rules 2008 (NSW)?

Consider the following case before formulating your answer.

The following is an extract from a case that was decided last year in the South Australian Supreme Court. It has been cut down and simplified for the purposes of this exercise. Since it has been modified, it is not authoritative and should not, in its amended form, be relied on in any formal legal setting. The purpose of this exercise is not to learn the contents of this case but to learn how to apply it (and cases like it) in legal reasoning.

SUPREME COURT OF SOUTH AUSTRALIA

Harvey v Police [2009] SASC 302
25 September 2009

White J.

On 5 May 2008, the appellant was a front-seat passenger in a manually-geared Ford Fiesta being driven by a friend. The friend drove the car into the Mobil Service Station on Main South Road at Morphett Vale in order to refuel. After he had used the petrol pump, the friend went inside to the console operator to make payment. While he was inside, the events giving rise to this appeal occurred. The appellant noticed that the friend had left the driver's door open. He was concerned that it may be struck by other motor vehicles. Without unbuckling his seat belt, he reached over the driver's seat and closed the door. While leaning over, he also turned the key which the friend had left in the ignition. His intention was to activate the car radio by turning the key to the accessories position. However, he turned the key one notch too far, activating the starter motor with the effect that he cranked over the Fiesta's engine. Although the engine did not start, the car, which was in gear, lurched forward. It then kept moving very slowly towards the console operator's position in the service station shop, just over five metres away. From his position in the front passenger seat, and using his right hand on the steering wheel, the appellant endeavoured to steer the car away from the building. He was unsuccessful and the Fiesta struck the metal frame at the console operator's window. ….

The word "drive" is defined in s 5(1) of the RTA (SA) as follows: *drive* includes be in control of.

The question of whether a person has driven a vehicle has arisen in a variety of factual circumstances and often involves a finely balanced decision. Although the word "drive" and its cognates are commonly used, the courts have not been able to develop a single test with which to determine whether a person was driving a vehicle. Instead, courts have, depending upon the circumstances, had regard to a number of factors, including the extent of the control in fact exercised by the defendant over the movement of the vehicle; the extent of the defendant's capacity to control the vehicle; the source of the vehicle's propulsion; the position of the defendant in, or in relation to, the vehicle; the perceived legislative policy underlying the statutory provision in question, or a combination of some or all of those matters.

… [t]here are cases suggesting that when a defendant performs an act which has the unintended effect that the vehicle moves, he or she may be regarded as driving it. In *Insurance Commissioner of State Motor Car Insurance Office v Pullin* (1971) 45 ALJR 176, the High Court upheld a finding that a youth who, while sitting in the driver's seat of a car which was stationary but with the engine running while receiving mechanical attention, had driven the car when he put the car into gear and released the clutch with the effect that the car moved forward a few metres. McTiernan J, with whom the other members of court agreed, said:
A contention was put forward that Baldwin did not intend to drive the motor car. It was not shown that the manipulation of the gear stick by which the motor car could be changed from neutral to a forward gear, and the operation of the clutch

were not voluntary acts on the part of Baldwin. The conclusion that he was driving the motor car when it caused the injury to Pullin was amply justified by the evidence. Even though Baldwin may not have intended to put the motor car in motion, in fact, he did so … Whether Baldwin set the motor car in motion intentionally or not he, as the driver of the motor car, incurred liability in respect of the injury caused to Pullin.

In the present circumstances, the appellant was exercising some control. It was his action in turning the ignition key one notch further than he intended which caused the Fiesta to move. Once it started moving, he attempted to control the direction of its travel by his movement of the steering wheel. In addition, if the appellant had wished to do so, he could have applied the handbrake. He said that he did not do so because of panic. In some of the cases reviewed above, even less control than that exercised by, or open to, the appellant in this case has been sufficient to amount to the driving of a vehicle. On the other hand, the appellant remained seat-belted in the passenger seat at all times. He could not operate the clutch, footbrake or accelerator and could not have changed gear. In addition, it would have been difficult for him to operate the other controls available to a driver of the Fiesta such as the indicator, lights or warning device. The engine of the car had not started and it moved only some five metres. In these circumstances it does not seem apt, using the ordinary meaning of the word “drive”, to describe the appellant as the driver of the Fiesta. It would be more natural to regard him as having interfered with the driving of the vehicle during the friend’s temporary absence from the vehicle. Reference to the appellant’s subjective intentions confirms that conclusion.
…

The putting of the Fiesta into motion was quite short. The appellant remained at all times seat-belted in the front passenger seat. He took hold of the steering wheel only as a reaction to the movement of the car which he had precipitated. He did so only in an endeavor to take evasive action. It would be a curious consequence if a person in his position was to be dissuaded from taking such evasive action …

When one has regard to all those circumstances, I do not consider that it can be concluded, beyond all reasonable doubt, that the appellant was a driver of the Fiesta. In my respectful opinion, the decision of the magistrate was wrong.

Accordingly, I will allow the appeal and set aside the convictions entered on 22 June 2009 and sentences imposed by the magistrate on 24 June 2009. I direct verdicts of acquittal on each of the charges against the appellant.

Heading/Issue

Is Fred guilty of an offence under section 20 of the *Road Rules 2008* (NSW)?

Rule including Source/Authority.

Section 20 of the *Road Rules 2008* (NSW) states that:
"It is an offence for a driver to drive a vehicle at a speed over the speed limit applying to the driver for the length of road where the driver is driving."

There are three elements to this offence.

Fred must be:
- a driver (element a) **and**
- in a vehicle (element b) **and**

over the speed limit applying to the road etc (element c)

Clearly in a vehicle and travelling over the speed limit. **But is Fred a 'driver' on this occasion?** What is the scope of the rule? Does it extend to someone not in the driver's seat who is accidentally driving?

What will the prosecutor argue?
That the **relevant rule** is: "when a defendant performs an act which has the unintended effect that the vehicle moves, he or she may be regarded as driving it" (*Ins Com v Pullin, HCA*).
Applying this to Fred – Fred's actions of letting off the hand-brake, even though movement was unintended, did make the vehicle move. Therefore, **(in conclusion)** he is 'driving' and guilty of the offence.

What will Fred argue?
That the **relevant rule** is contained in *Harvey v Police*. A person who is not in the driver's seat and not in control of the vehicle's controls is not driving but rather, "has interfered with the driving of the vehicle during the friend's temporary absence from the vehicle (*Harvey v Police*).
Applying this, as Fred was not in the driver's seat and not able to operate the foot controls he would argue that the court ought to **conclude** that he is not driving and therefore not guilty of the offence.

What is your overall conclusion?
Have to predict how the HCA would resolve these competing arguments?

You prediction is based on the relative strengths of argument and the strength of precedent (persuasive or binding).

Is there a 'right' answer? (No – you are making a prediction?)
Is there such a thing as 'good' or 'bad' legal advice?

How comfortable are you, as a student, with having to make a prediction? How confident are you with your prediction? What increases/decrease your confidence?

When would you not be needing to make a prediction? (When there is clarity, certainty as to the legal rule or component parts and/or facts fall easily within the scope of the rule)

Appendix 9: Law assessment design

Law Post Tests

Participants used the following short answer question and problem exercise to assess students' understanding of legal reasoning following implementation of the curriculum design. At ANU and UTS, both the question and problem exercise were used in the final course exam, but at UTS the short answer question was an optional question in the exam. At QUT and UTS, the short answer question was used on its own immediately following the curriculum design intervention.

Open ended question:

Someone who couldn't come to the class today asks you the question
"What is the purpose of legal reasoning?"
Write a paragraph replying to their question.

Problem exercise:
[Based on the following:]

The Fact Scenario

Two young constables, Constable Andrew and Constable Petersham, are on patrol in Kings Cross in New South Wales on a road known as The Golden Mile. As they pass a semi-detached terrace house owned by Cleo, the two police officers observe a man, known only to them as Chook, nearby. The police have been keen to speak with Chook for some time about driving without a licence. They decide to approach Chook. Seeing the police coming towards him, Chook panics and runs, ducking through an open gate into Cleo's front courtyard.

Except for the small narrow wrought iron gate Cleo's front courtyard is obscured from the street by a 2 metre high ornamental hedge. There is access from Cleo's front courtyard to Cleo's back courtyard via a pathway along the side of the house. When the two police officers enter the front courtyard, Chook is nowhere to be seen. The police go down the pathway along the side of the house where they find Chook knocking on Cleo's back door. They arrest Chook. Cleo observes Chook's arrest from inside the house but she says and does nothing.

Later that day Constable Andrew, who is now off duty and out of uniform, takes his dog ('Pup') for a walk along The Golden Mile. Along the side fence of Cleo's house there is also a fountain within an ornamental pool. Pup loves to play in water and runs into the pathway beside Cleo's house and jumps into the ornamental pool. Constable Andrew stands at the gate and no matter how persistently he calls to Pup the dog will not get out of the water. In the end Constable Andrew goes through the gate to fetch Pup. At that moment Cleo opens her front window and calmly says: "Get out of my courtyard now. I am going to sue you for coming onto my land to get that filthy dog". Constable Andrew hesitates for a moment but decides to ignore Cleo and walks across the courtyard to the ornamental pool. He grabs hold of Pup before leaving the courtyard as quickly as he can.

The Question (to be answered in your examination book).

Constable Andrew comes to you for legal advice.

Advise Constable Andrew about the Lawfulness of the arrest of Chook AND advise Constable Andrew about the Lawfulness of his entry into Cleo's property to retrieve Pup.

In your advice to Constable Andrew refer only to authority provided by Halliday v Nevill (1984) 155 CLR 1 *in the attached case extract. Be sure to demonstrate legal reasoning in your answer using HIRAC. You may also refer to the cases referred to within* Halliday v Nevill*. However, do not refer to any other legal rules (either cases or legislation) that you may happen to know and that are not expressly referred to in the attached case.*

The Case Extract

Halliday v Nevill (1984) 155 CLR 1
HIGH COURT OF AUSTRALIA

High Court of Australia
Gibbs C.J.(1), Mason(1), Wilson(1), Brennan(2) and Deane(1) JJ.

DECISION

GIBBS C.J., MASON, WILSON and DEANE JJ.

This is an appeal by special leave from the decision of Brooking J. of the Supreme Court of Victoria in which his Honour made absolute orders nisi to review five decisions of a Stipendiary Magistrate dismissing five informations laid against the appellant. The informations charged the appellant with one offence of escaping from legal custody, two offences of resisting police in the execution of their duty and two offences of assault. These charges, together with a charge of driving a motor car while disqualified from obtaining a licence and driving a motor car whilst his blood alcohol content exceeded the prescribed maximum on each of which the appellant was convicted, all arose from an incident which occurred in West Heidelberg shortly after five o'clock one afternoon in January 1982. At that time two police officers named Nevill and Brida were on a motorised patrol of the area. As they drove along Liberty Parade they saw the appellant, who was known to Police Constable Brida as a disqualified driver, reversing a motor car out of the driveway of premises at 375 Liberty Parade. Having driven out into the street, the appellant apparently saw the police car approaching and immediately drove back into the driveway from which he had come. The police officers stopped their vehicle across the mouth of the driveway, alighted and entered the premises at 375 Liberty Parade by walking down the open driveway. There they engaged the appellant in conversation. He had been drinking. He was aggressive and denied that he had driven on the roadway. Police Constable Nevill then arrested the appellant for driving whilst disqualified; this happened while the three men were standing on the driveway inside the premises near the rear of the car that the appellant had been driving.

Then, while the appellant and Police Constable Nevill were walking back down the driveway towards the police car, the appellant suddenly broke away from Police Constable Nevill's grasp and ran across Liberty Parade and entered his own home at number 370. The police officers pursued him into the house where a scuffle took place before he was finally overcome. The two charges of resisting the police officers and the two charges of assault all relate to the scuffle that occurred in his own home.

The Magistrate held that the arrest of the appellant in the driveway of 375 Liberty Parade was unLawful because the arresting officer was a trespasser on those premises at the time of the arrest. He therefore dismissed the five informations to which we have referred. …

… In the course of his argument, counsel for the appellant has raised issues of fundamental importance touching the liberty of the subject. It is unnecessary however that we embark on a consideration of those issues. It is common ground that the appeal must fail unless Police Constable Nevill was, at the time he arrested the appellant in the driveway of premises at 375 Liberty Parade, a trespasser on that driveway. The evidence on that question is sparse. On that evidence however, we consider that the only conclusion which is open as a matter of Law is that Police

Constable Nevill had an implied licence from the occupier of the premises to be upon the driveway.

While the question whether an occupier of land has granted a licence to another to enter upon it is essentially a question of fact, there are circumstances in which such a licence will, as a matter of Law, be implied unless there is something additional in the objective facts which is capable of founding a conclusion that any such implied or tacit licence was negated or was revoked (cf. *Edwards v. Railway Executive* (1952) AC 737 at p 744). The most common instance of such an implied licence relates to the means of access, whether path, driveway or both, leading to the entrance of the ordinary suburban dwelling house. If the path or driveway leading to the entrance of such a dwelling is left unobstructed and with entrance gate unlocked and there is no notice or other indication that entry by visitors generally or particularly designated visitors is forbidden or unauthorized, the Law will imply a licence in favour of any member of the public to go upon the path or driveway to the entrance of the dwelling for the purpose of Lawful communication with, or delivery to, any person in the house. Such an implied or tacit licence can be precluded or at any time revoked by express or implied refusal or withdrawal of it. The occupier will not however be heard to say that while he or she had neither done nor said anything to negate or revoke any such licence, it should not be implied because subjectively he or she had not intended to give it (see, generally, *Robson v. Hallett* (1967) 2 QB 939, at pp 950-952,953-954; *Lipman v. Clendinnen* (1932) 46 CLR 550, at pp 556-557; *Lambert v. Roberts* (1980) 72 Cr App R 223, at p 230). Nor, in such a case, will the implied licence ordinarily be restricted to presence on the open driveway or path for the purpose of going to the entrance of the house. A passer-by is not a trespasser if, on passing an open driveway with no indication that entry is forbidden or unauthorized, he or she steps upon it either unintentionally or to avoid an obstruction such as a vehicle parked across the footpath. Nor will such a passer-by be a trespasser if, for example, he or she goes upon the driveway to recover some item of his or her property which has fallen or blown upon it or to lead away an errant child. To adapt the words of Lord Parker C.J. in *Robson* (at p.950), the Law is not such an ass that the implied or tacit licence in such a case is restricted to stepping over the item of property or around the child for the purpose of going to the entrance and asking the householder whether the item of property can be reclaimed or the child led away. The path or driveway is, in such circumstances, held out by the occupier as the bridge between the public thoroughfare and his or her private dwelling upon which a passer-by may go for a legitimate purpose that in itself involves no interference with the occupier's possession nor injury to the occupier, his or her guests or his, her or their property.

The evidence indicates that the premises at 375 Liberty Parade were residential premises with an open driveway to the roadway. There is no suggestion that the driveway was closed off by a locked gate or any other obstruction or that there was any notice or other indication advising either visitors generally or a particular class or type of visitor that intrusion upon the open driveway was forbidden. That being so, a variety of persons with a variety of legitimate purposes had, as a matter of Law, an implied licence from the occupier to go upon the driveway. The question which arises is whether, in those circumstances, the proper inference as a matter of Law is that a member of the police force had an implied or tacit licence from the occupier to set foot on the open driveway for the purpose of questioning or arresting a person whom he had observed committing an offence on a public street in the immediate vicinity of that driveway. The conclusion which we have reached is that common sense, reinforced by considerations of public policy, requires that that question be answered in the affirmative. That conclusion does not involve any derogation of the right of an occupier of a suburban dwelling to prevent a member of the police force

who has no overriding statutory or common Law right of entry from coming upon his land. Any such occupier who desires to convert his path or driveway adjoining the public road into a haven for minor miscreants can, by taking appropriate steps, preclude the implication of a licence to a member of the police force to enter upon the path or driveway to effect an arrest with the result that a police officer's rights of entry are restricted to whatever overriding rights he might possess under some express provision or necessary implication of a statute (cf. *Crimes Act,* s.459A and note generally *Morris v. Beardmore* (1981) AC 446 and the discussion in the judgment of Kennedy J. in *Dobie v. Pinker* (1983) WAR 48, at pp 53ff.) or the common Law. All that that conclusion involves is that, in the absence of any indication to the contrary, the implied or tacit licence to persons to go upon the open driveway of a suburban dwelling for legitimate purposes is not so confined as to exclude from its scope a member of the police force who goes upon the driveway in the ordinary course of his duty for the purpose of questioning or arresting a trespasser or a Lawful visitor upon it. It follows that Police Constable Nevill was Lawfully upon the driveway of 375 Liberty Parade when he arrested the appellant. …

We would dismiss the appeal.

BRENNAN J.

This case is about privacy in the home, the garden and the yard. It is about the Lawfulness of police entering on private premises without asking for permission. It is a contest between public authority and the security of private dwellings. …

The common Law principles relevant to the present case are of ancient origin but of enduring importance. In *Entick v. Carrington* [1765] EWHC J98; (1765) 19 St Tr 1029 Lord Camden L.C.J. said, at p 1066:

> " By the Laws of England, every invasion of private property, be it ever so minute, is a trespass. No man can set his foot upon my ground without my licence, but he is liable to an action, though the damage be nothing. ... If he admits the fact, he is bound to shew by way of justification, that some positive Law has empowered or excused him."

That statement, as Lord Scarman said in *Morris v. Beardmore* (1981) AC 446, at p 464, is still true. The principle applies alike to officers of government and to private persons. A police officer who enters or remains on private property without the leave and licence of the person in possession or entitled to possession commits a trespass and acts outside the course of his duty unless his entering or remaining on the premises is authorized or excused by Law. Thus in *Great Central Railway Company v. Bates* (1921) 3 K B 578, a police officer who had the powers of a common Law constable and who, seeing the door of a warehouse open after dark, entered it in order to see that everything was all right, was held to be a trespasser. …

> A licence is revocable, and a police officer who has no right to remain on premises must leave if the licence is revoked. He is not acting in the execution of his duty once he becomes a trespasser: *Morris v. Beardmore*, at pp 458-459; *Davis v. Lisle* (1936) 2 KB 434; *McArdle v. Wallace* (1964) 108 SJ 483; at all events where the trespass is more than trivial (cf. the cases discussed by Lanham "Arrest, Detention and Compulsion", *The Criminal Law Review* (1974), 288). A police officer who has grounds for arresting a person on a criminal charge needs to be armed with more than leave and licence if he is

> not to be frustrated in effecting the arrest. He needs the authority of an independent right, else offenders can find an Alsatia in their homes or in the homes of their friends. …

Although the common Law has long protected the privacy of the home, it has never treated that privacy as inviolate against the exercise of a power to arrest. The first proposition laid down in *Semayne's Case* (1604) 5 Co.Rep.91a (77 E.R.194) that everyone's house "is to him as his castle and fortress, as well for his defence against injury and violence, as for his repose" was qualified by the third proposition in the same case. It was laid down (at p.916; p.195):

"In all cases when the King is party, the sheriff (if the doors be not open) may break the party's house, either to arrest him, or to do other execution of the K.'s process, if otherwise he cannot enter. But before he breaks it, he ought to signify the cause of his coming, and to make request to open doors ...".

Where entry is sought to effect an arrest for a criminal offence, it is a case "when the King is party". The person effecting the arrest is entitled not only to enter as of right but to break down the outer doors of the offender's home after making the customary demand: "Open in the name of the King" (per Lord Denning M.R in *Southam v. Smout* (1964) 1 QB 308, at p 320). The privilege of keeping the outer doors shut against process was confined to execution at the suit of a private individual. *Semayne's Case* gives an offender no immunity from arrest on criminal process: *Burdett v. Abbot* (1811) 14 East 1 at p 162 (104 ER 501, at p 563); *Harvey v. Harvey* (1884) 26 ChD 644; *Southam v. Smout,* at p 320. Nor does *Semayne's Case* give an offender any such immunity if he takes refuge in the home of another for "the house of any one is not a castle or privilege but for himself" and the offender cannot claim the benefit of sanctuary in the other's home (at p.93a (p.198); and see Foster's Crown Law 3rd ed. (1809), p.320, sect.21).

Of course, a constable's power to arrest without warrant is limited. At common Law, a constable is empowered to arrest without warrant any person whom he suspects on reasonable grounds of having committed a felony, but he is not empowered to arrest a person guilty or suspected of misdemeanours except where an actual breach of the peace by an affray or by personal violence occurs and the offender is arrested while committing the misdemeanour or immediately after its commission (Stephen, A History of the Criminal Law of England (1883), vol.1, p.193; Hale's Pleas of the Crown (1800), vol.2, p.85). And so it was held that a constable could not Lawfully arrest an offender who, having assaulted the constable an hour earlier, retires to his house and closes and fastens his door: *R v. Marsden* (1868) LR 1 C.C.R 131. At common Law, a constable is entitled to enter on private property to effect an arrest within the limits of his common Law power to arrest without warrant, although he would be a trespasser if he entered or remained on the property for any other purpose.

In Victoria, the distinction between felonies and misdemeanours has been abolished and, by s.457 of the *Crimes Act 1958* (Vic.) ("the Act"), common Law powers to arrest without warrant have been abolished. In place of the common Law power to arrest without warrant, a statute now confers power to arrest without warrant for various offences. The question arises whether the conferment of the statutory power carries with it a power to enter on private property without a licence (by force, if necessary) or whether there is a territorial restriction on the exercise of the statutory power to arrest.

When ss.458 and 459 were inserted into the Act in their present form by the *Crimes (Powers of Arrest) Act 1972* (Vic.), the Act contained no express power to enter on

and search private property for the purpose of arresting an offender or a suspected offender. The *Crimes (Classification of Offences) Act 1981* (Vic.) inserted s.459A in the Act, and a limited power of entry and search is conferred by that section:

" (1) A member of the police force may, for the purpose of arresting under section 458 or 459 or any other enactment a person whom he -
(a) believes on reasonable grounds -
(i) to have committed in Victoria a serious indictable offence;
(ii) to have committed an offence elsewhere which if committed in Victoria would be a serious indictable offence; or
(iii)to be escaping from legal custody; or
(b) finds committing a serious indictable offence -
enter and search any place where the member of the police force on reasonable grounds believes him to be.

(2) In order to enter a place pursuant to sub-section (1), a member of the police force
may, if it is necessary to do so, use reasonable force.

(3) In this section 'serious indictable offence' has the same meaning as it has in section 325."

Section 459A has no application in the present case.

The appellant submits that the power to arrest conferred by s.458 is restricted and that an arrest in purported exercise of that power cannot be effected Lawfully on private property unless the case falls within s.459A, and this case does not. …

In 1981, when s.459A was inserted in the Act, Parliament clearly intended to attach an express statutory right of entry to the general arrest powers conferred by ss.458 and 459; equally clearly, Parliament intended to restrict the right of entry and search for the purpose of effecting an arrest under those sections to cases falling within the terms of s.459A. Section 459A was itself a code of the power of entry and search for the purpose of effecting an arrest under s.458 or s.459. Unlike the provision considered by *Muirhead J. in McDowell v. Newchurch*, s.459A conferred power to enter and search "any place", whether the place be "premises" or not. But conditions were imposed. The power of entry and search for the purpose of arresting was conferred only on a member of the police force, and only in respect of persons found committing or believed on reasonable grounds to have committed a "serious indictable offence" (a term defined by s.325(6) of the Act). The common Law restriction on forcible entry was altered to authorize the use of necessary and reasonable force to effect an entry. In the light of the legislative intervention in 1981, the general powers to arrest conferred by ss.458 and 459 cannot now be construed as carrying with them any powers of entry and search save those conferred by s.459A. From that conclusion, it follows that police officers have no independent right to enter or remain on private property to effect an arrest under s.458 or s.459 in cases that fall outside s.459A.

In cases falling outside s.459A, the statutory powers to arrest - shorn of any power of entry - stand in no different position from those novel statutory powers that cannot be exercised on private property without the leave and licence of the person in possession of the property or the person entitled to possession: see *Transport Ministry v. Payn* (1977) 2 NZLR 50; *Allen v. Napier City Council* (1978) 1 NZLR 273. The statutory powers to arrest are no longer effective to diminish the common Law rights of persons in possession of land except in the circumstances specified in s.459A. Those powers cannot now be construed as authorizing an arrest which can

be effected only by trespassing on private property. If a purported arrest is made in circumstances where the power is not intended to be exercised, the arrest is invalid. The arrest is not struck with invalidity because the person arrested is not liable to arrest under s.458 or s.459 but because the power conferred by those sections can be exercised only if it is otherwise Lawful to act in execution of the power. If a police officer could validly arrest by entering a place which he has no power to enter and which he is given no permission to enter, the statutory limitation on the power of entry would be nugatory and the protection of individual privacy which Parliament intended would be denied in practice. …

There is, of course, no general licence implied by Law permitting police officers on police business to enter on private property. It is clear from what Atkin L.J said in *Great Central Railway Company v. Bates* (at p 582) that a police officer has no right to enter merely because most reasonable householders "would not as a rule object if the matter was done bona fide and no nuisance was caused". Is some licence to be inferred in fact, at least in the generality of cases? The circumstances of each case determine whether it is reasonable to infer that the person in possession of the premises has given permission to the police officer to enter and remain. However legitimate or even laudable from the public viewpoint the business of a police officer may be, it cannot be inferred that in general the police officer has an implied licence to enter and remain on private property to transact that business, at least where the business is of no benefit to the person in possession. Permission to enter to transact the business may be sought, but permission cannot be assumed. A police officer, in common with any other person on legitimate business, has an implied licence from the occupier of a dwelling-house "to come through the gate, up the steps, and knock on the door of the house" (per Lord Parker C.J. in *Robson v. Hallett*, at p 951). That, as Lord Widgery C.J. explained in *Brunner v. Williams* (1975) 73 LGR 266, at p 272, "means that anyone who has any genuine reason for wishing to enter the house or the garden has implied licence from the occupier to approach the front or nearest door and ask whether he may be given permission for what he wishes to do". Now a licence in the terms thus discussed is fairly to be implied in the generality of cases as an incident of living in society. Unless a notice says "Keep Out" it is, generally speaking, reasonable to imply a licence to come up and ask "May I come in?" In the line of cases between *Morris v. Beardmore* and the insertion of s.7(6) into the *Road Traffic Act*, however, the implied licence to enter on the curtilage of a dwelling to get permission to do something on the premises was treated as a licence to the police to perform their functions under s.8 of that Act on any part of the premises between the entrance to the curtilage and the front door without seeking the permission of the person in possession. It then became a question of deciding whether the implied licence to perform those functions - on a path or driveway - had been revoked before the requirement to provide a sample of breath for the breathalyzer had been made. Perhaps the most extreme examples of these cases were *Snook v. Mannion* (1982) RTR 321 and *Gilham v. Breidenbach* (1982) RTR 328 where vulgar and vigorous injunctions to depart were construed as mere abuse falling short of an express withdrawal of a licence to be on the premises. With great respect, I am unable to adopt the reasoning in these cases. To imply that a police officer who is pursuing a fugitive onto his home ground has the fugitive's permission to enter and remain there until the police officer's work is done is, in my opinion, contrary to the inference ordinarily to be drawn from those facts. To hold that a licence impliedly given by the person in possession (who might or might not have been the fugitive) endures until it is revoked in unmistakeable terms reverses the onus which *Entick v. Carrington* places upon the person entering. Such an implied licence could be distinguished from a legal right of entry only by its revocability.

In the present case, if the police had an implied licence to enter on the driveway of 375 Liberty Parade, by whom was that licence revocable? Presumably not by the appellant, for he was not the person in possession of 375 Liberty Parade. For what purposes did the police have that person's implied licence to enter? Once it is admitted that the police officers have an implied licence to enter to arrest, might a licence for other police purposes be implied? To install a traffic radar device on the driveway? Or carry out surveillance of neighbouring premises from there? The presence of the police officers on the driveway of 375 Liberty Parade was not for any purpose with which the person in possession was concerned. I am unable to see in the facts of the case any ground for inferring that the police had a licence from that person to come onto his driveway without his permission for the purpose of arresting a suspected offender.

There is, of course, a tension between the common Law privileges that secure the privacy of individuals in their own homes, gardens and yards and the efficient exercise of statutory powers in aid of Law enforcement. The contest is not to be resolved by too ready an implication of a licence to police officers to enter on private property. The legislature has carefully defined the rights of the police to enter; it is not for the courts to alter the balance between individual privacy and the power of public officials. It is not incumbent on a person in possession to protect his privacy by a notice of revocation of a licence that he has not given; it is for those who infringe his privacy to justify their presence on his property. There may well be a case for enlarging police powers of entry and search, but that is a matter for the legislature.

I would allow the appeal, set aside the order of Brooking J. and the convictions of the appellant, and in lieu thereof order that the orders nisi to review be discharged.

End of case

END OF EXAMINATION PAPER

Appendix 10: Physics curriculum design, ANU

At ANU, there were three lectures on uncertainty, followed by a tutorial designed using Variation Theory. This was then followed up with two laboratories and a number of homework tasks on uncertainty. However, only the tutorial was explicitly designed using Variation Theory. The tutorial worksheet is below.

Tutorial Worksheet: the Meaning of Standard Deviations.
Discuss these questions in your groups, and then write down your agreed interpretations on this sheet and show them to your tutor.

Exercise 1a: Two Numbers
A = 4.51±1.2
B = 4.83±1.2
The quoted uncertainties are standard deviations.
What would you conclude from these two numbers if…
1. You are designing a bridge, which will be held together by bolts, which go through holes in girders. A is the measurement of the diameter of the bolts, and B is the measurement of the diameter of the holes.
2. You are measuring the mass of a newly discovered subatomic particle. A is the mass you measure, and B is a theoretical prediction, made by a Nobel Prize winning physicist.
3. You are starting a PhD in astroPhysics. Your supervisor just published a paper in which she measured the mass of a particular galaxy to be B. On your very first observing run at the telescope, you measure the mass of this same galaxy to be A.

Exercise 1b:
Now let's keep the same numbers and the same scenarios, but change the standard deviations.
A = 4.51±0.02
B = 4.83±0.02
What would you conclude from these two numbers if…
4. You are designing a bridge, which will be held together by bolts, which go through holes in girders. A is the measurement of the diameter of the bolts, and B is the measurement of the diameter of the holes.
5. You are measuring the mass of a newly discovered subatomic particle. A is the mass you measure, and B is a theoretical prediction, made by a Nobel Prize winning physicist.
6. You are starting a PhD in astroPhysics. Your supervisor just published a paper in which she measured the mass of a particular galaxy to be B. On your very first observing run at the telescope, you measure the mass of this same galaxy to be A.

Exercise 1c:
Now let's keep the same numbers and the same scenarios, but change the standard deviations a second time.
A = 4.51±0.15
B = 4.83±0.15
What would you conclude from these two numbers if…
7. You are designing a bridge, which will be held together by bolts, which go through holes in girders. A is the measurement of the diameter of the bolts, and B is the measurement of the diameter of the holes.
8. You are measuring the mass of a newly discovered subatomic particle. A is the mass you measure, and B is a theoretical prediction, made by a Nobel Prize winning physicist.

9. You are starting a PhD in AstroPhysics. Your supervisor just published a paper in which she measured the mass of a particular galaxy to be B. On your very first observing run at the telescope, you measure the mass of this same galaxy to be A.

Exercise 2
Imagine that you like your classmates so much that you want to buy everyone of them a lolly.
You have 280 classmates.
You buy the lollies in jars. Each jar contains 50±10 lollies. 10 is the standard deviation of the number of lollies in a jar.
You really don't want anyone to miss out. But your budget is tight so you don't want to buy too more jars of lollies than you really need to.
How many jars of lollies should you buy?

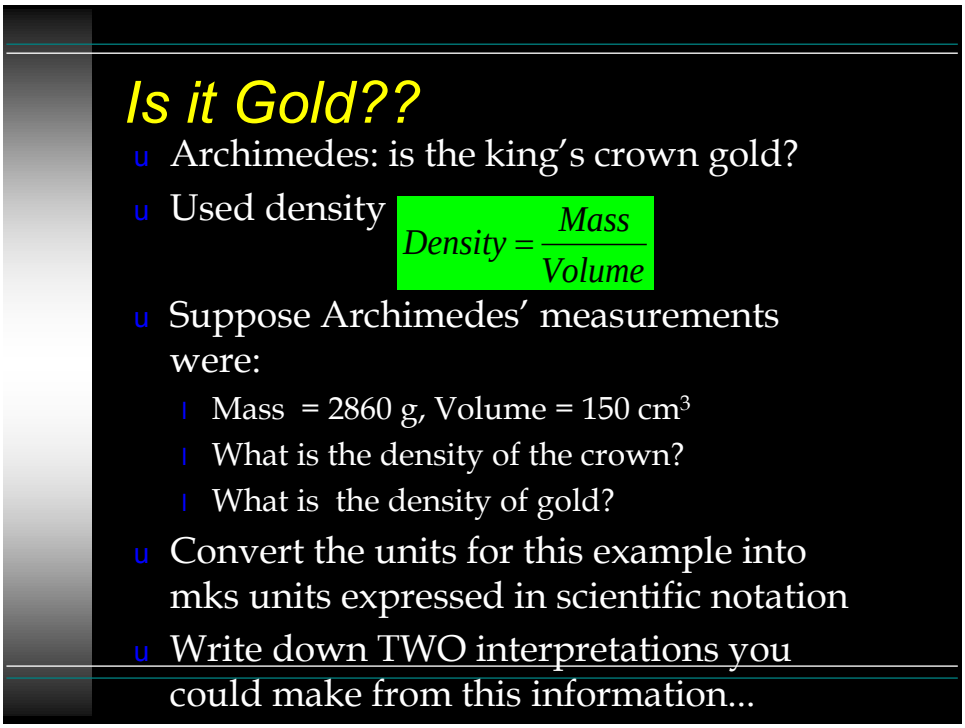
Exercise 3
Imagine that you work for a company bidding to get the contract to measure ball speeds at the next Wimbledon tennis competition. You plan to do this using a specially calibrated video system. This system will measure the position and time whenever a ball touches the grass or a racket.
A rival company claims that they can measure the ball speed to an accuracy (standard deviation) of 1 m/s.
Your system can measure positions with an accuracy of 25cm (standard deviation). How accurately will you need to measure times to beat the rival company?

Appendix 11: Physics curriculum design, QUT

At QUT, there was a lecture and lab on uncertainty, including lab guidelines that the lecturer forwarded to the demonstrators, with a rationale and a run sheet for the session.

Lecture slides

The following slides were used as pen-and-paper and class discussion exercises within the usual lecture on uncertainty. Only this aspect of the lecture was explicitly designed using variation theory.



Exercises

5. Calculate the density and it's uncertainty for experimental values

	Mass m (kg)	Volume V (m^{-3})	Density ρ (kg m^{-3})
a	2.860 ± 0.005	$(1.50 \pm 0.05) \times 10^{-4}$	
b	2.860 ± 0.001	$(1.50 \pm 0.05) \times 10^{-4}$	
c	2.860 ± 0.005	$(1.50 \pm 0.01) \times 10^{-4}$	
d	2.860 ± 0.001	$(1.50 \pm 0.01) \times 10^{-4}$	

6. Suggest *at least two plausible conclusions* for EACH of the outcomes in 5

Compare conclusions with your neighbour…

Any arguments??

Reflection

- Compare the density of gold result using the "significant figures" rule only with the results using calculated uncertainty values
- Which conveys more meaning?

Guidelines to Demonstrators

Skills 1 Lab Session Semester 1 2010
Demonstrator Guide
Laboratory sessions give students an extraordinary opportunity to apply skills which are essential for scientists. As the first lab session in the semester, Skills 1 gives us the opportunity as teachers to communicate our expectations for lab classes to follow.

The Skills 1 exercise (volume of the room and density of steel) provides opportunity for students

- to make and record real measurements using accepted scientific conventions (tabulation, units)
- to identify limitations of instruments
- to express uncertainty in data and uncertainty in results calculated from data
- to interpret and communicate results in terms of context and technique based on results and uncertainties

Many of you will have demonstrated Skills 1 in previous semesters and in other units using slightly different approaches. My experience in the lab shows that some of these skills from the Skills 1 exercise don't get transferred well to later experiments. This is particularly true for interpreting a result using the uncertainty and communicating conclusions. This is partly because time constraints discourage thinking and discussion in the lab during the effort to complete the data taking and calculations.
By emphasising the interpretation and communication phases of the Skills 1 exercise I hope to generate the expectation of more logical and thoughtful conclusions for other experiments. To allow time for this I propose for skills one this semester:

1. Half the lab group does the "volume of the room" exercise in pairs (in the big lab, Q332), while the other half does the "density of steel" exercise (also in pairs, in the small lab Q325). This includes measurements, uncertainties and calculations. We can tabulate a number of results on a whiteboard or the projector for comparison.
2. Each "volume of the room" pair then joins with a "density of steel" pair, effectively now a team of four with two experimental data sets. We will allow them to then share this data within their team of four. This should (in theory) halve the time required for taking measurements and calculations.
3. 'Room" people should first try to interpret the "Steel" results and vice-versa. Whole team should than agree on valid conclusions from both exercises.
4. Should be time for some whole group discussion near the end of the session to identify different plausible conclusions from at least a couple of teams.

A notional timeline of activities is outlined overleaf.
Shifting the focus from the data taking aspects of the experiments to

- the role of uncertainty in interpretation and
- reporting as a communication tool

will (hopefully) result in a deeper learning experience in this exercise and in later experiments.

Skills 1 Session Timeline

Approx time after session start (hr:min)	Student activity / Demonstrator directions
0:00	All In Q332. Welcome and intro selves. Check shoes are covered, and that each person has skills 1 proforma.
0:02	Data projector powerpoint presentation “First Year Physics Lab Intro” and Skills 1. First couple of slides to highlight safety, punctuality and finish time, proformas collected at end of session.
0:05	Session outline: Do pracs in pairs, so choose a partner. Each pair will do EITHER volume of room (in Q332) OR density of steel (in Q325). Will swap results with one opposite pair later and discuss outcomes near end of session.
0:10	Move half of pairs nearest the doorway into Q325.
0:15	Q332 (Volume of the room) PPT slides showing volume and calc for uncertainty in volume. Record ROUGH (pre-measurement) estimate of L, W, H on proforma. Q325 (Density of Steel) on whiteboard or OHP show formula for density and uncertainty in density. Discuss available measuring techniques and their limitations. This should lead to a REALISTIC uncertainty value for EACH individual measurement. Encourage students to justify (with calculation or explanation) WHY the uncertainty values they quote are realistic.
0:25	Students record raw measurements – apply STRICT time limit <~8 minutes. Monitor techniques, recorded values, uncertainty justifications significant figures. “Steel” pairs will probably require help verifying readings.
0:35	Uncertainty Calculations set out in provided spaces Final result in mks units rounded to appropriate number of sig. figs. (Uncertainty to 1 sig fig, result to same place as uncertainty)
0:50	Q332 Tabulate volume results from 7 pairs and calculate “class” average from this Q325 Quote published density of steel ≈ 7.7×10^{3} m^{3}. Discuss possible meanings with partner
1:00	Bring Class together in Q332, each “Steel” pair join one “Room” pair and swap data.
1:15	Form opinions on possible conclusions for other pair’s results and discuss in group of four.
1:25	On whiteboard record several “room” conclusions and discuss as whole group. Then repeat for “steel”.
1.45	Packup. Return equipment, chairs under benches, Submit proformas with partners.
1:50	Exit

Appendix 12: Physics curriculum design, UTS

At UTS, redesigned curriculum was implemented through a lecture, tutorial and laboratory session:

Lecture

Running Schedule (lesson plan!)

1. Intro
1 clip + YouTube clip on blood pressure measurement (Google 'Blood Pressure Measurement Youtube)

Robbie video: 'Nailing' the speed at which Robbie must leave the ramp is vital to the success of the jump (ie if he is too slow he won't reach the top - if his velocity is too great he will overshoot)

Hypertension (high blood pressure) is major risk factor linked to coronary heart disease and stroke. Blood pressure measurement is important consequences as inaccurate measurement could lead to medication being prescribed that is not warranted if blood pressure measurement readings are higher than the true value.

What values of take-off velocity will still allow for a safe and successful jump? When the physician measures the blood pressure how far from the 'true value' of the blood pressure might the value recorded be?

In both examples (Robbie's jump, and the blood pressure measurement) we're not only keen to know the value of a particular quantity (speed and blood pressure) but also the likely variability in the quantities. In this lecture we will deal with a number of matters relating to measurement and in particular introduce the important concept of *uncertainty* in measurement.

2. Go through Powerpoint slides up to and including slide 9.

3. Have students do experiment (s). Get volunteer to enter data into prepared spreadsheet (see end of these notes)
In all cases drop a ball from 3 m (put post-it sticker on the wall at 3 m to 'ensure' ball is released from 2.7 m.

a) Single student measures 5 successive times for ball to fall to ground. Initiate discussion on the factors that affect the measurement of the time of fall. Put values in Excel file (get a volunteer to do this).
Introduce idea of 'true value' and error.
Mean as best estimate of true value. How to calculate uncertainty
Show slides 10 to 13 inclusive.

b) what is the influence of the experimenter? Give out 5 digital stopwatches and collect data from 5 people. Does the scatter look similar from person to person or are there features that are different?

c) what is the influence of the instrument? Measure the time of fall (from 3m) (using same students that used the digital stop watches) using two more types of instrument; give out 5 analogue stopwatches and have students use the stopwatch on their mobile phone. Is the scatter of the data different depending on the type of stopwatch used?

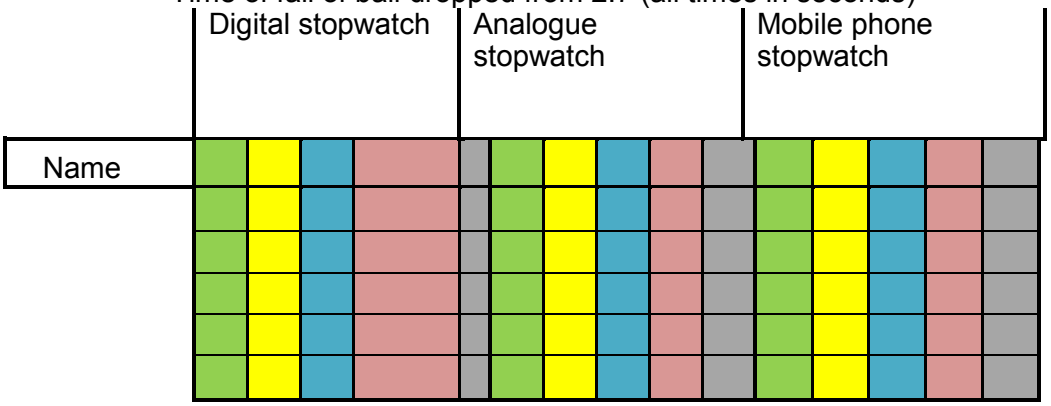
d) Comparison with theoretical value. We can use $s = 0.5\ at^2$, and assuming $s = -2.7$ m, $a = -9.8 m/s^2$ we can calculate $t = 0.74$ s. How does the 'theoretical' value

compare with those obtained in the experiment - who was closest to the 'theoretical value'? Note this theoretical value ignores air resistance.

e) Returning to the experiment - how could you improve it (ie get a better estimate of the true value of the time of fall with a smaller uncertainty)?

4 Now go through remainder of slides (but probably omit slides 30 to 33, if time runs out)

Time of fall of ball dropped from 2.7 (all times in seconds)



Tutorial *(following the lecture)*

1. **Give out 6 thermocouple thermometers and alcohol in glass thermometers to 6 people in the room -ask them to place them on the desk in front of them with a view to measuring the air temperature in the room. Ask them not to disturb the thermometers ie they should touch the thermometers as little as possible.**

Deal with the following questions from the Resource book.

Page 9, Q 1, 2

Return to the thermometers and have the students read out the temperature shown by the digital thermometers - put numbers in spreadsheet. Likewise have them read out the temperatures as indicated on the alcohol in glass thermometers - record them too in a spreadsheet.

Do values vary ? What might be the causes of the variation? Is there any systematic difference between the two types of thermometer?

What would be the best estimate of the room temperature based on the digital thermometer? based on the alcohol in glass thermometer? Which one is correct?

Is it fair to say that there is a true value for the temperature in the room? - does true value have any meaning here?

How would you calculate the uncertainty in the temperature? Calculate it for both thermometers.

If all the air in the room was truly at the same temperature, would all the thermometers give the same reading of temperature?

Take all thermometers and put in a container of water at room temperature. Have student read out the temperatures indicated by all the thermometers - put into spreadsheet. Why might thermometers indicate different temperatures?

Remind students of two important equations
Do questions 5 then 4 on page 9 of tut book

Lab: Sticky tape experiment *(following the tutorial)*

Learning Experiences:

1. Uncertainty & reproducibility of measurements

2. Using uncertainties in quantitative comparisons

3. Using uncertainties as a basis of improving experimental design

PART A : Getting Out of a Sticky Situation

Background to Experiment

You are working for a company that produces a sticky tape called Brand X. The Executive Officer of the company approaches you with a tape just released by a competitor (Brand Y) who claims it to be far superior to any other brand on the market. Your Executive Officer wants to know the truth of the matter. Which is the best? Brand X or Brand Y?

You are given the task of determining which one is the best by carrying out a "stickiness" test on a set of samples of each brand. You are to report back to the Executive Officer. Given the circumstances it is important that when you report back there are no fLaws in either your method of measurement or any subsequent analysis. Whatever the outcome you must be confident that **your measurements** could stand up to scrutiny.

Procedure

1. In the "stickiness" test you are required to stick a length of Brand X tape to the laboratory bench. The end of each piece of tape should be reinforced with a small piece of card so that the tape will not tear when a force is applied.

2. "Stickiness" is measured by peeling off the tape using an experimental rig such as the one shown below. As most sticky tapes will eventually lift off no matter what lifting force is applied, the normal method of assessing "stickiness" is to apply a fixed force and measure the time for a fixed length of tape to peel off. This is the approach recommended here. It is your responsibility to choose the conditions of measurement (eg. the lifting weight, the length of tape to lift). Give some thought to appropriate conditions.

3. To test for reproducibility, repeat this procedure at least five times with Brand X tape. Carefully tabulate your data. Record the results of any other measurements, uncertainties or features of the procedure that may be relevant.

4. Now determine the "stickiness" of the Brand Y tape.

Analysis of Measurements : Part A

1. Set out all the measurements into **one** carefully and thoughtfully drawn up table.

2. Calculate the average peel-off time and the uncertainty in the peel of time for each type of tape.

3. Write a short summary of your results. Discuss whether there are any significant differences between the two sets of measurements. What is the relevance of the uncertainty? What limitations does the method of measurement have?

4. What are the major sources of uncertainty in this experiment? Suggest methods by which the uncertainty can be reduced.

PART B : Improving the experiment

The goal of this part of the experiment is to improve your experiment in order to more clearly discriminate between the two brands of sticky tape you have been given.

The key question is ‘how can you reduce the uncertainty in the peel off times that you obtained in Part A of this experiment?’ – and hence better advise the Managing Director as to which is the preferred tape.

Based on the class discussion at the end of part A, redesign your experiment with a view to reducing the uncertainty in the peel off times. You have been given a range of materials that you can incorporate in your experiment (as examples, alcohol is available to clean the surface of the bench between peel off trials, and the surface onto which the tape is pressed can be changed to glass, metal or ceramic.)

Analysis of Measurements : Part B

1. Set out all the measurements into **one** carefully and thoughtfully drawn up table.
2. Calculate the average “stickiness” and the uncertainty for each set of tapes.
3. Is your new experimental method an improvement over that used in Part A?
4. Do you believe you have correctly identified the dominant source responsible for uncertainty? If not, what do you think is the dominant source of uncertainty? How would you go reducing that source of uncertainty?

Based on your measurements, are you able to advise your Managing Director as to which of the tapes is the ‘stickiest’?

Appendix 13: Physics assessment design

Physics Post Tests

To assess student understanding of measurement uncertainty after implementation of the revised curriculum, participants used the following question in the final exam for their course.

The same **short answer question** was used by all participants:

A golf ball manufacturer has developed a new ball called GoFar. The manufacturer believes the ball will fly farther than the Flyrite ball made by its main competitor. An experiment is performed which consists of launching each type of ball several times at the same velocity and angle and measuring the distance travelled before the ball touches the ground. Data obtained are shown in the table below.

Distance travelled by Flyrite ball (m)	Distance travelled by GoFar ball (m)
212	232
217	213
220	225
213	217
222	240
220	243

The managing director of the makers of the GoFar ball wants her company to dominate the golf ball market by promoting that the GoFar ball flies further than the Flyrite ball. Do you think there is sufficient evidence to support this claim? Explain how you arrive at your conclusion. Which golf ball would you recommend to your golfing friends? (5 marks)

And an (additional) **multiple choice question** at one institution (QUT):

QUESTION 1

Blood glucose concentration is an important quantity in diagnosing and managing disorders such as diabetes. The clinical “normal” range for blood glucose concentration is between 4.0 and 8.0 millimoles per litre. A particular device has been shown to measure blood glucose concentration to within ± 1%. Which of the following statements about the device can be supported by this information?

(a) The device is precise enough to determine a useful reading.
(b) The device is not precise enough to determine a useful reading.
(c) The device is accurate enough to determine a useful reading.
(d) The device is not accurate enough to determine a useful reading.
(e) Both A and C are true.

QUESTION 2

A cylindrical water tank with radius 1.80 ± 0.01 metres and height 1.4 ± 0.01 metres is full to its capacity. The most realistic value of the volume of water contained in the tank with its uncertainty is closest to

(a) 4.54 ± 0.03 m3
(b) 4.54 ± 0.02 m3
(c) 4.54 ± 0.08 m3
(d) 4.54 ± 0.01 m3
(e) 4.54 ± 0.06 m3

Appendix 14: Evaluation and Observations, December 2008-September 2009

A Threshold Concepts focus to curriculum design: supporting student learning through application of Variation Theory

Evaluation and observations (December 2008 – September 2009)

In my role as project evaluator I have undertaken three different types of activities to provide assistance and feedback to the project team. The first is to attend the face-to-face meetings scheduled for the project leaders and project participants (thus far including December 2008, September 2009); the second entails regular observation of project activities via the project moodle site and inclusion in project emails/communication (throughout November 2008-September 2009); and the third involves telephone meetings with the project CI Professor Gerlese Akerlind and/or the project officer Christine Kertesz. Together these activities provide a rich source of data from which to observe project activity, engagement and progress.

Project leader/participant face-to-face meetings
The project team and project participants met for a two-day working session on the 17th-18th December 2008 and again on the 28th -29th September 2009. Attending these meetings gave me a strong sense of how the project was proceeding in both the early phase (2008) and at an important transition point between phase 1 and phase 2 (2009). I was also able to observe the levels of engagement of the project team with the project participants, and of the individual participants within their disciplinary clusters. In consultation with the project leader I gathered some written feedback from the project participants that could inform and guide the project leaders in future planning.

Meeting 1 - Some observations: The session offered in December 2008 was well planned and offered participants a very useful entry into the first phase of the project, to review the aim of the project and the key steps within the first phase, and introduce them to key concepts (which for phase 1 focused on 'Threshold Concepts'). The two-day program entailed sessions that were highly interactive, and the project team successfully engaged the project participants in collaborative, detailed conversations about the application of this concept within the discipline, and in some consideration of the processes each participant and team would undertake during phase 1. The activities were well resourced and supported. Facilitation by project leaders enabled both disciplinary clusters to achieve productive outcomes by the end of day two. The sessions ended with an overview of a range of tools and strategies that the project team would use for collaboration, resource sharing, and project tracking. In summary, the planning, organisation, and implementation of this meeting went exceptionally well. Of note is the process of communication employed before, during and after the meeting. The provision of meeting schedules and administration tasks by the project leader and project officer enabled the meeting to run smoothly, and engaged participants well beyond the meeting.

Data collected: On the conclusion of each day I administered a short answer survey to participants seeking their feedback and emerging understanding of the project. Responses to the following question stems were sought:
1. The aim of this project is to…
2. By participating in this project I hope to…
3. The aspects of the two days that worked well for me were..
4. Things that didn't work so well for me were…
5. Three things I learned …

Summary of responses:
In response to question 1) most participants saw the aim of the project in terms of improving the curriculum, and in turn, improving the learning outcomes of their students. Some used the phrase 'making better Lawyers/physicists' which indicated a desire to consolidate students' abilities within the discipline or their capabilities as *practitioners* in the discipline, which are noted in the literature as sophisticated pedagogical orientations. Another common response to this question was the potential for this process to address areas of difficulty that students found challenging across the discipline. For both groups, the additional aim of using educational theory (particularly Variation Theory and the Threshold Concepts heuristic) to guide curriculum planning and teaching/learning processes was highlighted.

Responses to question 2 indicated that participants hoped to achieve both gains in teaching and learning as well as scholarly, publishable outcomes through their participation in the project. The project was viewed by most as an opportunity to look more deeply into the subject matter of the discipline, and to gain insights into student learning/learning difficulties. Some participants noted the opportunity to gain greater personal understanding of educational theory and literature, and to learn more about the processes of undertaking research within teaching and learning contexts. Many also noted their keenness to connect with other colleagues interested in teaching and learning, both within and beyond their discipline. One participant captured a sentiment expressed by other participants quite regularly over the two days: that the project would offer an opportunity to *'break away from my usual unimaginative thinking about pedagogy and curriculum design'.* In sum there was overall alignment between responses to questions 1 and 2: the perceived aims of the project and the participants' desired personal outcomes.

This opportunity to collaborate and engage deeply in conversations about learning and teaching Physics and/or Law was asserted in participants' responses to question 3 (*aspects of the day that worked well for me).* The collaborative group discussions were mentioned frequently, as was the opportunity to brainstorm and discuss 'Threshold Concepts' within the field. Participants appreciated hearing a diverse range of ways of thinking about there discipline concepts, as well as spending time: *"nutting out what we initially think are the problematic concepts that are pivotal to advancement of learning …"* Participants also found the clarification of the term 'Threshold Concept' useful for their thinking about their own discipline, and their involvement in the project. Many day two responses to this item highlighted how the second day helped to clarify participants' understanding of the phase 1 processes and of the use of Threshold Concepts and Variation Theory in curriculum planning.

Overall, participants had little to say about what did *not* go well for them (many writing '*nothing or N/A'* in response). This indicates their experience of the two-day session was, overall, quite positive and productive. Two comments on day two indicated that participants preferred *'shorter, sharper'* sessions that enabled an earlier finish on day two; and two comments requested '*less structure*' in the discussion sessions.

Lastly, responses to item 5 (*three things I learned today)* indicated that participants gained some insights into both teaching and learning within their discipline, and of the project aims and objectives. Some provided quite detailed albeit short recounts of new ways of thinking about the Threshold Concept in their discipline; some noted a new teaching strategy or experiment shared by a colleague; some noted new learning about educational research; and some noted a better understanding of Variation Theory and Threshold Concepts.

In all, the survey indicated that project participants found the design, focus and outcomes of the meeting to be positive and beneficial, both for their professional learning, their teaching practice, and their participation in the project.

Meeting 2 – observations

The second face-to-face meeting between project leaders and project participants was held on 28th-29th September 2009. As with all activities, this meeting was well organised and pre-meeting tasks well planned and communicated by the project leader and project officer. Participants arrived having completed pre-meeting tasks and with salient enthusiasm to undertake the activities set for the meeting.

In consultation with the project team and evaluator, the project leader opened the meeting with a focus group style discussion of participants' progress through the following project stages to date:

1. Selection of a Threshold Concept
2. Design of student interviews
3. Conduct of interviews
4. Preliminary analysis of interviews

The project leader also sought feedback on the benefits, pros/cons of various project tools and strategies used to date, including: face-to-face meetings, project website (as a central site for materials), email discussions, access grid meetings, brief overviews and instructions provided by the project leader, reminders and updates from the project officer, and the role of the institutional project leaders.

This discussion elicited some valuable and direct feedback from participants, who were happy to comment on each of these points succinctly and honestly. Both positive and negative experiences were reported, and together this feedback will provide the project team with some valuable guidance in the continued use of various tools and strategies. As the project evaluator, I summarised responses provided by the participants, and will pass these on to the project team for consideration. In summary, the participants felt they were progressing well through each stage of the project and noted that the presence of the institutional project leaders is instrumental in achieving this progress at various points. All participants agreed that the face-to-face meetings were valuable and vital to their effective participation in the project. Some found the project website less useful than direct emails for distribution of resources/discussion points. There was general agreement that the access grid meetings were valuable, providing essential opportunities to progress challenging stages in the project (such as planning the interviews). So too were the resources and instructions for various activities that were provided by the project team and project leader (participants particularly found that papers within their discipline were helpful in moving their understanding of the project concepts and process forward). Similarly, the use of emailed reminders and updates from the project officer was useful. Some areas participants noted as challenging included: writing and conducting interviews with students (a process the physicists were particularly unfamiliar with); and the use of trigger materials in the interview process (Lawyers). In both instances the presence and immediate assistance provided by the relevant co-located project leaders were noted as invaluable.

Following the focus-group feedback session, participants proceeded with the main activity for the two-day meeting – collaborative analysis of interview data to identify students' conceptions of the respective Threshold Concepts. The design of these sessions (disciplinary clusters supported by project leaders, all having pre-read the interview transcripts) was particularly useful in generating engagement in the task. By the end of the first day, both groups made significant progress in this task. Day two involved a review of Variation Theory as it may be understood and applied in the

project context. This process helped to facilitate each groups' progress in using the findings from the interview data to make preliminary plans for curriculum planning/modules for phase 2.

Data collected: On the conclusion of day two I distributed a short answer survey to participants seeking their feedback and emerging understanding of the project. Responses to the following question stems (also used in September 2009 meeting) were sought:
1. The aim of this project is to…
2. By participating in this project I hope to…
3. The aspects of the two days that worked well for me were..
4. Things that didn't work so well for me were…
5. Three things I learned …

Summary of responses:
As the participants within the Law cluster had to leave early, feedback is being collected via email and will be summarised and reported by the evaluator shortly. The following summary reflects comments from the Physics participants only:

The Physics participants maintain a clear view of the project aim to improve student learning via an improvement in teaching, learning and curriculum that is informed by an analysis of the students' conceptions of the nominated concept (via the application of Variation Theory). Some note the opportunity to evaluate the usefulness of this process for curriculum development, and to provide a model for others to use at a later stage.

All Physics participants noted their hope to gain some insights into their subject matter/concepts and to gain improvements in student learning outcomes or '*tangible outcomes that improve student learning and my professional development'.*

The aspects of the meeting that went well again included the opportunity for in-depth time spent on group discussion with disciplinary peers; and the '*mini lectures'* about educational research/Variation Theory.

Aspects the Physics group noted did not go well included: having enough time to check discussions with the transcript data, ambiguous findings thus far, and *"some tension between trying to do what was required of us and exploring what was interesting in the data".*

In summary, the Physics participants noted a range of personal learning outcomes from the meeting, including: Variation Theory, the application of Variation Theory to Physics contexts/subject matter, that physicists think alike, and interestingly *"coming up with a purely qualitative and subjective, but none-the-less valuable clarification [*of the subject matter] *was really an eye-opener!"*

As with meeting 1, the survey indicated that project participants found the design, focus and outcomes of the meeting to be positive and beneficial, both for their professional learning and their participation in the project. There was general appreciation for the way in which the meeting was communicated and organised, and for the various strategies used to facilitate progress to date.

Observations on Project Activities (January – September 2009)

Throughout January – September 2009 the project leaders and participants were working through the consolidation of the selected Threshold Concept and the design/implementation of student interviews. This process was undertaken remotely, with each disciplinary team supported by their relevant, co-located project leader. Collaboration and sharing of ideas, resources and discussion was achieved

via a project moodle site, regular email updates, and some access grid meetings. The moodle site engaged the Physics cluster much more than the Law cluster. The project leaders' use of an access grid meeting with video-conference facilities enabled the Law team to engage more readily. The moodle site is well resourced with relevant papers, instructions for key project processes (e.g. designing an interview), and allows participants and project leaders to post comments and share ideas readily. The addition of a project overview/timeline noting project milestones provides a valuable summary and point of reference.

The focus-group discussion seeking participants' feedback on progress through these key stages and the strategies used to facilitate progress on day 1 of the September 2009 meeting provided valuable information for the project team. A summary of the feedback has been provided above. A short answer survey will be administered in early October 2009 to provide participants with an additional opportunity to provide individual/anonymous feedback on their experiences to date.

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Changes in participants' understandings as an outcome of the Threshold Concepts project

November 2010

A Threshold Concepts focus to curriculum design: supporting student learning through application of Variation Theory.

Project No. PP8-885

Report prepared by Camille McMahon

Introduction

This report is based on the findings of a research component that feeds into the evaluation of the ALTC-funded project entitled, *A Threshold Concepts focus to curriculum design: supporting student learning through application of Variation Theory.*

It explores the transformative effects of the project on project participants in the following areas:

- impact on their understanding of student difficulties in learning about the disciplinary Threshold Concept
- impact on their understanding of ways to teach the disciplinary Threshold Concept and other disciplinary concepts
- changes in their practice of teaching and curriculum design
- impact on their understanding of the disciplinary Threshold Concept itself.

The report highlights key understandings and transformative outcomes according to each of the areas above. It will also feed into the design of less resource-intensive approaches to curriculum design coming from the model that is tested in the project. It summarises participants' changes in practice that they might carry into the future and also outlines their views of what they might do differently in the project if it were to be repeated or continued. Participant experiences as presented in this report were elicited during a series of interviews as described below.

Method

Interviews were conducted with 13 people who had been involved in the project. The composition of the group of respondents included demonstrators/tutors, sessional academics and full-time academics. The experience across this group was quite diverse, including people who had participated only in the teaching of the curriculum intervention, to people who had been involved from the beginning of the project, who had conducted all the student interviews, and attended all project meetings. Detailed reference to the roles of each respondent has not been included in the report in an effort to retain the anonymity of the interview process. Throughout the report, reference is made to individuals' level of involvement in the project where it was determined to be relevant to the discussion of results.

All interviews, except one that was conducted face-to-face, were conducted via telephone or Skype. Interviews were recorded (with prior consent) and were an average of approximately 45 minutes long. Interviews were then transcribed, with the transcripts checked for accuracy against the recording. The interview schedule was piloted on one participant, and adopted almost unchanged for the remaining participants except for the addition of two questions. Subsequently, the responses of the pilot participant are included in the discussion. The full interview schedule is included as Attachment 1. In addition to the set questions in the schedule, the interviewer used further probing questions to elicit more in-depth understanding of the participants' responses. In brief the interview sought to:

- identify the participants' role in the project
- elicit their sense of overall impact of the project on them
- investigate specific areas of impact in relation to their teaching, learning and curriculum design
- identify what aspects of the project they would use, avoid or do differently in the future, and
- discover what aspects of the project they may or may not recommend to colleagues.

Throughout the report, direct quotes from participants are included to illustrate findings. These quotes are labeled with 'P' or 'L' to identify the respondents' discipline (Physics or Law), and a number for the purposes of analysis.

Structure of the report

The categories of transformation in understanding, as described above, were explicitly addressed in the interview in order to assist in eliciting information from the participant. As separate categories they are also helpful in presenting the results of the interviews. In reality, however, each of these is also intertwined with the others, and respondents referred to impacts across these four areas throughout their whole interview. For example, when asked about student difficulties, respondents also referred to ways of teaching. Likewise, when asked about their own understanding of the disciplinary Threshold Concept itself, some participants could not separate their own understanding of it from their understanding of how to teach, or how students understand it.

The interviews also sought to identify any triggers that led to the impacts as identified by the participants. Respondents were asked to identify what it was about their involvement in the project – or what particular aspect(s) of the project – that led them to their change in understanding or practice. While participants referred to triggers for each area of impact about which they were asked, many of the triggers acted as catalyst for change in a number of areas and thus the report presents them as a discrete section (Section 3).

Impacts of the project on the participants

Impacts on understanding of student difficulties

Respondents were asked whether the project had any impact, or further impact, on their understanding of student difficulties in learning about the disciplinary Threshold Concept. Every respondent referred to some change in their understanding in this regard as a result of their involvement in this project. The responses ranged from *'to a degree' (P3)* to *'absolutely' (P2)* and *'definitely' (L2).*

Respondents were also asked to identify any particular aspect(s) of the project that led to their change in understanding. These 'triggers' are summarised in Section 3.

The most prominent impact on respondents was the revelation of the diverse range of understandings of the disciplinary Threshold Concept held by students (e.g. p5, L2, L3, L4).

So it really brings home to you the diversity of understanding and the students can hear the same thing but experience it very differently (L5)

..quite a mixed bag as to what their understanding of legal reasoning was (L4)

Not only was the range of student understanding exposed, but the depth of that range was also exposed:

So the kind of depth of understanding or misunderstanding was larger than I thought and so that impact from that was good. So I guess that was probably a slightly larger impact than … just finding out what kind of range and the variability within the range (P5)

In relation to the lower end of the exposed range of student understandings, there was an element of disappointment or a certain level of surprise about their lack of understanding of the disciplinary Threshold Concept (L4). The realization that the students are having such difficulty was also emphasised as one of the key impacts of the project (L3):

They were unexpected …. I was surprised and a little bit disappointed rereading their interviews (L4)

… realising that students aren't mastering the simple application of legal reasoning is a big impact for me. For me that was a pretty significant finding (L3)

… recognising that students didn't spontaneously connect uncertainty with the meanings of the content, the meaning of the experiments or their data… was a widespread thing (P6)

Whilst reference was made to the lower end of the range of student understanding through identifying common misconceptions (P5), or *'that they didn't really know' (L3),* an unexpected outcome for some respondents was the revelation that some students had a much better insight than first expected (P1):

[the project] … did highlight some areas for sure where students lacked across the board. But then it also showed some really interesting examples where students have just a complete grasp of it (P5)

..a lot of rather simplistic ideas about your students and their misconceptions that has to be confronted … and you realise that in fact it's a little bit more complicated - what's going on in the students' minds than that (P2).

Similarly, it was also acknowledged that in some cases students also have a natural, intuitive understanding of the concept that is *'actually quite sensible' (P7)*.

Aside from the exposure to the range of student understandings, there were other specific impacts, or learnings, about the various ways students think about the disciplinary Threshold Concept, sometimes as an outcome of the curriculum redesign and intervention rather than the action research component.

… had difficulty applying what they'd learnt in lectures to the specific situations they were encountering in the lab (P3)

… the key problem … being how the students link their theory with their common sense (P2)…

… when students didn't understand the units their critical analysis went way down (P5)

A number of participants commented that being involved in the project enabled them to reflect on things that they'd been concerned about for a while in relation to student difficulties or understanding (e.g. L1) and that it helped clarify things they'd already suspected:

I think it was an example of degree and getting a better understanding of things I'd already suspected and maybe getting an idea of how they maybe work together (P3)

I guess I had a big shopping list of things I knew were difficult from my previous experience but this really focused it down to a few main topics (P2)

I've been conscious that there's a problem with students getting a sense of what identifying legal issues means and applying Law to facts. Being part of this research process reflected concern I'd had for a while (L1)

… a confirmation of what I always suspected (L3)

I always knew that some students had trouble with this and, in fact, that some students never really got it, even - they could go through an entire Law degree and not get it … confirmed that suspicion that some students got it and some students didn't (L6)

Some participants found it very difficult to disaggregate their enhanced understanding of student difficulties from *'the way we teach' (P7)*:

I started to think that a lot of the difficulties that students have are just because we teach it really badly, typically (P7)

… when you get that much data and that many interactions with the students you inevitably realise your ideas are too simplistic (P2)

The link between student difficulties and the way disciplinary specialists teach was highlighted in references to specific existing teaching practices or contexts that aren't conducive to students developing a more sophisticated understanding of the disciplinary Threshold Concept:

… there's a real sense of the time pressure in the lab. As I say, they're quite stressed (P3)

One of the problems that the lab course has is that there's kind of a dual role, in that you're teaching students, but at the same time you're assessing them … So it creates all these unfortunate and un-ideal teaching practices where there's pressure on the demonstrators (P3)

… how artificial it is, the emphasis we place on uncertainties in the first year lab and why it's not really that surprising that students see them as a thing you need to do to trick the demonstrator into giving you good marks, because a lot of the labs that we're asking them to do don't really have a particularly good point. So they don't see why they're performing the experiment … (P3)

When we really worked through it we realised that what we were asking was too much … (L2)

We expect too much. That's what came through really dramatically (L4)

… affirms that the students aren't grasping the basics of legal reasoning before we force them into trying to apply a much more sophisticated model (L3)

... we gave lip service to its importance but were not reflecting that in the teaching (P2)

we don't, as a discipline, I think, communicate very coherently to students what our expectations are … (L6)

The natural sense of understanding the disciplinary Threshold Concept that some participants realised some students have was referred to in the context of how current teaching practice either fails to tap into it, or even erodes it:

…most of the students have a kind of natural sense of uncertainty and scatter and dispersions that's actually quite sensible. And yet somehow we don't exploit that property, that natural sense when we're teaching it. So that's something that I hadn't really thought about before (P7)

… how you can see quite a good understanding … when I was talking to them at the beginning of the lab; and then, when I was seeing them three weeks later, having been taught uncertainties, that that good understanding had gone out the window…(P3)

Reflected in the insight about existing teaching being linked to student difficulties, is the impact of the project on participants' understanding of how to better teach the disciplinary Threshold Concept. Further discussion on ways of teaching is included in Section 2.2 below, where the impact of the project on respondents' understandings of how best to teach the disciplinary Threshold Concept is investigated.

Impacts on understanding how best to teach

Respondents were asked if the project had had any impact, or further impact, on their understanding of how best to teach the disciplinary Threshold Concept and other concepts within their discipline. Clearly, the project had a major transformative outcome in this regard, and the results are presented below.

Teaching the Disciplinary Threshold Concept

Participants were asked to identify if the project had had any impact on their sense of how best to teach the disciplinary Threshold Concept. Only one respondent indicated that it had had no impact (P4), and that respondent was not teaching the subject. Eight respondents indicated that the project had had a considerable impact

on their understanding in this regard. Responses included *'absolutely' (L4)*,'certainly' (L6, P6) and *'definitely' (L2)*, with one respondent referring to the *'massive' (P2)* changes in the way they taught the concept and that those changes would continue. Two respondents indicated that the project had an impact *'to an extent' (P5)* or *'to a degree' (P3)*.

Some participants referred to their involvement in the project as being only one factor in their change in understanding of how to best teach the disciplinary Threshold Concept:

I've definitely changed the way I think about teaching, about what I should do over the course while I was involved in the project. It certainly would have helped, but I can't say it was the key factor there (P3)

−and that it served as a means of confirming and assisting them in their own previous understandings:

… I had always thought it was so important to do that with the students. But I hadn't done it in this framework before. So the framework really gave us this opportunity to teach in this way (L5)

Some respondents pointed to a general impact that they acknowledged will influence their teaching in the future, without necessarily pointing to specific curricular or methodological change that they had implemented:

… certainly it was informative … and changes how I think about what I'll do in my own Physics teaching (P7)

… the way that we worked out the methodology will certainly be effective and will definitely be used in all future introductory Law subjects (L4)

Many respondents were quite explicit in the details of a range of required changes in teaching strategies or curriculum, when referring to their changed understanding of how best to teach the disciplinary Threshold Concept. These are summarised in Table 1.

Table 1.Specific teaching and curriculum design strategies suggested by respondents as a result of their change in understanding of how best to teach the disciplinary Threshold Concept

How best to teach the disciplinary Threshold Concept	*Illustrative quotation*
Deconstruct exercises into simple steps; be a lot more explicit about what is being done and how it is being done; and go from simpler scenarios before going to more complex scenarios. Don't assume understanding at the basic level	*… so perhaps spend a little more time on those initial very simple scenarios and not just assume that they're too simple and the students are bored, because the evidence would suggest that they're not (L3)* *... deconstruct that so that you're focusing on one aspect at a time in those introductory exercise (L3)* *... getting them to look at the Law and analyse elements of Law and also separating Law and facts so that you're not reading the Law coloured by the facts. So that's separating them out and then looking at the way the Law might apply…that really helped them a lot (L1)*
Engage them with hands on involvement	*… [it] made a big difference (P1)*
Greater focus on discussion between students and between teachers and students	*Discussing things… rather than just writing things down on bits of paper… so it becomes much more open … what they're thinking about and I'm much more open about what I think about uncertainty (P1)* *We don't get students to discuss or investigate or look at the consequences of uncertainty. Yet that was one of the things that came out that we felt was the difference between what a student who really got it could pick out of what they'd done and those that didn't get it. So the consequences, the communication about uncertainty (P1)* *So it's changed the way I would teach. I did teach it this semester by putting much more emphasis in the discussion phase. So what are the consequences of this, what are the major sources, how can we do something about that. How could we do it, let's go and do something about it. So you don't just sort of come up with a set of vague ideas, you act on the ideas. So this acting on the information you've got, making a difference, that's something I hadn't done in the past (P1)*
Increase the amount of time devoted to the disciplinary Threshold Concept	*… we more than tripled the length of how much time we devote to it. So, yes, massive changes in the way we taught it and those will continue (P2)*
More effort on bridging the link between theory and their common sense	*… very much we focused in our entire effort on bridging that link rather than just using the formalities (P2)*
Change the marking key in the lab sessions.. to something less specified	*…the marking key and trying to move it away from something that says in this experiment you must do this, this, this and this, towards something that's a bit less specified (P3)*
Change emphasis of lab sessions	*… you can't just teach them uncertainties, record keeping, time management, totting graphs or whatever, as separate skills by making them do these things in the course of an experiment and expect them to get a deep understanding and how they all tie*

	together and understand the importance, if you haven't given them, to start with, some sort of sense of why they might want to do an experiment (P3)
Teach the disciplinary Threshold Concept within a context	*… to understand why uncertainties are important and to be able to use them properly you have to first understand what exactly it is you're doing and why you want to be able to do that, rather than just talk about uncertainties in isolation (P3)*
Pre-empt the common misconceptions in the beginning, but be aware of the fine line between giving away too much and giving enough that they're conscious of the potential pitfalls (P5)	*So if we're introducing it at the beginning of a practical session I might just mention a few little things that people might commonly have a misconception about. So in that respect it probably does make the teaching better that you're pre-empting these areas that the students might have issues with (P5)* *[the project]... just highlighted which are common pitfalls and so which is worth your time spending a little bit more on at the beginning (P5)*
Ignore the units >> reduce the fear factor>> allows them to think better (P5)	*… with the magnetic fields, because they didn't understand what teslors were or whatever, they thought they … couldn't analyse the situation in any meaningful respect. … oh well just ignore the units and look at the graph [and] that … fear factor allowed them to think a bit better (P5)*
Use analogies that are familiar to the students – in their own words	*.. using an analogy they're used to goes a long way (P5)* *Also coming from the project ... some of the student responses are the best ones to teach students with and that makes sense. Like what they think of themselves will probably extend better to other students as well (P5)*
Teach an entire class about [the TC...] in a structured way (L1)	*… being able to teach an entire class about this in a structured way that's put into work is probably a better way forward (L1)*
Needs to be multi-pronged and in multi-subjects	*…think what we've realised, it's [IRAC] just one aspect of them getting a sophisticated idea of what legal reasoning is (L2)* *What we need to do - as well as what we've done in the trial teaching materials - is to link it with another aspect we teach - case analysis - but to link it much more directly into legal reasoning (L2)*
Need to be consistent in what we teach and the faculty must get together and have consistency	*... we need to be consistent in what we teach....we might be teaching variations of a problem solving method or variation of case analysis and whatever. That, in fact, may be more confusing to a student (L2)*

A number of participants acknowledged a need for further refinement to continue to make improvements in their understanding of how best to teach the disciplinary Threshold Concept:

I'm not sure that any of them or us actually hit on the kind of magic formulae of the right way of doing it if there is such a thing (P7)

… we've made fairly major changes … and these changes will stick and they'll be iterated further because we certainly haven't reached perfection yet and probably never will (P2)

I could see from what we had implemented… that it was a very good exercise and I guess it needs a little bit more fine tuning in the future, but I think it was a very worthwhile exercise indeed (L4)

Section 5 provides more detail of how participants intend to use what they have learned or experienced in this project in their future teaching and curriculum design.

Teaching other disciplinary concepts

Respondents were also asked if the project had any impact on insights into the teaching and learning of other disciplinary concepts.

There was a little more uncertainty or hesitancy in participants' responses in relation to this area. One respondent suggested that *'it's a difficult question' (L3)* because of the integral nature of the disciplinary Threshold Concept across the whole discipline:

That's a difficult question because legal reasoning is so intrinsic to everything you do in a Law context. It's difficult for me to isolate legal reasoning from some other part of Law because it's just so basic and integral to what you do....it reaffirms the importance of laying the base when you're teaching any sort of skill or process (L3)

One respondent suggested they hadn't thought about it beyond their disciplinary Threshold Concept, although when asked later in the interview if they would recommend anything to colleagues from other disciplines, they said they would. More about what participants would recommend to colleagues is included in the discussion in Section 8.

Interestingly, one respondent suggested *'not really' (P1)* but then referred to a certain level of impact in linking the disciplinary Threshold Concept to other disciplinary concepts:

… it's made me think more about how I would be integrating the uncertainty into other aspects of the laboratory work rather than any greater insights or effect on how I might teach let's say thermodynamics or how I might teach electromagnetism (P1)

Seven respondents agreed that it had some impact, with one respondent saying that it *'absolutely'* did (L4). Two respondents indicated that it *'confirmed' (P4)* or *'reaffirmed' (L3)* ideas from before. Another respondent said that it *'probably helped'* but wouldn't directly attribute it to the project saying that *'there was a lot of stuff that's contributing to all these ideas' (P3)*.

Some of the responses to how the project had impacted on their sense of learning and teaching other disciplinary concepts include:

I started to link the way I was thinking about teaching uncertainty to the way that I think about teaching other things that could be taught in a formulated way (P7)

… strong parallel between the way that we try and teach students to be able to do the formulaic propagation of uncertainties kind of stuff and don't necessarily check for the deep understanding in the same - so there's a strong parallel between the two … it's just a generic problem with Physics (P7)

Thinking about the Threshold Concept of legal reasoning causes you to think about other Threshold Concepts that Law students need and the interrelationship between them (L2)

… it's certainly given me food for thought in how one would go about teaching other concepts, yes (L5)

it's made me think about how I could use the same process for other concepts that my students are having trouble with… (P6)

While Table 1 lists specific strategies in response to their changed understanding of how best to teach the disciplinary Threshold Concept, additional strategies are listed below, which were cited in response to the question about the impact of the project on their sense of learning and teaching other disciplinary concepts.

- Introduce real-life examples

Having a real world example like a car crash or a bungee jump or something like that which a lot of kids have experienced, they can relate to the forces and how it actually affected them at the time. And then that helps them understand it generally quicker. As opposed to talking about the abstract side of it and just solving equations on a board (P5)

- Provide a range of examples

… little things like you know you might find on YouTube or something funny that's happened but then you get the students to work out what was the velocity of the test balls that hit the dude or whatever. You know it's something they've done in real life and the context isn't scary for them so they can think about the Physics side of it without being scared of the context (P5)

- Layering complexity

Yes because conceptually difficult things may be more easily understandable if you have a series of concrete examples where there's increasing complexity or added layers so students can see the differences … it's something I think about now when I'm lecturing that I may not have thought about before … (L1)

- Go back to the beginning and not assume knowledge

…but I guess that is transferrable across pretty much anything you teach. You have to go right back to the beginning (L3)

- Applying Variation Theory

… certainly applying what I think is Variation Theory to more of those and making small adjustments to the activities to better delineate those concepts...(P6)

Impact on own understanding of the disciplinary Threshold Concept

Respondents were asked directly if the project had any impact on their own understanding of the disciplinary Threshold Concept. Eight respondents indicated that the project did have an impact to some degree, with responses ranging from *'absolutely' (L4, P6*) to 'a little' (L6). Five respondents indicated that it did not have an impact, two of these saying 'not particularly' (P3, P2). Even where there was little or no acknowledgement of a change in their own understanding, a number of these respondents did refer to an impact on their understanding of how others view it (students or academics) (P2, P4); that any change was restricted to how they teach it (L1, L6, P5), or that they had had their own ideas affirmed (L3).

It sort of changed how I perceived why the students are finding it difficult but I think my own understanding of measurement uncertainty was - hasn't changed much because of this … I think in my understanding it was all a bit unusual compared to most people so I think for most researchers the position we've come to would be quite a radical one but for me it wasn't (P2)

Where the real sort of epiphany was, I guess, was in what the student was thinking. I hadn't quite tapped into that (L3)

Not my own thinking and understanding of it, but it had an impact on seeing how others actually think about measurement uncertainty (P4)

No I wouldn't say I changed my thinking about it. It changed the way I think about teaching it to people who aren't used to it (P5)

I think I pretty much had my own conception of it affirmed (P3)

I really only focused on thinking about teaching legal reasoning (L6)

One respondent who has said that the impact had only been on the way of teaching, once questioned with a further, probing question, did acknowledge that there may have been a subtle impact on his own way of understanding the disciplinary Threshold Concept:

… maybe not. I think it's restricted to teaching legal reasoning rather than my understanding of legal reasoning, itself. It's maybe because I do research in that legal reasoning area anyway … (L1)
[So you mentioned that it did have impacts on your understanding of teaching and learning of it but not the concept, itself?]
Yes, except that … That level of analysis sort of makes you think a little bit more in a structured way about things you might take for granted. So it's a subtle impact but it's not a sort of observation or a way of analysing facts on Law that I would have done otherwise (L1)

The types of impacts cited by the respondents who indicated that a change did occur in their own understanding are illustrated in the following quotes:

I think I have a more sophisticated understanding of what legal reasoning is than before I started the project … So I think it's expanded, I guess, my view of legal reasoning (L2)

… it's certainly triggered a new cycle of thinking about it and possibly a different order of thinking about it (P7)

So I think that made me think again about uncertainty and what really matters. You know what are the key things, what are the absolutely essential things that matter about measurement and uncertainty (P1)

I definitely learnt something myself about the concept and it required me to … actually go a lot deeper and learn a lot more about the concept myself (L4)

So something that I thought was up front and central …was something which the other person thought was marginal or much more peripheral (P7)

absolutely .. It made me go back and question what I thought about it, what I thought it was. So much of what I thought… had become sub-conscious …. That it made me start afresh (P6)

Two respondents, who had suggested that there was an impact on their understanding didn't separate the idea of personal understanding of the concept from a teaching context, as illustrated in the following quotes:

It's changed what I give emphasis to. … It really gave me permission to think about plurality of views and to, as a teacher, take time to explore it in different ways ….
[So you're thinking about the concept itself or … thinking about different ways of teaching it?]
Thinking about the concept itself. I probably would have blended those two. Thinking about the concept itself I've probably blended those two there. Thinking about the concept itself, in my own mind and then in the context of a classroom, thinking about and talking about the concept with others, i.e. students (L5)

Yes… so I needed to re-jig the way I was explaining it to the students so that it was able to link to that starting point for understanding uncertainties. ..I had to think about that and change the emphasis of what I was explaining (P3)

Participant perceptions of most significant impact

Respondents were asked early in the interview to summarise the overall impacts of the project on them. They were then asked to indicate which of those impacts, if any, were the most significant for them. In some cases respondents referred directly to an impact to which they'd referred in their overall summary. In other cases they cited one(s) they hadn't already mentioned. The results in this section refer to responses that were given in response to the direct question asking them to label their most significant impact.

A number of participants had some difficulty in identifying the most significant impact. One of these chose not to identify the most significant impact:

I can't really think of one thing that stands out as what I got from the project specifically, as distinct from all the other things I was thinking about at the same time (P3)

A number of respondents found the notion of identifying the one most significant as a difficult task either because of their own definition of significance:

So the significance in my practice and the significance in myself. I'm not sure how you would say which of those two are the most significant, I'm not sure you can measure that sort of difference (P1)

–or, because they simply didn't want to prioritise between the impacts (e.g. P, P2, L5, L4, L2).
Table 2 provides a summary of the most significant impacts as stated by the participants.

Table 2: A summary of respondents' perceptions of the most significant impacts of the project

	Most significant impact or impacts
L1	That one self-contained lesson had such an impact on a number of students
L2	1. *Extending my own view of what the Threshold Concept is, apart from the secondary question, well how do we better teach the Threshold Concept? I think that's probably the most significant impact* 2. Realising that research can inform your teaching
L3	Realising that students aren't mastering the simple application of legal reasoning
L4	1. Learning the different style of teaching IRAC or HIRAC 2. Student lack of understanding - *Realising that not all the students who had been taught it, actually remembered or embraced it* 3. Coming up with the teaching exercise
L5	1. Both the way I think about learning and the way I think about teaching 2. Seeing the students gain confidence *I think it's helped my teaching because its allowed me to think about how I teach, rather than focussing simply on content. Now I've always thought about how one teaches, but it really gave me a chance to reflect more deeply on that (L5)*
L6	1. Revising our teaching in first year; revising our teaching materials and the way we approach it in classes. 2. Developing a group that were interested in the same things across the first year curriculum in Australia.
P1	Depends how you measure significance *'I usually measure impact by how it changes my practice. It's changed me in the sense of I think of uncertainty a little bit more differently than I did before'*

	1. Finding new ways to think about something even though you've thought about it for a long time 2. Working with others and realising different perspectives
P2	1. Plugged into the research network 2. Having thought hard about uncertainty 3. How you use phenomenographic surveys to probe student understandings
P3	Not one that really stands out
P4	1. Working with others - across universities = highlight 2. Realising the independence the others have over running their courses
P5	Seeing the range of students and that they'd been made more explicit
P6	Being able to talk to other people who were interested in the same problem…. It was … motivating….
P7	1. Different views of the physicists – all assuming that they're talking about the same thing without actually checking and that somehow the project still worked 2. Finding out what others are doing

Triggers for changes in understanding

Throughout the interview, respondents were asked about any particular aspect(s) of the project that triggered the various impacts to which they referred. There was a range of triggers reported and these have been categorised as follows:

- Conducting or analysing the student interviews
- Focused discussion with disciplinary colleagues
- Time to reflect
- Designing or implementing the curriculum intervention
- Educational theory.

Each of these categories, and observations about the impacts they were reported to have triggered, are discussed below.

Conducting and/or analysing student interviews

The very nature of the phenomenographic action research methodology and the associated data collection process of in-depth interviews with students was identified as a key trigger for a change in understanding. Specifically, it served as the key factor in changing participants' understanding of student difficulties in learning about the disciplinary Threshold Concept. Only four respondents (L1, L5, L6, P2) did not refer to the significance of the interviews in changing their understanding in this regard, and three of these were not involved in conducting the inverviews. Four respondents cited the interviews as being the key trigger for the most significant impacts of the project (L3, L4, L5, P5).

Those respondents who referred to the interviews as the primary, or most significant, trigger for their change in understanding of student difficulties, did not necessarily have to conduct the interviews. The process of reading the transcripts (e.g. L2) and being involved in the group discussions around the analysis were described as productive (e.g. P1).

So just through the interview process was how I was exposed to it (P5)

Just from interviewing them… (L4)

… the insights came from listening to what they had to say... then reading the transcripts (P1)

Ah the interview data, reading the transcripts actually showed up different features, different aspects which hearing it, … the student voice, was enlightening (P4)

A really good trigger for me was actually when I found time … to sit down and read all the interviews in depth. … found time to do all the interviews from all the universities in depth and to really sit down and analyse those (L2)

Through having done the interviews and when you sit down with student after student and you focus specifically on the topic … you realise how much diversity there is in understanding (L5)

It was mainly through the interviews; because I was doing them myself and then reading back over them. It was mainly at that level (P3)

… came about when we really actually analysed the interviews and we were able to - we built a grid, almost, of, I guess, levels of understanding, levels of sophistication... (L2)

… through the phenomenographic analysis, getting all those interview transcripts (P6)

A number of participants highlighted the reasons that the interviews were so helpful in facilitating their change in understanding of student difficulties and levels of understanding:

It's the data and how they express what they have understood that was really important. Because we don't quite often get to look at the transcripts of what students understand. We actually talk to them in the labs and the tutorials and so on or after lectures or whatever it is and they don't repeat what they are saying (P4)

… one of the things that was really important was actually getting the students to explain things. We very rarely do that in Physics. You might get a chance in a tutorial, but not in this sort of let's hear what they've got to say, then let's dissect it afterward (P1)

While the interviews were a key factor in a change in understanding of student difficulties, in turn, the interviews were also reported to have acted as a trigger for a change in the sense of how to teach the disciplinary Threshold Concept and other disciplinary concepts. A number of respondents specifically refer to the insights gained through the interviews as having an impact on their sense of learning and teaching:

… it's more complicated - what's going on in the student's minds than that …. I suppose that's a lesson I would take from this project back to the other areas of Physics (P2)

Again, realising the range of student understanding … It has taught me to approach the teaching of it a bit differently (P5)

So interviewing them and then working with them in class gave me confidence in what we've been doing (L5)

It is important to note that some respondents (e.g. P1, P4, P7) referred simultaneously to both the importance and effectiveness of the interviews as a method for gaining an understanding of student difficulties and to the potential difficulties in using interviews as an approach in future teaching and curriculum design. This will be further discussed in Section 5.

In some cases, it was the discussion with colleagues associated with the process of analyzing the interviews that was highlighted as being important in its own right:

Certainly the large amount of discussion with other people about these things and the interviews and the careful monitoring of what was going on were all valuable things (P2)

… that first phase interviews that the students did were very useful as well as part of helping us to focus as a group (L6)

Focused discussion with disciplinary colleagues

Focused discussion between participants not only took place around the analysis of the interview data but was built into all project processes − when identifying the disciplinary Threshold Concept to focus on, when discussing the curriculum intervention, and at other scheduled meetings that formed a part of the project. It was this focused discussion that participants reported as having had a significant impact on their understandings across a range of areas. Indeed, the opportunities for discussion and collaboration at all stages throughout the project was noted by most participants as significantly impacting on their understandings of student difficulties (e.g. L6), of better ways to teach (e.g. L2, L6, P2, P), and of their own understanding of the disciplinary Threshold Concept itself (e.g. P1, L2, L3, P6). Three participants attributed discussions with colleagues as the trigger for the most significant impacts of the project (L2, P1, P2). The nature of the discussion was important − as a focused conversation, with colleagues from different institutions, with at least two respondents saying that it was the biggest positive to come from the project:

:… to have discussions with other colleagues; more fruitful discussions than the quick five minute discussion you might have in the lunch room… (L2)

…time talking to other people about it … other institutions… discussions with my own colleagues (L6)

… getting together and talking with other people from the same discipline and trying to come up with shared ways of doing things has been a really - for me a very useful process (P7)

… good to be able to have it challenged by your peers or have them say things you wouldn't have said then you have to rethink them. So that challenge, it wasn't set up as a challenge it just turned out that way (P1)

… sitting down in a group and all of us brainstorming and pulling it apart (L4)

… biggest plus - opportunity to talk to people across the different institutions about the same problems…(P6)

it's the working with the other people that is something that I have enjoyed in all of my projects. ...In fact I think it was the highlight of it. (P4)

Focused conversation between fellow disciplinary specialists including from different institutions, provided a means of gaining insight into different perspectives and understandings of the Threshold Concept held by different academics within the same discipline. The opportunity to collaborate in the project gave academics the opportunity to *'think out loud as professionals' (P1)*, and through sharing these thoughts came the exposure of the diversity in the way that academics thought about the concept; even within the same discipline. The structured or semi-structured nature of these conversations as an integral part of the project provided more opportunity to '*get beneath the surface of what people actually believe' (P1)* as opposed to casual conversations which may or may not occur in an ad hoc manner, and on a serendipitous level in contexts outside the project. The exposed diversity of views that came through these conversations was cited as a major trigger for impacting on their own understanding of the disciplinary Threshold Concept itself.

The transformative outcomes of these conversations were also triggered through the use of video-conferences and emails, as well as face-to-face discussions, with one respondent referring to the significance of reading the meeting notes and discussions on the Moodle project site (P1).

Some respondents specifically referred to the diversity of opinion that was revealed through their ongoing discussion as providing insight into their understanding of teaching and learning:

It's become much more tangible to me that we're to some extent groping ourselves towards what should we all be thinking about this?... If we can work that out, we can give the students better guidance or support (P7)

… first of all realising how differently other academics would see the same thing (P2)

… it was some of the things that some of the other people at the project were saying that I disagreed with (P3)

So this sense of there is one way, we've got it in our heads and if only the students understood what we understood they'd be fine. It's not that way at all. We each have our own understanding of it. There may be some commonality. Hopefully there is. But also some quite important and profound differences (P1)

The opportunity to discuss the disciplinary Threshold Concept with educational developers and researchers, and not just those people within their own discipline was also considered a valuable opportunity that impacted upon a sense of how best to teach the disciplinary Threshold Concept.

… given me the opportunity to actually work in a meaningful way with educational developers rather than just my discipline specific peers (P7)

Three respondents referred to the important impact of the interaction with peers that occurred through putting together a conference paper coming out of the project, and attending the conference.

One respondent specifically referred to the discussion that came out of the phenomenographic analysis and the determining of the outcome space, as the key for a change in understanding – particularly in relation to how best to teach the disciplinary Threshold Concept. The respondent didn't refer to an 'outcome space' as such, but noted the significance of the process in changing their understanding of how to better teach the disciplinary Threshold Concept:

We were trying to map something - I can't remember how it was - and suddenly the penny dropped for me as to what was missing in teaching (L6)

We created a table on a whiteboard and we kind of pushed and pushed until we filled it on that day. It was, mentally, absolutely exhausting, but at that point I felt that there was something really important in what we discovered (L6)

It was that day at UTS; that table on that day at UTS….Yes. I just don't know quite what happened on that day. It was, at one point - it was a combination of explaining or discussing aspects of our teaching with some of the things that the project leaders were saying, but I can't remember what it was they were doing. I can't remember (L6)

Time to reflect

In addition to the value of the interviews and the focused discussions with colleagues, many participants also referred to the amount of time that they devoted to thinking about this particular disciplinary Threshold Concept as a trigger for impacting on their understanding of students' difficulties with learning about the disciplinary Threshold Concept and their own understanding of the disciplinary Threshold Concept:

I think the main thing was having this much time and this much motivation to look into one aspect of what the students find difficult … (P2)

I think it's the luxury of time, doing a project like this, to sit and think about what we're teaching, what they're learning …(L2)

… having the luxury of time, of really thinking about, I guess, the whole concept of threshold learning. What is it that students really need to get on top of? Then that enables you to connect the dots (L2)

I got a lot out of it when I really had the time to sit down and really think about it (L2)

…spending a lot of time working on it (P2)

… if only we'd had that time and resources to go through every lesson in every subject the same way (L1)

So when you give this extra emphasis, this extra thought about things, it's amazing what emerges that you didn't expect (P7)

Designing and/or implementing curricula

A number of participants noted that they gained key insights through either designing and/or implementing the actual curriculum intervention, and through their observations and serendipitous feedback in the classes/workshops in which the participants were involved (e.g. L3). Two respondents indicated that their involvement in teaching the lesson was the trigger for the most significant impacts (L1, L5).

I sort of got a sense of right from the interviews, but I guess it solidified in my mind since we've done the workshops [implementation with students] and since I've been hearing about the workshops from the other universities as well (L3)

[interviewer: so how did you identify their propensity to do that (jump to conclusions)?]… Just in the class itself… Really watching them in class, listening to them in class and seeing them absorb what we were teaching them, or what I was teaching them… (L5)

…because I saw the effectiveness of the way this lesson panned out and the way it was structured (L1)

… that was reinforced when I was working on devising the exercises (L6)

Educational theory

Some respondents referred directly or indirectly to one or more of the theoretical concepts or approaches used in the project – Phenomenography, Variation Theory and the notion of Threshold Concepts – as both a trigger for change in their understanding, particularly in relation to student difficulties:

It was that table that we produced. I'm not sure quite how we got on to that table on that day, but there was that aspect - whatever it was with that aspect of the project, which, I guess, was the analysis (L6)

- or as a means of changing their understanding of how best to teach:

Using Variation Theory to spot the differences - so to work out what are students' different understandings of this Threshold Concept? That was a good way of really analysing students' existing knowledge (L2)

It's not enough to say that I've been teaching for a long time. I can teach better if I actually take on board some of the educational research that's out there to inform my teaching. So that's been really good (L2)

… in terms of teaching methods, there was a method of variation that I was exposed to through this project. That certainly seems like a quite useful idea that I would take on board (P3)

Did illustrate to me that a lesson [curriculum design] that is designed to take into account a particular theory of learning (difference theory - sic*) can have an impact both on the person teaching it and the students who are there (L1)*

A little bit of Variation Theory, keeping some things constant and changing other things. That was helpful, again I'm not sure it was critical. But it certainly meant you could plan an intervention, if I can put it that way, to say well we'll do this and this (P1)

I guess the whole notion of legal reasoning is the stepping stone to open into other Law concepts, and again it's a threshold one. If you don't get that, you are going to be held back from appreciating and understanding the other concepts that will flow from that (L4)

Three respondents referred to one of the theoretical approaches underlying the project as being the trigger for the most significant impacts (L5, L6, P6). More discussion on participants' views of Variation Theory and the notion of Disciplinary Threshold Concepts as used in this project is included in Section 4.

… just the very nature of the project, the decision to make uncertainties a target Threshold Concept (P7)

… and then a little bit of reading, a couple of articles about what academics had thought legal reasoning is and things like that....I would not necessarily have done that without this project. Well, I'm sure I wouldn't have done that without this project (L2)

It is important to note that, even while acknowledging the value and significance of the phenomenographic interviews on the overall project, not every participant was convinced of the relationship between the interviews and the phenomenographic outcome space derived from the interview data:

… the conclusions we came up with were very valuable or interesting but it's not actually clear to me they were particularly based on the interview transcripts; so much as having a bunch of people who were very interested in this and with lots of experience with students talking about what the problems were (P2)

This participant was not downplaying the value of the interviews, and indeed suggests that learning how to use a phenomenographic approach to *'probe students' understandings' (P2)* was an important trigger for a change in understanding and one of the most significant, and unexpected, impacts to come from the project:

… discussing these things and trying to come up with a conceptual map of it... I mean to someone with Physics training it all seems awfully vague and fluffy. But by the end I did feel that something had been achieved and that we had actually come to an understanding of some things that hadn't been understood before (P2)

… the fact that these rather vague discussions can actually lead to something … was a bit of a revelation (P2)

Combination

It was not always easy to identify one particular trigger as having the most impact on their understanding. In some cases it is the combination of factors such as the interviews, discussions between colleagues and having the time and resources to focus on the disciplinary Threshold Concept, discussed as individual triggers above, which have acted as the catalyst for change.

I think it's the luxury of time, doing a project like this, to sit and think about what we're teaching, what they're learning, and also to have discussions with other colleagues: more fruitful discussions than the quick five minute discussion you might have in the lunch room; things like that… It's the ability to look at something in a bit more depth and to have some more thinking time about why we're doing what we're doing and how can we do it better (L2)

… that different theoretical framework, in addition to practically implementing it, gave me the chance [to change my understanding of the concept] … I'd say that there was the theoretical framework, but also the experience of working on the redesign of a course. So both as important as the other (L5)

Theoretical approaches

At various times throughout the interview, many respondents serendipitously referred to the theoretical approaches used in the project. In some cases Variation Theory and disciplinary Threshold Concepts were cited as a trigger for the participants' change in understanding (e.g. L5), as a new technique or method (e.g. P1, P2), or as an aspect of this project that might not be very reproducible in other contexts (e.g. P2).

Respondents were also asked directly what impact the two theories had on their thinking about teaching, learning and curriculum design. The following section summarises their responses to the specific questions and also attempts to integrate impacts of the theoretical approaches as mentioned by respondents throughout the interviews. At no stage during the interview were the respondents asked what they understood to be the various educational theories to which they referred. Thus, for example, when referring to Variation Theory or the theory of disciplinary Threshold Concepts, responses can only be representative of each individual's own interpretation of what the theories actually entail. For some respondents, this was a consideration when answering the question about the impact of the various theories on them:

I must admit I never really got a very good idea of what that [Variation Theory] was ….and I think that was a fairly common feeling, and we were all a bit worried about whether we were 'doing it right' in inverted commas. We were doing our interpretation of what we thought that was in a way that we thought worked best in the context (P6)

Interestingly, this same respondent referred to the notion of Variation Theory throughout the interview as something that helped in their understanding of how best to teach the disciplinary Threshold Concept, and also as something that they would use in the future. More about what respondents would use in the future is discussed in Section 5.

Disciplinary Threshold Concepts

The responses in these interviews reveal a difference between how the respondents from each discipline think about the notion of disciplinary Threshold Concepts in teaching, learning and curriculum design, with Law respondents appearing to find the notion more useful than Physics respondents.

All but one of the respondents from the Law discipline indicated that the notion of disciplinary Threshold Concepts had had an impact on their insights into learning, teaching and curriculum design. Two respondents referred to the specific and direct impacts of the concept on their understanding of teaching Law:

I think it's been important, in that it forces you to look at the bigger picture than just your own subject....because the Threshold Concept, I think, cuts across subjects. So content or knowledge is merely one aspect of what you should be trying to achieve in your teaching and learning in a particular subject. … Thinking about the Threshold Concept of legal reasoning causes you to think about other Threshold Concepts that Law students need and the interrelationship between them (L2)

The most important impact I think, is it reminds me as a teacher how important it is just to spend time on seemingly simple, but actually very difficult concepts, Threshold Concepts, which the students have more trouble in understanding than traditionally we've thought they have had (L5)

Another respondent from the Law discipline suggested the impact was *'subtle' (L1)*, and another did suggest that it might not be useful across all areas of the Law discipline:

Again going back to a Threshold Concept, it would be quite difficult to implement that in other components of Law because it is quite black and white, a lot of the Law, but certainly for the introductory Law subjects I think it could be an effective method of teaching (L4)

Of the physicists, one respondent indicated that the notion of disciplinary Threshold Concepts had a big impact and *'has changed the way I teach quite significantly'* (P5); one respondent did not express an opinion except to indicate that being involved in the project had provided the opportunity to learn more about the concept that he'd been exposed to for a while (P4). Another respondent from the Physics discipline reported that:

… the actual idea of a Threshold Concept was quite appealing at the beginning … and the more I've thought about it and whether what we were doing met the criteria for a Threshold Concept … the less sure I was that it really was. But ... in the end, what I really thought was that it didn't matter actually whether it was a TC or not, the fact that it was a troublesome concept that had far-reaching consequences ... that it was a concept that was interrelated with so many other concepts and that it really needed addressing ... something had to be done, and to me that was the main thing - whether it met the criteria ... or not, didn't really matter (P6)

The other four physicists indicated a sense of skepticism about the notion of disciplinary Threshold Concepts. All those who responded that they are not convinced of the usefulness of the concept, however, did acknowledge some level of usefulness (e.g. P7, P1, P2, P3).

Where a positive impact of the concept of disciplinary thresholds was identified, respondents across both disciplines cited them as:

- Providing an opportunity for discussion

The Threshold Concept aspect of it, trying to work out what the nature of the threshold is. I think that can be a useful way of making a discussion happen (P7)

- Providing a shared vocabulary

I think the benefit of Threshold Concepts is throwing together academics in the disciplines and giving them a vocabulary they can relate to … (P1)

- Providing a new way of thinking about an approach already used, or an experienced problem

… some of that stuff I was doing subconsciously before but now you have proper reasoning behind it, … so it also gives you another approach to expand or modify or quantitatively analyse (P5)

I guess there are changes that I've seen in students that I would classify as going through a Threshold Concept and being aware of the Threshold Concepts stuff has given me a way of thinking about that (P3)

Each of these steps I see now as a threshold issue so I am reading things in the context of student assessment in a slightly different way … I might have focused on something slightly different or tried to articulate the same thing but with less clarity. So it's given me a way to read in a way which structures the Law that'll assist a student (L1)

- Helping to focus on what students might be having difficulty with

The idea of a Threshold Concept, it's an interesting one and it might have a lot of merit. It certainly gets you focusing on what particular thing that might be stopping the students moving forward. Is there a critical point at which the students are not able to progress? Are you able to either help them to progress or give them some examples or opportunities to learn and make a difference? (P1)

… it was quite a new method of thinking that, indeed, if there is something that students don't get at an early stage, it's going to hold them back. So no, I wasn't familiar with it at all ...but just having this notion of something that was so significant that if they didn't grasp it, it would really hinder their further learning was an interesting and new concept to me (L4)

- Expanding the academics' view beyond their own subject

I think it's been important, in that it forces you to look at the bigger picture than just your own subject....because the Threshold Concept, I think, cuts across subjects (L2)

One Physics respondent identified a positive impact in that it confirmed previously held negative opinions of the notion of disciplinary Threshold Concepts:

I guess the Threshold Concept has been helpful for me and very interesting to think about, in terms of documenting and coming up with all the reasons why I think it's wrong (P3)

This respondent suggested that *'there are some good ideas in Threshold Concepts' (P3)* but suggested that it is too simplistic and too readily applied:

There seems to be this huge tendency that as soon as anything is considered difficult that people rush to label it as a Threshold Concept. I think it glosses over the difference between some things that are key and you do get them reasonably quickly and, with a bit of practice, you start to apply them and you understand them in lots of different contexts, and other things that are just the build-up of years of experience that you get incrementally (P3)

My observation of it is that it's tended to be over-applied and it's tended to give an impression that difficult and challenging concepts can be taught by a short intervention; that all you need to do is get the students over the Threshold Concept through a half hour change to your current process and that's it. My experience and what I've seen seems to indicate that that's totally wrong (P3)

While this respondent's views are clear, it is important to note that the comments refer to how the concept of disciplinary thresholds is misused rather than the notion itself. Other issues of concern that respondents cited in relation to the impact of

disciplinary Threshold Concepts on their insights into learning, teaching and curriculum design include:

- There are too many to be useful

I find that in Physics there are so many things that are threshold in the sense that if you don't master them then you can't go on....I find when the numbers get that high I think it ceases to be a very useful distinction (P2)

… there would be many Threshold Concepts, probably too many for Threshold Concepts to have actual value in that point (P1)

- Difficulty in determining what a disciplinary Threshold Concept is compared to other core or difficult concepts

It's more like a continuum – there's lots of different concepts, some of them important, some more important than others, but it wasn't as if there was a big distinction between Threshold Concepts and non Threshold Concepts that was usable in some way (P2)

I think there's an awful lot of very core and difficult concepts. Distinguishing those from the threshold is something that I don't know how you do. I haven't managed to work out the difference (P1)

I'm still not sure whether there's a difference between a Threshold Concept and just a core concept … Where it has been interesting is that the one that we did pick, which was uncertainty in measurement, crosses a lot of boundaries and is a perennial problem for all scientists. So that may well be a genuine Threshold Concept, but I'm not sure (P1)

Section 5.4 includes a discussion about whether or not the respondents would use the notion of disciplinary Threshold Concepts in their future curriculum design and teaching, and whether or not they would recommend it to colleagues.

Variation Theory

In comparison with the notion of Threshold Concepts, there appears to be a slightly more even response to the notion of Variation Theory and phenomenographic action research, and their impact on participants' insight into learning, teaching and curriculum design, with no obvious split between the participants from the different disciplines. Once again, at no stage were respondents asked to define what Variation Theory or phenomenography were, and it is the individual respondents' interpretations of the theory that determine the impact on them. One respondent from the Physics discipline who had not been involved in the design phase of the curriculum intervention did not want to make a comment on its impact, being uncertain about the role Variation Theory played. Two respondents indicated that they had been intuitively aware of, or using, variation already in their teaching practice, and thus the notion of Variation Theory had no or little impact:

I just couldn't figure out what variation - how this variation is different to the variation that I would use in my teaching anyway… So it's a technique that I think I've been using and I couldn't see what was the difference between what we do and what this was. I'm sorry (P4)

No, I tried to drill down into it but I just couldn't get the answers … How this variation was different to the normal variation that we use (P4)

… with Variation Theory, it probably puts a word on something that I was probably doing to some extent anyway… I don't think it was this kind of ah, I'd never thought of doing that sort of moment, but it was useful to be able to say all right, so what I'm doing here is using Variation Theory, if I want to talk to someone else (P3)

One respondent from the Law discipline also cited an intuitive understanding and suggested that it did not have much of an impact, although they did refer to an impact of the project on their teaching:

I think I intuitively understood the hierarchy there, but whether that actually translated to what I was doing in terms of talking to the students and presenting it as a sort of a staged concept I don't think I was doing that before (L3)

Three other respondents mentioned an intuitive understanding of the notion of Variation Theory, yet simultaneously acknowledged the important impact of being exposed to the theory through involvement in this project, and the use of Variation Theory as providing a 'strategy to fix' (P6) an identified problem:

…Variation Theory had a really important impact … I guess it brought together instincts and practices I'd already had when it comes to teaching ...But new ways of doing it. So I think it brings to the fore things one's always thinking about, but it actually gives one far more clarity about how to think about things, but also how to put things into practice … It was entirely new. I have to say I think it's underpinned by a lot of common sense (L5)

… instinctively, I knew that varying one thing was a good way to learn, but I hadn't - if you've never been given any framework in which [unclear] think about it … So I had used it in simple kind of ways in my teaching previously, but hadn't sort of used it consciously; not consciously in relation to theory, if that makes sense. I wasn't consciously applying a theory (L6)

… using Variation Theory as a strategy to deal with it is something that I would at least consider now that I've had the experience of trying it once (P6)

Further discussion about what aspect(s) of the project participants would use in their future teaching and curriculum design is included in Section 5.

One respondent referred to an impact in the two specific areas of learning and teaching:

I guess two impacts...firstly… [using phenomenographic action research] to spot the differences - so to work out what are students' different understandings of this Threshold Concept? That was a good way of really analysing students' existing knowledge … then the second way … we've used Variation Theory to say well, we can teach this better because students may be able to grab a concept better if we can show - if they can see variations (L2)

One respondent indicated that the general notion of Variation Theory had a positive and unexpected impact on their insight into teaching, learning and curriculum design:

… I mean to someone with Physics training it all seems awfully vague and fluffy. But by the end I did feel that something had been achieved and that we had actually come to an understanding of some things that hadn't been understood before (P2)

−but that there were limits to that impact:

It's another tool in my toolkit and one I will continue to use quite a lot I think. It's not something that transforms my entire understanding but it's a useful tool (P2)

… I think the link between the interviews and conclusions we came to, were rather weak. In fact a different group of four people might well have come up with very different conclusions from the same interviews (P2)

Of particular importance to this respondent were the case studies introduced through the project meetings, rather than any of the literature on Variation Theory:

The whole variational method stuff - the other documentation … early on made no sense to me whatsoever; but when she actually gave some case studies of how it could be introduced into Physics, I was actually, oh, okay. That's makes sense (P2)

Three other respondents (from both disciplines) also acknowledged an impact while pointing to their uncertainty about using it in other contexts:

It has had an impact but I'm not sure I would go for Variation Theory as an approach for example in teaching other things. I'm not that convinced to be honest with you that it's a valid way to go. The jury's still out to see its bigger value. So I'm not convinced I'll be using that elsewhere, although I can see other people have and they've got useful results. So I feel I'm still sceptical about the use of that (P1)

Well, again, that wasn't a concept that I was familiar with … I suppose in the end it is a little bit influential in my thinking about design, that if you just change one factor that it can enhance a student's understanding of a concept. So I think that's quite beneficial for their learning process. Whether or not you could use it in all facets, I think it's just limited to certain topics within Law (L4)

… I'd query whether you'd use the Variation Theory across the whole course. I think my experience was that it was really helpful in the component in which we really focussed on … I think I'd want to integrate the approach, the project approach, rather than rely solely on it … I would question at this stage, I would question whether using it as a blanket approach to every aspect of a course is the way o go. That would be my only comment I think (L5)

Two respondents referred particularly to the complexity of the method and indicated an uncertainty as to whether they'd used it effectively:

My feeling was probably I was trying to use Variation Theory and Phenomenography very early on when we'd just about done the interviews. You're too much of a novice. You probably need to do a PhD in this area to really get a grasp. So I suspect … the application of Variation Theory ...I'm not sure that I used that terribly well either (P1)

So maybe for next time I'd be better set up to apply various theories … but the things that I did, trying little things in tutorials and that, they were useful in themselves but I'm not sure they ticked all the boxes for Variation Theory. I would say I was probably only moving in that direction rather than doing it in any serious way (P1)

… and we were all a bit worried about whether we were 'doing it right' in inverted commas. We were doing our interpretation of what we thought that was in a way that we thought worked best in the context (P6)

The following section includes further discussion about whether or not participants would use the notion of disciplinary Threshold Concepts or Variation Theory or any other aspects of the curriculum design processes from this project in their future teaching, learning or curriculum design work.

Which aspects of the project would they use in the future?

… oh it's changed the way I think about how I'm going to teach this subject and how I think of it myself which in itself is surprising, because I've taught this thing for many years (P1)

Respondents were asked if they expected to use anything they've gained from this project in their future teaching and curriculum design, either in relation to the disciplinary Threshold Concept or other disciplinary concepts.
All participants answered in the affirmative in some way with two saying *'certainly' (P1)* or *'definitely' (P3)*. Even those who were a little less certain, with responses including words like *'I suppose' (L4)*, *'not sure' (P4)*, or *'difficult to say' (L3)* referred

to some aspects of the project and their insights that they might potentially use in the future:

So it will make me stop and think, but I'm not sure if it will make me do things differently (P4)

Difficult to say because I usually work as a sessional … so my content and how I do it is often fairly determined for me. I think it will impact, where I do have a bit of a free hand… (L3)

The areas that respondents suggested they'd use in the future have been divided into a number of categories as discussed below.

The action research project approach

Some respondents referred to the specific processes undertaken as part of the phenomenographic action research project as being of potential use in their future work. Responses cited individual processes or referred to the methodology as a whole.

So I could envisage, if I were to teach in the same course again, another iteration of a similar process … I think it takes more than one go to get it really working productively and efficiently (L5)

I expect the whole methodology of the interviews and how we analyse them and try to discuss with a wide range of people with other institutions, then come up with an intervention, wondering how it works, and that's something that's clearly very powerful … My general philosophy of teaching's been each year to identify maybe two things that I want to really work on and this will give me an example of how to work on one of these things … So I may well try a rather similar method and pick another topic once the uncertainty one is bedded down and then keep working through the syllabus until everything's been revised this way (P2)

The latter respondent cited the desire to improve future teaching as a reason to use the project approach in the future:

Every year when I come to mark the exam scripts at the end of the course, I'm dismayed at how little some of the students have learnt and this may be a way to fix that or some things (P2)

One respondent hoped that the project itself, on a bigger scale, will get taken into the future:

I'm thinking it might even spawn a bigger project. I'm hoping I'll go overseas and talk about what I've done … so I'm hoping the whole momentum about looking at uncertainty … which this project has given more momentum to, is something that we can sustain (P1)

–and, another respondent would volunteer to be involved in similar projects:

… if there are similar things then I'd put my hand up to be involved (L1)

A number of respondents referred specifically to the interviews as a process that they would use, or would like to use, in the future.

… definitely working out what students are having difficulties with, doing interviews, trying to come up with ways of changing them and then evaluating them (P3)

Yeah look, this was the sort of first time for me to conduct sort of formally scripted interviews. So those kinds of techniques to try and get answers from kids without influencing them with your own words is very useful. Because that sort of - you get a much more accurate level of their understanding (P5)

It will affect the way I teach. I really like to be able to do things like interview the students and dig under the surface in many areas. Uncertainty in measurement is just one of them (P1)

One respondent who said that they were 'not sure' what they'd use, and who'd said that it would make them 'stop and think' was asked to clarify what about the project would make them stop and think. In reply, they referred to the impact of the interviews:

I think the interview data … in terms of when I am - when we are talking about something in class, to actually listen to what the students are asking more carefully and to try and probe what is exactly their question and so on (P4)

Other respondents referred to the opportunities for discussion that were built into the project as the thing that they'd take into their future work:

… talking with other Physics academics, especially ones from outside of my institution … I do hope that I'll be able to occasionally pick up the phone or email people and say, oh I'm just thinking about how to teach this and what do you do and what do you think the critical elements are? … Because I think that my perspective on Physics is only one person's perspective on Physics and there are multiple potentially valid perspectives and because there are multiple different students with different perspectives and different interests (P7)

So first of all, I guess, a talk fest in identification ... can you come up with a two page proposal about - in what subject and how we might create different teaching materials … Probably nothing as sophisticated as what we've done in this project, but at least - and mostly because it's also a question of time and commitment - but at least keep the discussion growing (L2)

Their insights gained from the project

Some respondents referred to specific insights that they'd gained through the project rather than to specific processes or methods used as part of the project. Interestingly these did not necessarily match their responses to the most significant impact, or impacts that had been cited earlier in the interview.

… I'll just be a bit more aware about trying to unwrap concepts a bit more and starting from a base and then moving up rather than just sort of presenting them [students] with the whole thing … it's just reminding myself we need to not presuppose the knowledge; we need to really illustrate each step along the way so that they can replicate it (L3)

In other courses, with other concepts I think, whether it be informally or formally, a lot of what we've been doing could be really useful for students in future years, yeah...using it informally I mean that I take awareness's and understanding that I've personally got from the project and I think that that impacts what I do in other courses (L5)

The whole idea of evaluating what you're doing, taking nothing for granted, listening to the students, absolutely and definitely (P3)

The intervention materials

Some respondents referred to the whole lesson that was implemented as the curriculum intervention as something they would use in the future, and cite that they've incorporated it into another course (e.g. L1). Others referred more generally to the teaching materials or approaches that were included as part of the intervention.

I mean the materials and approach we developed for uncertainty will be the basis of what we'll do next year and the year afterwards (P2)

This idea of giving them advanced specific reading I hadn't thought of before but it really makes them look at something closely … So just that little thing, making the readings available a fortnight before the exam and it's got nothing to do with IRAC but it's a simple thing that makes them do some close reading of something, which I just hadn't been doing before – it's a very simple idea....So that's something else I've gotten out of that exercise (L1)

Yeah, yeah like already I started using [teaching materials]. So that seems to be working successfully and you see a few more moments click in the kids. So yeah, for sure (P5)

The underlying theoretical concepts

A number of participants referred to the theoretical concepts underlying the project as something they would use in future. Brief reference was made to this earlier in Section 4.

It was quite a constructive exercise and one thing I might point out is that often you read a lot about theories of teaching, you don't often get to test out that theory and see what the impact is (L1)

The following quotes illustrate how some respondents would take elements of the notion of disciplinary Threshold Concepts into their future work in teaching and curriculum design:

I guess the other thing is to look at what are other Threshold Concepts that we think they're having trouble with, and can we target those expressly as well … and to look at what some of those other Threshold Concepts are and develop materials and methods of teaching to get them along quicker (L2)

Well I'd go back to … the literature and just see if there are areas where there might be conceptual difficulty … the actual thresholds in a legal topic and see if lessons or seminars can be structured in that way so that you get a threshold issue in a specific legal topic and have a range of cases or a range of scenarios that illustrate how that threshold might have an impact on an outcome (L1)

I have identified another Threshold Concept, I suppose, that would be relevant … So yeah, there's possible future potential there to use that as a threshold, and the way of doing that would be to possibly do it a similar way … so set up the similar problem question, similar methodology using variation. I suppose you could. I'd have to give that a lot more thought, but certainly that is a key Threshold Concept (L4)

Variation Theory was also cited as an aspect of the project that some respondents would use in the future.

So certainly prepared to now look at other aspects of curriculum design about whether Variation Theory would be appropriate in that as well (L2)

… Variation Theory ...I think in a sense it is a pity to get the idea of some of these principles if you like and not use them again … So I think I would like to use these things. To gain experience and more confidence. If opportunities came along I'd probably take them (P1)

What this project has taught me is that when a student finds something troublesome, to consider whether or not using Variation Theory would assist. So where a student or a group of students or a cohort finds something difficult to learn, or there's disparity in the extent to which students within the cohort learn whatever it is, then I would, hopefully, consider remembering to use Variation Theory (L6)

One respondent referred to the potential future use of Phenomenography:

It would depend on what it was I was trying to do. Phenomenography's really useful when what you're wanting to get is not any sort of right or wrong answer if you like; what you're looking for is the continuum, the different ways that someone can understand a concept. What you want to do is you want to map those different ways and in our case teach to those ... Probably now that we've got this sort of mapped out you might learn though that there's some other different types of methods … (L3)

The next section summarises findings in relation to respondents' suggestions about potential alternative methods – things they would do differently than they did in this project, and potential abbreviations to the approaches used in the project.

Which aspects of the project would they avoid using in the future?

When respondents were asked if they would avoid using anything from the project in their future teaching and curriculum design, most respondents (all except two) said there was nothing that they would avoid using.

However, most respondents did make some reference to the resource-intensive nature of the project, and thus the difficulty of reproducing the approach in its entirety. These respondents, despite voicing positive transformative outcomes of the project, voiced some uncertainty about the 'reproducibility' (P2) or 'sustainability' (P1, P6) of the processes involved in the project, and whether it is likely to be applied more broadly in future teaching and curriculum design:

I'm not sure it's a very reproducible model. I don't think we - there are so many difficult issues in the curriculum I don't think I can follow that enormously complicated and time consuming model for everything. It's just very interesting to see what a difference it makes when you put that much effort into having discussions battling one small issue (P2)

... the time and effort required to interview and then decipher these student interviews. I read the interviews over and over and over again, you could go on forever, they're endlessly interesting there's no doubt about it. But could you do that for everything you teach the students in the first year? No you couldn't, you'd just drive yourself mad. So you've got to keep these things in perspective. They're valuable, they give you an insight into students, but you couldn't apply them everywhere. I couldn't anyway, I couldn't set aside the time. So it's effective for some things, but other things I think it would not be viable to try and use them in other contexts (P1)

My negativity if I can put it that way is to do with the sustainability based on resource availability … (P1)

As useful as I found the interviews, they were time consuming. I guess the counterargument to that is does the benefit outweigh the cost. I think so far it has and so I would do that again. I obviously can't do it the same way without forking out for plane tickets… (P6)

… well I can't get interview data for all of the different concepts and ideas and so on, so I'd avoid getting data for all the different sorts of things … The interview process was the part that was useful. It's just too expensive to do it (P4)

Realistically I think they become sort of academic exercises. You can get money to do projects on these things. But the reality of being able to set aside the time and have things transcribed and spend hours reading these things, means they become a legitimate academic exercise but not real legitimate day to day exercises. So I would say in reality no I don't think you can do that. You can do it as a project but not as a day to day process you'd go through. I may be wrong, but I think just the burden is too great (P1)

It takes too long to do it, it takes resources. Then you're only doing a little bit of the curriculum at any one time. So you're really just nibbling away. Uncertainty, as important as it is, it's really a very small fraction. So it would be like trying to paint the Fourth Road Bridge or the Sydney Harbour Bridge. You can go through the whole of your curriculum and it would take you 25 years and you'd start again. Life's too short for that … So I think many of the ideas I would like to use but I don't think I would be able to (P1)

… also it may assist in developing other lessons but the problem is it's incredibly time consuming (L1)

One respondent referred to some of the project literature as being something to avoid:

I think that the literature I looked through, a lot of it I didn't particularly like. In particular there seemed to be a huge amount of debate about is this a Threshold Concept or is it not? Or is this a

variational approach and people trying to define what the variational approach actually was and what a Threshold Concept was. … So, the whole stuff in the literature about trying to define exactly what these things were was probably a bit of waste time as far as I was concerned but that was about the only thing I think (P2)

Two respondents suggested that there was nothing that they'd avoid using, but rather:

I think it's more that there are the additional things that I'd do that weren't part of the project … (P3)

Things to do differently

As indicated above, some reference was made to aspects of the project approach where respondents might do things differently if they had an opportunity to redo the project. Responses related to the following quite specific areas:

- Involve demonstrators and teachers more, and earlier

… the key one is getting the demonstrators, as a group, more involved …(P3)

I think having mechanisms to involve all the team right from the start, or in different ways right from the start - they have to be there every step of the way ... I think you need to get them on the same page and keep them there, and just giving them exercises won't necessarily work (L6)

One of these respondents was enthusiastic in their responses about why demonstrators should be involved all the way through the project:

I think you go through a much deeper process over a period of time, being involved in the research, than you do just hearing someone give a half hour presentation on it or something. That's why I'm saying you should get them involved all the way through. It obviously has the added benefit that you don't have to do it all yourself; the disadvantage is that you have to somehow find the money to pay them to do it (P3)

If the demonstrators and the people who are actually in the lab - interacting one on one with the students - don't have these good ideas and understand the insights that are being gained from the research into how students learn about uncertainties or whatever, then you're missing out on more than half of the possible impact that the research could have (P3)

- Do more iterations of the interviews

I guess one of the things with the way it was done - obviously due to time limitation - was that there was only one iteration through the interviews. We didn't have that kind of detailed understanding about what the students were doing after the intervention that you had before - from the stuff from before; so some more information about how they actually responded to the different activities. I guess that's one thing (P3)

I think we had a rather low data rate in the sense that we decided to come out with the questions, then we arranged for large numbers of people across all the universities to answer those ones and I think we very rapidly discovered that we weren't asking the right questions … So I think a system of writing a prototype in a rather less formal system where you could come up with some ideas, ask a few people, see how it worked, try something else [unclear] and work that way up to a large scale trial would be a lot more effective. So, again, more like an iterative action research type approach. Maybe working initially in a much smaller scale but in one university and then building up to a larger thing might be more effective and make it a bit shorter (P2)

In response to being asked what the gains might be from adopting an approach that might indeed involve more time, this respondent replied:

The gain is that … I think a lot of the things we tried didn't work the way we expected them to do. Given that we'd spent a long time thinking about what to do and then we'd implemented it across a very large scale and then ran it; you couldn't change it quickly; so sometimes it was a very cumbersome process. We came up with this thing then implemented it and then that took a long time so if anything went wrong, which of course it did, you'd just have to wait another year before fixing it (P2)

Two other respondents also suggested alternatives or refinements that might result in more time consuming processes:

I think it had to be time consuming, I mean you had to - when I reflect on what was time consuming for me, it was the interviews took longer, the preparation for interviews took longer, the analysis of interviews took longer than we thought. Then the amount of effort that goes into curriculum redesign and then implementing that initial curriculum redesign that we did this first semester, and then reflecting on it … Each week working with it, I think is necessary if you're going to do it properly and if you're taking it seriously … You could probably - and this would not save time, it would add time, but you could add other things. You could add a written questionnaire to the interviewing so that students talked to us and then responded to a written questionnaire about it and that would give you different types of information I suspect. I wouldn't cut out the interviewing, no (L5)

- Alter the interview questions or the ordering of the questions and examples

… maybe the order of the questions … I would however introduce the phone data first before the magnetic data personally. Because I think that would have been a more gradual ramp and during the interview process it probably would have got them thinking about it [in] a bit more sophisticated [way]. ....[would lead to] Just better accuracy in the answers from the students in determining their level of understanding … (P5)

I found it very hard to read all the interview transcripts and to get anything useful out of them. I mean, I thought essay marking was bad but this was a lot worse. And ... there were very few gems of information in there, I felt. So, design maybe a different sort of questions or something else, as well as improving the amount of data we got out of that (P2)

Abbreviated processes

As well as being asked what they would and would not use in the future, respondents were given the opportunity to suggest potential abbreviations to project approaches. They were also asked to identify any gains or losses from any such approaches. Most respondents who suggested an abbreviated process, acknowledged some loss that would be a consequence of adopting such abbreviated processes.

Only one respondent did not suggest an abbreviated process, suggesting that *'with something like this I don't know if you'd want to cut corners' (L1)*. This respondent was involved in teaching the curriculum intervention workshop and was not involved in the interviews or the curriculum design process.

So it really wasn't a time consuming exercise. The lesson itself was an hour and a half. I might have spent a few hours doing the reading and going through what I was going to say in preparation… (L1)

Another respondent suggested:

… look I think as with all things new, refinement's going to make it better. Whether that's abbreviation or expansion, I don't know (P5)

The areas for which respondents suggested abbreviated processes are categorised and summarised below.

Project management

One respondent suggested potential abbreviations could be made to the actual project management approaches:

Well, I think there was a little bit of time wasting … some of the meetings could have been a bit shorter, and we needed to be a little bit more succinct, that's all. I suppose we were working with arts people and teaching people who talk a lot, but I mean academics do talk a lot, but I guess there was a little bit of impatience on my part. I think that's even harsh to say. It's just that time's a pretty precious thing when you've got lots of work to do … (L4)

This respondent simultaneously acknowledged:

... My expectations were actually probably a bit foolish because we couldn't have done it any faster because we actually needed to have time to put it into a subject and check the results, that's all. That's just me who wants everything done straightaway (L4)

Strategies other than interviews

A number of respondents initially suggested that no abbreviated processes be used, but did indeed identify certain processes that might be used in different circumstances (e.g. P3, P4, L2, L3, L5). In suggesting abbreviations, they also reiterated the substantial advantage of using the approaches in the project – particularly the interviews:

I don't see how you could get the information that you'd want …
[followed by] *… I mean, obviously, there's a place for surveys, in terms of once you know some of the key ways that students think you can probably identify them and get quantitative figures for stuff. But in terms of really understanding what the students are on about, I don't think there's any other way to do it but interviews (P3)*

No I think this was quite rushed as it was. I don't think so. I actually don't think so …
[followed by] *… Well we already have conceptual questions where students write down little descriptions and so on, that's an alternative … But again you actually can't tease out all the features and they don't say everything that they - it's really hard. They might write something down, but they really mean something else (P4)*

In terms of that initial step of trying to map the continuum of how different people understand a particular concept or principle, it's probably as time efficient and as resource efficient as any other method really …
[followed by] *… I question whether you … could achieve much the same result by doing workshops … focus groups, perhaps even by doing some surveys or something like that or running one class one way and another class another way and comparing results. You could move into more qualitative and even quantitative methods.* [Int: You mentioned workshops and focus groups as a potential alternative]. *Not at that initial stage of mapping the concepts but in terms of testing out the models and testing out the change in the curriculum or the lesson plan. That's what you would use that for (L3)*

Because most respondents who were involved in the interview processes referred to them as being the most time intensive component of the project, those who suggested abbreviations mostly related them to the interviews. However, a loss in the type of data was cited each time alternatives to interviews were given:

I think if you really want to get to the - if you really want to know what your students think, you have to interview them … you can do it with online surveys and things like that which would be an awful lot quicker, but then you don't have the ability to follow up there and then what a student's saying and find out what their thinking is behind what they say (P7)

… you could cut down the number of interviews, you could cut down the number of people you talk to about it, you could cut down the number of meetings you have with people, but the more of that you do, the less reliable it is likely to be …. In terms of getting breadth of opinion, in terms of getting a better sample of data ... because it is hard to get a pattern (P6)

One respondent suggested that although the interview process was the most time-intensive, the key thing that needs to be changed in the future would be workload planning:

I think the interview process for the students was excellent in helping us. It's just time intensive. So to do something similar I think we have to plan it as part of workload better. I'm not sure how you do that. Which means, also, that you need faculty commitment … it is so important that it has to be built into everyone's workload (L2)

Analysis of interviews

Analysis of the interviews was also cited as a time-consuming and complex process. Suggested abbreviations included a *'more superficial' (P1)* approach to the analysis:

I suspect you can look at the transcript - and I did this right at the very beginning actually. You can look at it without really understand Phenomenography and I picked out the key things that were being said in each transcript and how often they were being said … So I think you can probably get a lot out of listening to what they've got to say and having a fairly simplistic approach to deciphering what each student says, rather than trying to find a collective voice that comes out of many transcripts (P1)

This respondent acknowledged such a shortcut as deviating from the underlying theory behind the project and thus a potential loss in data quality, but also perhaps providing sufficient data for teaching and curriculum design purposes:

So yes, there are probably shortcuts there that would probably cause most phenomenographers to go grey and fall over. Nevertheless for your purposes of how you might adapt a change of curriculum it might be sufficient. So that would be one shortcut I'd say …

Well you probably couldn't put together one of these charts, I've forgotten what they're called now. Variation space or whatever it is. You wouldn't be able to with confidence say well I've found five different conceptions

… It would be a bit more bitty. It would be a bit less refined, you might miss some key ideas, you might miss something else … So you'd miss that getting another perspective on things which would maybe help you decipher what the students are saying. So yes there would be something lost inevitably, but you might get enough (P1)

The same respondent also suggested that there could be no abbreviated process for one of the most time-intensive processes in the project – the curriculum redesign:

One of the big time and resource consuming things was actually making changes in the laboratory. I don't see how you'd get round that (P1)

Recommend to colleagues

As well as asking the respondents to consider what aspects of the curriculum design process used in this project they would use or avoid in the future, they were asked what they would recommend to colleagues, either in their own discipline or outside of their specific discipline. Most respondents suggested some element or elements of the project that they might pass onto colleagues, with responses including 'yes', 'definitely' or 'certainly'.

Four respondents gave qualified responses to the question, with one being reluctant because of not being involved in the curriculum design process:

Now because I was introduced to the lesson a little later on in the project and even though I've read the literature … there's not something that I can easily point to that I would suggest to other colleagues to adopt (L1)

This same respondent, however, when asked about recommending to colleagues outside of the discipline, replied:

… it was a constructive experience so there wasn't something in it that I would not – I would be able to refer to as not being worth doing (L1)

–and, when asked about the most significant impact of the project earlier in the interview, stated:

Comments I made to colleagues were – if we had tens of thousands of dollars to develop every lesson in this subject that way we'd have a fantastic course 'cause it shows what you can achieve where a lot of experience is brought to bear on a particular aspect of legal education in a course (L1)

Another respondent who gave a qualified response of *'yes and no'* suggested that they would in certain situations, with certain colleagues:

Because teaching skill can be such a range as well, some colleagues are already awesome teachers, you know far, far better than me and far, far more experienced … other tutors my age, yeah we talk really openly about it… What stuff worked and what stuff didn't but we're not really at the design stage of curriculum so it's not quite the same (P5)

Another respondent suggested that they would definitely recommend to their colleagues who taught first year courses:

… I definitely think that the first year curriculum needs to be slightly altered to take this, to have a discrete subject or to have legal reasoning taught in a little bit more depth, and in this new method. So in that regard, yes, for first-year subjects. So it could be a little bit tricky as you go past the first-year threshold subjects (L4)

One respondent suggested an uncertainty about being able to pass on particular aspects because of uncertainty about applying the underlying theory correctly, even though they found the theory (Variation Theory in particular) useful:

But how I would get that across is something I haven't really thought about … particularly when I and some of my colleagues .....are so unsure as to whether we are doing the right thing or not... but at least it gives us a strategy that we find appealing. Whether we've got the hang of it or not... it should be transferrable to other concepts (P6)

All the other respondents were enthusiastic in their responses about encouraging colleagues within their discipline:

I do think the idea of talking through critical ideas, core ideas with other people is something that I'd strongly encourage (P7)

Certainly the large amount of discussion with other people about these things and the interviews and the careful monitoring of what was going on were all valuable things (P2)

Colleagues in other disciplines

Most respondents who would encourage their disciplinary colleagues to use some aspect of the curriculum design process used in this project, would also make similar recommendations to colleagues in other disciplines:

Yeah. I think this idea can be generalised across pretty much every area. Every area that Threshold Concepts exists I think looking at interventions and alternative teaching types, yeah definitely (P5)

I don't think it's limited to Physics in any way (P3)

Yes. I don't think there's anything specific about Physics in it (P2)

I think this project illustrated that it could be used in any discipline (L2)

I guess the project itself demonstrates this, that it doesn't necessarily apply to Law, every discipline has a Threshold Concept and there's benefits of working out the continuum of understanding how different people view that concept and then teaching to that. It's not something that's discipline specific, it could apply across the board (L3)

During the actual [conference] session itself there were a few people from other disciplines who thought it was very interesting and were really quite interested in seeing how they could adapt it (L3)

I think it would be beneficial if faculties did undertake a similar process to say, look, is there something that you all think is a difficult concept for students to get over, and what is that concept and could we teach it better by teaching different methods. So absolutely (L4)

Three respondents also qualified their responses about encouraging colleagues outside of their discipline, by saying that it would depend somewhat on the discipline:

I think it would depend on the other area, the other discipline and whether it was appropriate. I think it would be for certain disciplines, but I think I'd have to take it on a case by case basis (L5)

Yeah, I think so. I think it would be useful certainly in health. ...so yeah, I think there's definitely room for that to be used in medical science … You wouldn't really need a threshold in anatomy because it's general, but in the Physics part of it (L4)

... I would believe it would be beneficial for them… whether I would do it personally myself...I would feel more comfortable doing it in a Physics discipline context…(P6)

One respondent suggested that they would pass on some of the aspects of the project to colleagues outside their discipline, but indicated that they weren't sure how they would go about that, or in what context:

Yes. I think it has a lot to offer. I'm not sure how I would engage people to do that; I suppose conferences and things. Perhaps more obvious opportunities would be to think about where, in other disciplines, reasoning is taught. Maybe you could get people interested where they were interested in different forms of reasoning. I guess that's philosophy and - I don't know. I don't know where reasoning is done and taught (L6)

Another two respondents qualified their response by highlighting the need to inform any colleague about the time and resources involved:

So certainly in a world where there were no constraints I would say this is extremely valuable, 'cause it gets you to work closely with academics in your discipline, closely with educational developers and specialists and you're working with students. It's a win-win situation. Something positive has got to come out of this. So I would certainly encourage them but I would give the proviso that I've had to spend a lot of time on this (P1)

My negativity … is to do with the sustainability based on resource availability. If you say well let's put that aside it's not an issue, let's assume that's not an issue, then I would say that's an extremely valuable thing to come to grips with what students have to say then try and design interventions and see if the interventions work (P1)

I'd probably be hesitant about it getting very wide use because it was so time consuming and I know that most of my colleagues put far less time into their teaching than I do, so, would be extremely unwilling to use something that was so time consuming (P2)

Specific aspects to recommend

When asked what specific aspects of the curriculum design process they would recommend to colleagues either within or outside their discipline, respondents mostly referred to the following:

- The project approach and underlying theory

For those people who are very keen about this, I would recommend it…. Because you got results and it is a lot of fun (P2)

I think it would be beneficial if faculties did undertake a similar process to say, look, is there something that you all think is a difficult concept for students to get over, and what is that concept and could we teach it better by teaching different methods. So absolutely (L4)

Well the part about variation, we do it anyway, but it's something that now I have an idea of the reason for doing it … If they are interested or if I am talking to them, then I can take them to certain papers and so on. To sort of say, here's how somebody else has used it. You know you use … different ways of giving examples and so on, on the same concept. Maybe you can use this methodology (P4)

Well I'd like the people who design the torts and contracts tutorials to vary one thing at a time. I don't think they're going to do that because of the amount they think they have to get through. So I think it's a really great way for students to learn, to practise their legal reasoning and to learn (L6)

One respondent suggested that, even though he would encourage others to use the project approach, he would also need to 'warn' his colleagues:

I've enjoyed doing it, but you would have to tell people if you're going to get something out of this, unless you're an expert in these particular areas, you need to find out what Phenomenography is, what Variation Theory is. That's going to be a learning curve for you before you get to any point of doing anything. So people need to be aware that there's a price to be paid if you like. I'd have to say that up front, terrific opportunities and great value what you do, but it's not going to happen just by you sitting at your desk and it's all going to fall in your lap, 'cause it won't (P1)

- The teaching approach used in the intervention

…that idea of breaking exercises down and spending a lot more time at that initial stage, first year, first semester just really honing the basics. That would be it, and I guess trying to develop the synergies between units so that students don't always feel like they're learning something completely new

I'd say get some clickers or flash cards or what have you, because the evidence is just amazingly strong that once you start asking those questions you start to realise that what the students are having difficulty with is not what you expected them to have difficulty with; so you can adjust your teaching to focus on those things and spend less time on the things that they're finding easiest, and modify your teaching that way (P3)

- Collaboration with colleagues

… get as many people as possible involved in that and discussing it, and brainstorming ideas (P3)

… one of the aspects is a more consultative process, so that in putting together this new set of teaching materials and all that it was really good to have more than one head doing it… I think one of the most useful aspects of this whole project was the talking about it, the exchange of ideas in developing the curriculum. I thought that was very useful. I wish we could do more of it (L2)

Certainly the large amount of discussion with other people about these things … (P2)

I think perhaps the most valuable thing that I've found is this discussion with colleagues who are trying to sort out the same problem … So I think working together as a group and across universities – that really is very powerful. Whether you work within a particular approach, say Phenomenography or Variation Theory, may not matter that much (P1)

I do think the idea of talking through critical ideas, core ideas with other people is something that I'd strongly encourage (P7)

- Interviews

… I think that every Physics lecturer possibly should have to read a whole bunch of student interviews at some point in their life (P7)

I definitely think that the more feedback you can get about how students are thinking the better you can go about teaching. Doing the interviews was a fantastic way of going about that (P3)

Aspects they would not pass on

Respondents were also asked if there was anything that they would not pass on to colleagues in their discipline or in other disciplines.

Most respondents said that there was nothing they would not pass on, with responses including:

There is nothing that was not totally useful (P4)

it was a constructive experience so there wasn't something in it that I … would be able to refer to as not being worth doing (L1)

… I can't really think of any, to be honest (L4)

… if a colleague were interested I'd give them all the information I had. The readings and the benefit of the experience I had. Then let them develop it as they saw fit. So I would want them to have the benefit of what I did and the materials that I received and the opportunities I received, yeah (L5)

One respondent who suggested that *'everything is worth trying' (P1)* also offered a qualified response in terms of what they'd say to colleagues:

So it might well be you say this was really worth trying, it's based on some sound foundation. You should be aware that it could be a drain on your time. But whatever happens they'll get some enormous value out of it, but maybe different value and different parts of it will be valuable to them, different to the bits that I found most valuable. So I would not want to say to people look, whatever you do this bit works, the Threshold Concepts and focus on teaching that without finding out what students think, trying to get some idea of the different conceptions by talking to them (P1)

Specific areas referred to as areas respondents would not pass on to colleagues include:

- Some of the literature

I mean, I've talked about that some of the theoretical papers being very vague I would - I find I tend to learn from case studies better than from the more theoretical papers (P2)

- The underlying theoretical concepts

… the Threshold Concept stuff. I wouldn't be emphasising that. I think when people - as I was saying - hear about Threshold Concepts they tend to think it's an easy shortcut, whereas there's no shortcuts (P3)

One aspect of the project is … a lot of educational speak ... I think the Law teachers were feeling, at quite a few times, a little bit uncomfortable with the quite complex terminology, which is the educational terminology … I think it was unnecessary. I think when one discipline is talking to another discipline it's realising you have to moderate your language very much - simplify the language sometimes (L2)

Again I'd probably strip away some of the phenomenographic and Variation Theory aspects of it. You can simplify those really right down. You wouldn't necessarily have to go into a lot of that (L3)

The need for more evidence

It is important to remember that at the time of the interviews, the project was not complete and some data analysis – particularly in regard to student outcomes – had not been completed. The concerns about this were raised by a number of respondents who suggested that it would be helpful in being able to pass on aspects of the project if they could have evidence of it improving student learning outcomes (e.g. L1, L4, P5, P6):

It's a little bit hard to say at this stage until we get a better look at the data analysis. Obviously you wouldn't pass on techniques that show no change. But if we looked at analysis and found out there's a significant increase in the sophistication of answers, well then yeah. From a subjective experience, I'd say yeah it was a very good thing, I'd recommend it. But with all science type stuff, you want some quantitative data behind it before you make a recommendation (P5)

… the concern that I have is that it's going to be very difficult to prove that this is the way to go, or that this is going to revolutionise how your students learn or how much your students learn….. Because, I think you need hard data. You need numbers to say in well-controlled tests to show that they're doing better because of this. I don't think we have done that and I don't think we can do that... and so where it goes from here I don't know, particularly in terms of dissemination. We can go out and spread the word, and all someone's got to say is 'where's the proof' and we say 'well we just think it's working well' and unfortunately that's all I can say. In my heart I believe it, but ... do the numbers show it? I don't know that we can (P6)

Interestingly, a participant from the same discipline, but at a different institution, pointed to a 'dramatic' improvement in learning outcomes.

Well we looked at - monitored how much the students knew about the concepts of uncertainty at the end and probably about 90 per cent of our students, at the end of this year, were at the level which only about 10 per cent of students were at the previous year. So, I think we've [... made a dramatic] improvement in how much the students know and understand about these things. We still don't know how long lived that's going to be and whether it can be applied to different contexts but insofar as we can measure at this point the improvement has been stunning (P2)

One respondent who indicated that they had done some preliminary assessment analysis, expressed disappointment in not being able to provide evidence of improved student learning outcomes:

… but we found that there seemed to be no difference in marks between the students who attended this voluntary session and those who didn't. It surprises me considering the impact of the, or what I thought was the impact of that lesson on the students who attended. But we need to look at the marks more closely and it may have had an impact on a particular cohort, which is hidden within an average (L1)

Clearly, further analysis and research are required to get a substantive picture of the effect of the project on student learning outcomes. However, from the interviews conducted in this research, there is a generally positive attitude to what has been achieved. Even where respondents acknowledged a lack of evidence in improved learning outcomes, there was a tendency to acknowledge some sort of positive outcome in this regard, or to suggest that the improvement they might be looking for might come out in some other way – for instance, in the future:

… it's just a shame that there isn't an obvious outcome in relation to marks. But then again maybe looking at the marks is missing the point that you don't know until the students have gone through another semester or two semesters looking at substantive Law problem questions. Maybe that's the stage where you might find a difference or an improvement (L1)

… getting a hard answer as to whether it's really worked or not, and what does 'really worked' mean? So I really don't know whether we're going to get an answer to that. And that's a little bit of a concern..... what I'm concerned about is that I feel that my students have benefited from what we've done, and my feeling is that they have.. I've got trouble proving that (P6)

I don't have any hard evidence that it's worked once, I've only got a feeling and attitude from the students. I've got an impression from my teaching team that it's helping, that it's doing some good …. And the fact that it's making me think about what I can do and what needs to be done in more focus (P6)

So I think that one of the things from this that we will need to measure is the effectiveness of it later on. I mean, we're just marking those cohort of students' exams having just learnt it recently in a workshop. How will they be in two years? Will they remember, will it have sunk in? That's the question, isn't it?

Through some of their responses, participants acknowledged that the project wasn't complete at the time of their interviews by referring to ongoing investigation of assessment results. A number of respondents also suggested areas for further investigation:

We're actually just starting to analyse it now...We're just in the process of - for those - there are about 70 students - analysing their results against the rest of the cohort of students - basically, their final exam results - and seeing if it did seem to make a difference. Then we've just used that same trial teaching materials incorporated within the subject that we're teaching again to the new cohorts this semester. So we're doing the same type of analysis again...Did it really make a difference? Do we think that we achieved the objective to getting them to what we call level two analysis? Or how many do we think we got to level two analysis? … Then, I guess, the longer term project is those students will go on to subjects next year, probably only informally; ask the teachers in those subjects do they think there's any difference or whatever (L2)

I think [the wrap-up meeting's] where a lot of it will also come together, and we've really got a chance to really discuss what we've all got out of it and what conclusions we can reach; and also a bit about where do we go from here. I've got a couple of ideas, but I'm looking forward to sitting [with] everyone else and say well, what do we need to do now? We can't just have this as a discrete project and leave it (L2)

We're pretty much still at the interpretive analysis stage. There's been a little bit of post intervention analysis but not a great deal at this stage. I think that's a much more drawn out process where you would finalise all your analysis, come up with your conclusion, implement it into a curriculum design,

teach it and then evaluate. That was outside the scope of the project. We were really focusing on those less sophisticated notions of legal reasoning and how you get students to move between those less sophisticated notions. So there's scope there to say well how do we move them from the less sophisticated notions to the very sophisticated notions. That aspect wasn't really trialled. We were sort of just trying to move them between the less complicated notions of legal reasoning (L3)

I guess it's a shame that it's a fairly short lived project because it would have been good to push it further and start to identify some understandings about other groups like the different conceptions Law teachers have of legal reasoning. I guess a bit more evaluation of the curriculum design, it would have been useful to have. From my point of view it's certainly been a rather interesting project to be involved with and it will be interesting to see the papers and stuff that come out of it and see whether or not my feelings about it have been replicated in what the other people have thought or not (L3)

Conclusion

Overall, the project has had quite a significant transformative effect on project participants.

All respondents referred to some change in their understanding of student difficulties in learning about the various disciplinary Threshold Concepts under investigation. The predominant change in understanding related to participants' increased awareness of the range in student understanding.

There was also a significant transformative effect on participants' understandings of how best to teach – both the disciplinary Threshold Concept and other disciplinary concepts. This change in understanding is also highly likely to lead to a change in practice of those participants who acknowledged a change in understanding as a result of the project. Of most significance, is the overall feeling of participants that this project has had a positive impact on their understanding of teaching and learning – in spite of the fact that preliminary results do not, in all cases, necessarily indicate a change in student learning outcomes. The overall feeling from respondents in the project is that it has been a valuable process and that their teaching and curriculum design practice has changed as a result of it. Suggestions for further analysis of results and future research are offered by participants.

One, perhaps unexpected, transformative outcome is the change in understanding of the disciplinary Threshold Concept held by individual participants – often someone who has been involved in teaching the particular area for a long period of time. More than half the respondents clearly reported some sort of change in the way they regard the disciplinary Threshold Concept. Often their changed perceptions related to student difficulties or to different ways of teaching the concept.

Participants referred to five triggers that they saw as leading to changes in their understanding across the areas of investigation:

- Conducting or analysing student interviews (particularly in relation to changed understanding of student difficulties)
- Focused discussion with colleagues (particularly in relation to participants' changes in their own understanding of the disciplinary Threshold Concept in question)
- Having time to reflect
- Designing and/or implementing curricula
- The educational theory underlying the research, particularly Variation Theory and the notion of disciplinary Threshold Concepts.

It appears that participants from the Physics discipline view the theory of disciplinary Threshold Concepts in a more negative light than those from the Law discipline. All

but one of the respondents from the Law discipline indicated that the notion of disciplinary Threshold Concepts had had an impact on their insights into learning, teaching and curriculum design, whereas four of the seven Physics participants indicated a level of skepticism of the concept – mainly expressed in the view that there are too many to be useful and there is a difficulty in determining what a disciplinary Threshold Concept is compared to other core or troublesome concepts.

Variation Theory, on the other hand, appears to have had a more evenly distributed positive impact on participants from both disciplines. A number of participants reported that they had intuitively been using aspects of Variation Theory before their involvement in the project: this was not confirmed or refuted by the interview, as no follow up was done as to what they understood Variation Theory to be.

All participants indicated that there would be some change in their future teaching, learning and curriculum design practice in the future. The main ways in which their future practice would be different include:

- Using the action research project approach (the student interviews and how they analyse them, with a wide range of people with other institutions)
- Using their insights gained from the project (especially into their changed understanding of student difficulties and better ways to teach the disciplinary Threshold Concept)
- Using the curriculum intervention materials produced as a part of the project
- Using the underlying theoretical concepts of the project (Phenomenography, Variation Theory and disciplinary Threshold Concepts)

Most respondents said that there was nothing in the project that they would avoid using in the future, but suggested the sustainability or reproducibility of the project might create difficulties. They suggested that the resource intensive nature of the methodology underlying the project means that it would make it difficult to do on a regular basis in their curriculum design processes. While abbreviations in processes were suggested, particularly in relation to the student interviews, participants acknowledged the depth of data that was obtained through the interview process and the phenomenographic analysis that led to the outcome space for each discipline, and a potential loss of data quality through other methods.

Most respondents indicated that there was some aspect or aspects of the project that they would recommend to colleagues, both within and outside their own discipline. A number of respondents, however, suggested that they would have to also pass on the potential difficulties associated with the amount of effort and time involved in participating in the project. The specific aspects of the project that participants indicated that they would recommended to others include:

- The project approach and underlying theory
- The teaching approach used in the intervention
- Collaboration with colleagues
- Interviews with students

A number of participants referred to the need for more evidence, either as part of this project or as a part of future projects, which investigates student learning outcomes. Despite there being no conclusive evidence of any change in student learning outcomes, the general feeling amongst all the participants interviewed for this report, is that the curriculum model designed as a result of this project does have a positive impact on student learning outcomes and will positively influence their teaching and curriculum design into the future.

Attachment 1: Interview Schedule

1. I'd like to start with you telling me about your involvement in the project.
   What was your role?

2. Thinking back over the whole of your involvement in the project, could you give me a sense of the *overall impact* of the project on you?
   How did that happen?
   Can you identify any particular aspect of the project that triggered that impact?

3. Were any of these impacts *expected or unexpected* at the start of the project?

4. Were any of these experiences or impacts more significant than others?
   Could you say - what was the most significant impact of the project on you?

5. You might feel these questions are a little repetitive but to be thorough, I'd like to double-check a few different areas of *potential impact* with you.

   1) Did the project have any impact (or further impact) on your understanding of student difficulties in learning about measurement uncertainty/legal reasoning?
   If yes, how did that happen?

   2) Did the project have any impact (or further impact) on your sense of how best to teach measurement uncertainty/legal reasoning?
   If yes, how did that happen?

   3) Did the project have any impact (or further impact) on your own thinking about the nature of measurement uncertainty/legal reasoning?
   If yes, how did that happen?

   4) Did the project have any impact (or further impact) on insights you have had into the teaching and learning of other Physics/Law concepts?
   If yes, how did that happen?

   5) What impact, if any, did the general notion of disciplinary Threshold Concepts have on your thinking about teaching, learning and curriculum design in Physics?

   6) What impact, if any, did the general notion of Variation Theory have on your thinking about teaching, learning and curriculum design?

6. Do you expect to use anything you've gained from this project in your future teaching and curriculum design – either with measurement uncertainty/legal reasoning or other Physics/Law concepts?
   If yes, why is that?

7. Is there anything you would avoid using?
   If yes, why is that?

8. Is there any aspect of the curriculum design process used in this project that you would encourage your colleagues to use in their own teaching and curriculum design?
   If yes, why is that?

9. Would you encourage colleagues in other disciplines to use any aspect of the curriculum design model used in this project?

10. Are there any particular aspects that you would not pass on?
- either to colleagues in your own discipline or to colleagues in other disciplines
If yes, why is that?

11. Some aspects of the project were quite time-consuming. Are there any abbreviations of the process that you think you could use instead?
What would be gained and lost from this change?

12. Those are all my questions. Is there anything you'd like to add before we finish up?

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