Applying Threshold Learning Theory to teach Sustainable Business Practice in Post-Graduate Engineering Education

Abstract

This paper presents the results of a qualitative action-research inquiry into how a highly diverse cohort of post-graduate students could develop significant capacity in sustainable development within a single unit (course), in this case a compulsory component of four built environment masters programs. The method comprised applying threshold learning theory within the technical discipline of sustainable development, to transform student understanding of sustainable business practice in the built environment. This involved identifying a number of key threshold concepts, which once learned would provide a pathway to having a transformational learning experience. Curriculum was then revised, to focus on stepping through these targeted concepts using a scaffolded, problem-based-learning approach. Challenges included a large class size of 120 students, a majority of international students, and a wide span of disciplinary backgrounds across the spectrum of built environment professionals. Five 'key' threshold learning concepts were identified and the renewed curriculum was piloted in Semester 2 of 2011. The paper presents details of the study and findings from a mixed-method evaluation approach through the semester. The outcomes of this study will be used to inform further review of the course in 2012, including further consideration of the threshold concepts. In future, it is anticipated that this case study will inform a framework for rapidly embedding sustainability within curriculum.

Introduction

Discipline Context – Sustainable Business Practice

A current major consideration for universities around the world is how to rapidly equip professionals with the knowledge and skills required to address 21st Century built environment challenges. These relate to both mitigating environmental impacts of past and current development, and adapting future development to changes in climatic conditions, resource scarcity, and increasing levels of consumption and population pressures. Not only are the challenges grand in scale and complex in their interconnectedness, a number require a substantial – it could be said transformational - shift in understanding to be able to deliver solutions that are genuinely sustainable.

Smith *et al*[1] highlight a unique context for businesses operating at the beginning of this century, where future risks may be very different from past risks due to the potential for significant market and regulatory shifts across all sectors; time 't'. This includes for example the emergence of carbon taxes, hazardous waste legislation, pollution charges and so on. As shown in Figure 1, the current commitment to environmental performance has implications for the extent of investment required when time 't' occurs.
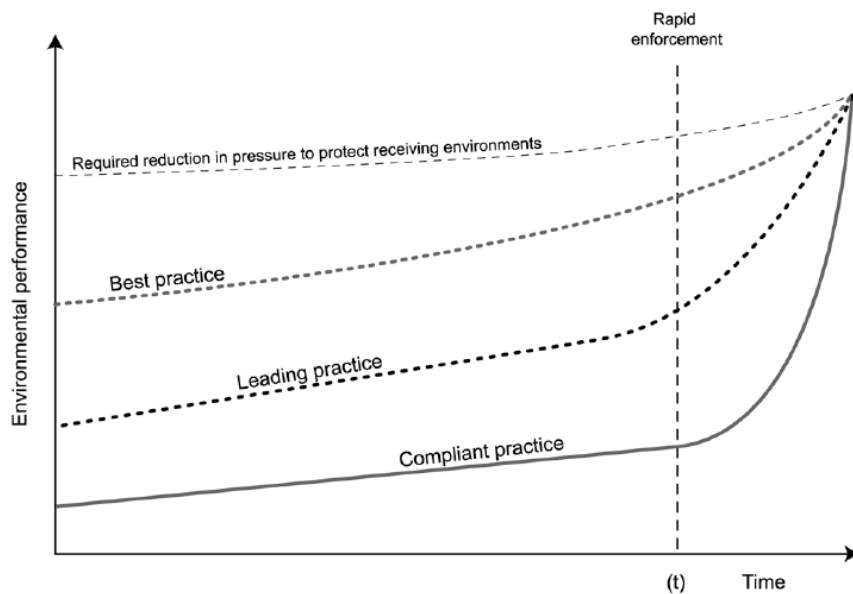
Figure 1. Level of commitment to environmental performance over time[2]

As businesses around the world seek to respond to these challenges and manage the transition highlighted in Figure 1, higher education institutions are being called on to rapidly build capacity amongst undergraduate and practising professionals.[3] A common complaint by students and teachers within this field is the overwhelming amount of knowledge and theory with which they struggle to make sense of the challenges and opportunities for sustainable development. In the built environment disciplines in particular, there are a number of critical but complex concepts spanning science and engineering, each of which has a substantial knowledge base.

Alongside bachelor degree programs, postgraduate education is emerging as a focus of significant attention to build capacity for immediate challenges such as carbon reforms, energy management and resource scarcity, with urgent demand for professionals that can practice sustainable development. This includes professional development short courses through to graduate certificates, graduate diplomas and masters degree programs. However, embedding such capacity within the postgraduate curriculum is significantly challenged by a number of factors including the limited number of courses in a typical graduate program (6-8), and the scarcity of academics with expertise in sustainable development. Such curriculum renewal is also compounded by regular pedagogical challenges including large class sizes, international cohorts, online learning environments, varying entry knowledge and skills, and a wide span of disciplinary backgrounds across the spectrum of professionals undertaking postgraduate studies.

In practice, education for sustainable development in postgraduate education is still in its infancy. For example in Australia, research funded by the National Framework for Energy Efficiency found that even the highly topical issue of energy efficiency is covered in detail by less than a third of the 27 universities offering postgraduate education in energy related

fields.[4] In those universities that are being proactive, the Australian study showed that awareness raising about education for sustainable development is being addressed through a compulsory or elective courses. Often these courses service more than one postgraduate degree, putting even more emphasis on these few 'flagship' courses achieving what they set out to accomplish with regard to sustainability related learning outcomes. As documented by Desha,[5] there are many papers highlighting the short term, *ad hoc*, vulnerable nature of these courses that provide great examples of innovation in education for sustainable development, but which for the most part cannot seem to make headway in developing critical sustainability related knowledge and skills in students. Furthermore, these courses are often led by enthusiastic but stressed, professionally isolated educators. In such contexts, at least in the short term there is no access to developing sustainability competencies throughout the program; this has previously been a significant impediment to education for sustainable development.

With this in mind, the authors inquired into teaching and learning processes that might provide some relief to isolated sustainability champions, where students could become quickly empowered and capable of continuing their own 'sustainability education' as they continued through their degree. Threshold learning theory provides a lens of transformative learning where educators have a new and empowering context to develop sustainable development attributes that students can then continue to apply immediately in their other courses and to their workplace.

Curriculum Context - Threshold Learning Concepts
Meyer and Land[6,7] and Cousin[8,9] discuss the importance of clarifying and building shared understanding of 'threshold concepts' in encouraging deep rather than surface learning that is empowering for the student and educator. Such concepts are identified by their troublesome nature for some students (seeming counter-intuitive or alien), and their critical role in enabling students to progress through a field of inquiry, making connections that were previously hidden from view. Furthermore, the experience of grasping a threshold concept can be transformative for students, where once it is learned, it cannot be 'unlearned' (i.e. it is often irreversible), becoming intrinsically embedded in the student's ontological (i.e. what is) and conceptual (i.e. how does it fit) frame of reference.

Cousin describes this as a 'less is more' approach to curriculum design. A key benefit of using this framework within curriculum renewal, is the opportunity to 'un-stuff' (i.e. de-clutter) a crowded curriculum, where educators can strategically consider what students need to be equipped within the context of their whole-of-university experience, to perform the desired role in their field.

These aspects of threshold learning concepts theory lend themselves very well to education for sustainability, which suffers from educators attempting to 'stuff' the curriculum with information, apply the latest one-size-fits-all approach, and requiring students to repeat or 'mimic' methods for developing solutions. In contrast the field is complex and rapidly evolving, where solutions require integrated understanding of systems behaviour and

interconnections, rather than 'knowing all there is to know'. Threshold learning concepts within the field of sustainable development abound, as discussed for example by Kabo and Baille for social justice,[10] and Byrne and Fitzpatrick in Chemical Engineering for the 21st Century.[11]

Using a threshold learning approach also lends itself to curriculum design in education for sustainability, which adopts a research-minded approach to mastery – through for example problem or project based learning.[12] Where there is space for iteratively questioning and exploring the concept and its connections to the real world, students can enter what Cousin refers to as a liminal state (i.e. oscillating between old and emergent understandings) where transformative learning can take place.

Authors Baille, Bowden and Meyer expand the 'threshold learning concept' terminology and address some ambiguity around 'concept', by introducing the term 'capability'. For these authors, the field of 'threshold capability theory' focuses on the ability to act effectively for unknown futures. They propose that graduates should also be able to identify a situation through some key aspects, relate the situation to other knowledge and then proceed to develop and complete a holistic solution.[13] According to the authors, students should also be exposed to variation within their curriculum, through multiple examples changing one dimension at a time. [14,15]

With this theory in mind, a threshold learning approach – including concepts and capabilities – was considered a robust theoretical base to create a deep-learning curriculum that encourages students to take their own journey of discovery toward the course learning outcomes.

Method

The authors reviewed several of their previously co-authored text books[16,17,18,19] and more than 150 hours of educational material in the field to which they have previously contributed,[20] to distil five threshold learning concepts that would act like rungs of a ladder towards students realising the overarching 'capstone' threshold concept/ capability of sustainable business practice.

Authors such as Holloway *et al*[21], Scott et al,[22] and Bernhard[23] have inquired into a range of quantitative and qualitative methods to reliably identify threshold learning concepts. For this project, and in the absence of time or budget to conduct a process described by Baille,[24] the identification process included reflection and consultation with colleagues, building on 8 years of the authors' inquiry into the jewels – or 'critical literacies' – for sustainable development, spanning many conversations and workshops with education and sustainability experts in the field.

The process for curriculum renewal and evaluation adopted a qualitative research approach grounded in literature review and consultation, and reflective analysis of assessment performance, and student evaluation. These aspects are summarized as follows:

- Literature Review and Consultation: This included a review of two fields of literature: a) teaching threshold concepts literature, focusing on post-graduate (i.e. adult) learning and opportunities to harness intensive and online learning environments; and b) core threshold concepts within education for sustainability literature, focusing on project management in the built environment in the 21st Century. Consultation was undertaken with the Masters Program Convenor to confirm learning expectations (i.e. with regard to graduate attributes and program aims), two other convenors whose courses are compulsory regarding their experiences, and two teaching and learning experts within the university's engineering Faculty.

- Curriculum Renewal: This comprised updating the Course Outline, creating a Study Guide, suitable criterion-referenced assessment items, and a supporting *Blackboard* student interface. Concurrently questionnaires were developed for the student evaluation process during the two-day intensive, and the assessment was structured such that the questions could be used as part of the reflective analysis of impact of this approach on learning outcomes.

- Assessment Performance: This comprised reviewing the results of the summative assessment items, and written feedback provided by tutors within the marked assessment items.

- Student Evaluation: Through the semester, a discussion board was used as a non-graded participation component of the website, where students were asked to reflect on their backgrounds and expectations for their masters study and this unit, and their progress in understanding and applying the threshold concepts. This qualitative data was then reviewed to gauge to what extent the threshold concepts are being acquired by students. In addition, students were asked to complete evaluation questionnaires prior to and during the intensive on-campus session and at the end of the semester through the formal university learning experience (LEX) survey.

Drawing on the education for sustainability literature, key threshold concepts were identified that are critical for built environment masters students to acquire within the QUT 'real world' postgraduate context for 21st Century professionals. Drawing on the teaching threshold concepts literature, the course was then reviewed and updated to take advantage of identified pedagogy that can improve student learning and the overall student experience within this unit.

Course Trial - University Context

This is the case for the Queensland University of Technology, where there has been top-level commitment from the Vice-Chancellor and University strategic plan, to embed sustainability within the university's curriculum offerings,[25] and a number of attempts within the undergraduate curriculum (for example Savage and Betts[26], Grey *et al*[27], Dawson and Brown[28]). In 2008, 'BEN710 Sustainable Business Practice in the Built Environment' was established in the Faculty of Built Environment and Engineering as a compulsory 'core' postgraduate course that would service approximately 150 students studying one of six built environment masters degree programs each year. These included (in decreasing order of student cohort sizes) Engineering Management, Project Management, Master of Urban Development (Urban and Regional Planning), Master of Design (Urban Design), Master of Engineering (Systems), Infrastructure Management, and a small group of exchange students.[29]

In the following three years, the course struggled with the types of logistical and pedagogical challenges described above, with student evaluations reflecting a polarisation of students who either perceived the course as very useful, or irrelevant to their studies. Furthermore, the course was considered to be a flagship stand-alone student experience that would address the sustainability requirements for the program; a common scenario for current undergraduate and postgraduate curriculum.[30] In addressing the evaluation data, it was concluded within the Teaching and Learning Committee that something substantially different would be required to attempt to meet targeted student expectations with a generic course.

Subsequently the first author of this paper was asked to consider options for curriculum renewal. Within this context, this action research project sought to build on prior experience with large student cohorts and developing resources for curriculum renewal in education for sustainability,[31] to study and apply the principle of teaching and learning threshold concepts towards strengthening, renewing, and de-cluttering curriculum in a masters course. As stated within the study guide,

> *"Using this material to highlight what we refer to as 'threshold learning concepts', the unit aims to provide breakthrough learning experiences for all students, regardless of where you are in your post graduate studies, on your career path, or where you are with regard to considering sustainable development."[32]*

The resultant course structure for the 2011 student cohort comprised a 2-day intensive on-campus session at the beginning of semester, followed by three 1-hour workshops and three 2-hour seminars (on campus and recorded). During the workshops students were provided with feedback on their assignments and project progress. During each 2-hour seminar three prominent guest speakers spoke about finance, governance and industry considerations for business in a carbon constrained world, including a panel session. This contact was interspersed with intranet communications. 20 readings were uploaded (5 per concept) just

prior to the weekend intensive, to ensure that students' perspectives would not be affected by pre-reading.

Assessment comprised one formative and three summative items that reinforced the course focus on grasping each of the threshold learning concepts in a sequential then iterative learning process as shown in Table 1. An individual short essay item on the first concept (i.e. Decoupling) was submitted in Week 4 and returned to students in Week 5 of the 13-week semester with comments. For this item students received 10 percent for submission and tutorial attendance. Summative assessment comprised a 10 percent individual short essay on another concept (Whole System Design) submitted in Week 7 and returned in Week 8 and a major 40 percent group report on identifying sustainability opportunities and challenges in a workplace of each group's choice. In this project students were required to incorporate discussion on each of the concepts and how they applied to the workplace. At the end of semester students sat a 40 percent exam, comprising a mixture of multiple choice and short answer questions, working through each of the five concepts.

Table 1. Course scaffold to trial threshold learning concepts approach

Week	1	2	3	4	5	6	7	8	9-10	11	12	13	14
Teach/ Learn		Intensive			Tutorial, Seminar			Tutorial, Seminar		Tutorial, Seminar			
Assess				Short essay	Submit & attend (10%)		Short essay (10%)				Group Report (40%)		Exam (40%)
Evaluate		Pre & Post Survey		Review			Review				Review		Review

Course Trial – Key Findings

The following paragraphs summarise key data obtained through the two-day teaching intensive, a review of assessment results, and feedback from student and peer evaluations. The authors were confident in the threshold learning concepts themselves, and the strategic development of terms to progress through the concepts. However we were unsure of whether the curriculum design was adequate in providing break-throughs across all five concepts. Hence, in analysing this information, we sought answers to two questions:

1) In the as-delivered curriculum, what parts of any the concepts did students find difficult?
2) To what extent did the students have break-throughs in each of the five concepts?

Our assumption was that if the course delivered transformative learning break-throughs across all five concepts, then this should be evident in the students' experience of the 2-day

intensive delivery of the curriculum, and in assessment results. Some level of confusion could be expected in the results,[33] but this should be resolved by the end of the semester.

Course Demographics

In 2011, there were 126 commencing students, of which 120 students completed the course 'Sustainable Business Practice in the Built Environment'. Table 2 highlights the cultural diversity of the cohort, through a summary of the 32 nationalities of students in the class by region (75 per cent male).

Table 2. 2011 student cohort's countries of origin

| Australia	23	Iraq	1	South Africa	2
Brazil	1	Italy	2	Sri Lanka	3
Canada	2	Malawi	1	Sweden	1
China	19	Malaysia	6	Taiwan	10
Columbia	5	Mauritius	1	Thailand	6
France	2	Northern Ireland	1	Turkey	1
Germany	2	Pakistan	1	United Arab Emirates	2
Hong Kong	4	Papua New Guinea	1	Vanuatu	1
India	1	Peru	2	Vietnam	7
Indonesia	4	Philippines	3	Zimbabwe	1
Iran	7	Saudi Arabia	3		

Results from the 2-day Teaching Intensive

During the two-day teaching intensive where the whole curriculum was covered, a number of questionnaires were distributed to the class, to establish their point-in-time perceptions of the concepts and the applicability to their workplace. 116 of the 126 enrolled students attended the first day, and 105 attended the second day.

The anonymous questionnaire results shown in Figure 3 highlight the diverse knowledge and competency levels of the student cohort. Notwithstanding the potential for other factors such as culture and self-image to influence students self-reporting, it is clear that prior to the course students perceptions of prior knowledge were highly variable, with a third of the cohort having confidence to apply sustainability within their workplace, while another third had very little or no confidence in application.
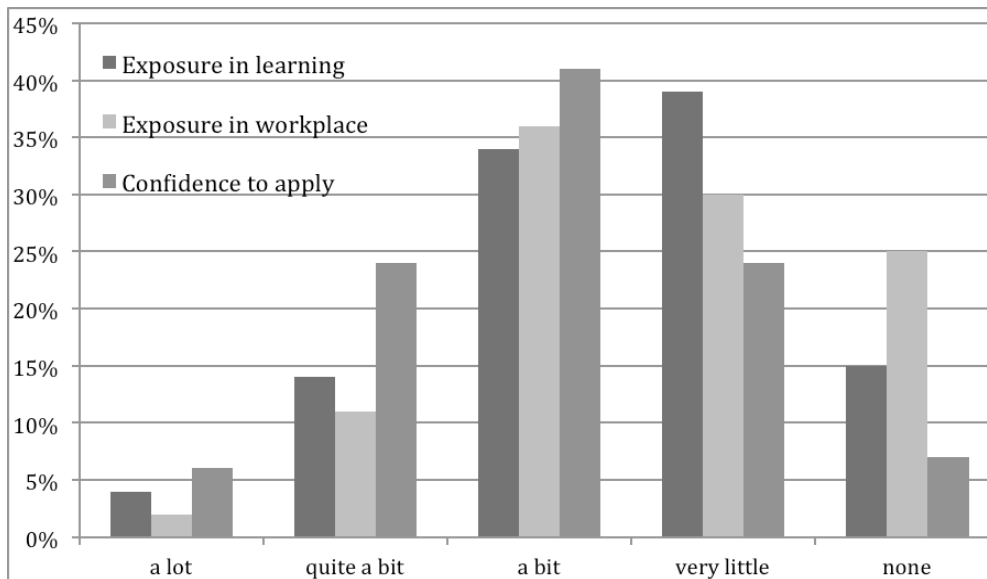
Figure 3. Pre-course student perceptions of sustainability

Students were then surveyed at the completion of the two-day intensive. The results shown in below indicate shifts in the students' perception of their overall confidence in applying sustainability concepts in the workplace (Figure 4), and how much each of the five sustainability related threshold learning concepts affect their workplace (Table 3).
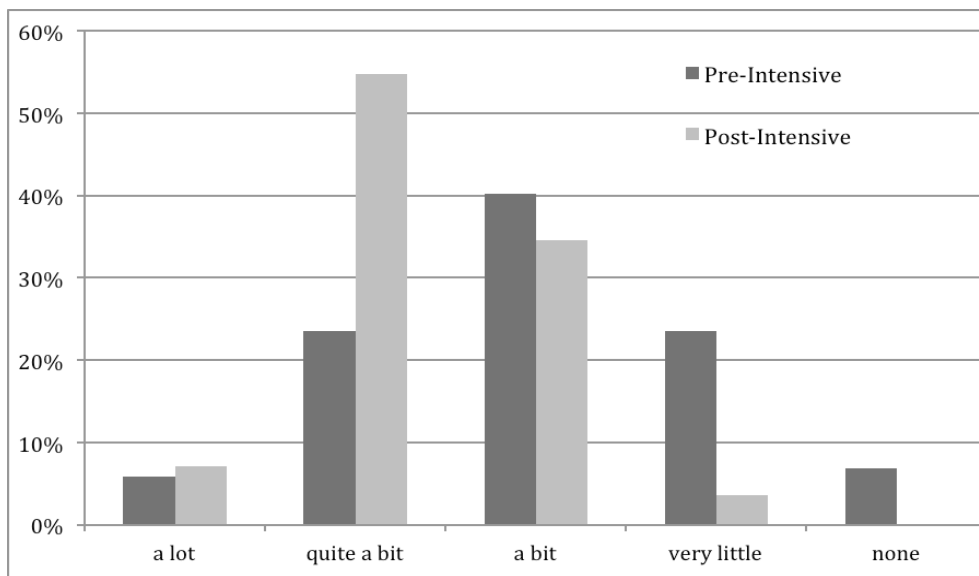
Figure 4. Student confidence in applying sustainability in the workplace

From Figure 4 it is inferred that for those students who entered the course with significant confidence (i.e. 'a lot' and 'quite a bit'), this was retained through the course. Students who entered with 'very little' or 'no' confidence jumped substantially, to having 'quite a bit' of confidence in applying sustainability in the workplace.

Considering Table 3, data shows that by the end of the 2-day intensive, there was no uncertainty about the connection between any of the first four threshold learning concepts and the students' workplace (see 'none' and 'unsure' for the 'post' columns).

Table 3. Perceptions of how concepts affect the student in the workplace

Extent	Decoupling (%)		Whole System Design (%)		Resource Productivity (%)		Biomimicry (%)		Sust. Business Practice (%)	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post	Pre	Post
A lot	10	17	15	21	17	31	7	20	19	10
Quite a bit	35	51	38	57	31	45	17	46	30	35
A bit	24	27	22	20	29	21	30	29	27	24
Very little	9	5	10	1	7	2	16	5	8	9
None	6	0	3	0	5	0	10	0	5	6
Unsure	16	0	13	0	12	0	21	0	12	16
Responses	88	70	87	70	86	70	86	70	88	69

Of the five threshold learning concept areas, students were least sure of how the concept of 'Biomimicry' related to their workplace. It was also concept for which students had the largest change in perception, from less than a quarter (24%) to more than two thirds (66%) of students thinking that Biomimicry has 'quite a bit' or 'a lot' to do with their workplace operations.

On entering the course, the cohort was most aware of the concept of 'Resource Productivity' and its application in the workplace, with more than three quarters (77%) having 'a bit' or more appreciation. By the end of the course, this jumped to almost all students (98%), with more than three quarters (76%) perceiving that this concept affects their workplace 'quite a bit' or 'a lot'.

However, for the final capstone threshold concept/ capability of 'Sustainable business practice', there is room for improvement. For this concept:
- The number of students who perceived 'a lot' of relevance almost halved, indicating that by the end of semester, these students were left with more uncertainty or a sense of the challenges of implementing sustainable business practice than when they arrived.
- This is also reflected in the increase in number of students who were 'unsure' of how the concepts affect their workplaces.
- The number of students who saw no connection between sustainable business practice and their workplace remained almost the same.

Assessment Results
Given the results above, the authors asked, do these results show that students actually got the answers right, even though they think they don't see the connections, particularly for the capstone threshold learning concept/ capability?

The 42 group assignments and individual exam results were marked after calibration, by four tutors. The average mark for the items were Short Essay (63%), Group Report (71%), Exam (68%). This information, while indicative of an 'average' class performance for the semester, did not provide much insight into student comprehension of the threshold learning concepts.

For the final exam, there were several introduction 'foundation theory' questions, followed by three multiple choice questions and two short answer questions for each threshold learning concept. From the student responses, 6 of the 20 multiple choice questions had a correct response of 65% of the class or less, for Foundation Theory (1 question, 63%), Decoupling (1 question, 65%), Resource Productivity (2 questions, 47% and 54%), and Whole System Design (2 questions, 59% and 59%). [Short answer question data to be provided in final paper] Assuming that the questions were appropriate (they were peer reviewed), these results suggest that students had some difficulty with the resource productivity concept and the whole system design concept. In contrast, students did well for the capstone threshold learning concept/ capability 'sustainable business practice', with more than 80 per cent of students getting all responses correct.

Student Evaluation
The authors were also interested to see whether feedback from the students about the course could provide insight into the perceived relevance of the threshold learning concepts to their workplace. At the end of the two-day intensive, students completed an evaluation form for the entire curriculum, which was anonymous and collected by a non-teaching team member of staff. At the end of the semester, students also completed a generic evaluation form for the entire course, centrally administered through the university evaluation system.

The following table (Table 4) summarises key questions from the 2-day intensive evaluation that relate to the relevance of the threshold learning concepts to students in their workplace (response rate 67.5%). Notwithstanding the cohort of students who felt uncertain about the questions (which could be due to issues of being early in the semester, cultural and language issues), it is clear that the students responded favourably to the use of threshold learning concepts.

Table 4. Perceptions of the curriculum – results of the 2-day intensive evaluation

Question	Strongly Agree	Agree	Uncertain	Disagree	Strongly Disagree
The content of this unit is clearly related to the objectives stated in the outline.	27%	61%	10%	3%	0%
The content of this unit is relevant to my interests and concerns as a student	36%	46%	15%	3%	0%
The content of this unit was presented in such a way that I was able to see the relationships among the various elements	31%	53%	9%	5%	1%
The various aspects of this unit work well together to help me to learn.	19%	62%	14%	3%	1%
The level of the unit is appropriate to my background	18%	52%	23%	8%	0%
The content of this unit is arranged so that it is easy to follow.	25%	53%	19%	0%	3%
The topics dealt with in this weekend intensive are presented in a logical sequence.	23%	56%	17%	3%	1%
The unit material links theory to practice by giving examples from real situations	29%	49%	18%	1%	3%
The content of the unit was presented and explained clearly	32%	49%	15%	3%	1%
The content of the unit was presented at a level that made it easy for me to understand	29%	46%	18%	6%	0%
This unit is helping me to develop my problem-solving skills.	8%	49%	35%	7%	1%
In this unit I am encouraged to look critically at accepted knowledge and practices	29%	50%	15%	4%	1%
In this unit I am encouraged to form and express my own ideas and opinions	31%	54%	10%	4%	1%
This course is helping me develop a greater sense of social and environmental responsibilities	34%	44%	16%	4%	1%

In the end of semester centrally administered course evaluation, the question of most relevance to this study was "U01 - The unit activities helped me develop useful skills and knowledge". Of the 48 responses (41% response rate), nearly two thirds (30 students) perceived that this happened 'often' (8), 'very often' (16), or 'always' (6). However 13 students (27% of the survey respondents) perceived that this 'rarely' happened, pointing to a subset of the class who did not get the intended break-throughs in learning.

Conclusions

In a rapidly emerging conversation around challenges and opportunities for achieving sustainability, it is critical that various communities understand of core concepts that provide access to action. This paper has presented a method for creating a platform for the conversation around achieving sustainability, from defining the problem through to behaviour change and the role of technological solutions. The authors have drawn on five key terms to build a 'conversation domain' for sustainability, comprising the following: decoupling economic growth from environmental pressure, transforming resource productivity, adopting whole system design, incorporating biomimicry principles, and achieving sustainable practice. Through this design it was intended that by moving sequentially through these topics, students would develop a dual appreciation of the complexity and elegance of a sustainable society, where transformational improvements are possible and exciting.

A pilot of this teaching scaffold within a postgraduate unit at QUT identified a favorable response from students seeking direction and tangible opportunities for sustainable business practice. The trial results suggest that threshold learning concepts, when scaffolded within a course structure, can create a conversational context – or a 'conversation domain' – that caters to students with highly variable entry knowledge. In effect, the five 'threshold learning concepts' introduced key terms to introduce the reader to what's possible, highlighting that there are no 'truths' but this is one (empowering) way of interpreting the global situation. In this context, experienced students could attach their prior and subsequent knowledge, while students new to the field could create a framework for subsequent knowledge. Taking a complex field of enquiry, this approach allowed the course to focus on key terms, networking them together to create a breakthrough in understanding for the reader.

Moreover, as it is proposed that such breakthroughs cannot be 'unlearned', the approach has provided a way for students to acquire significant knowledge and skills related to sustainable development in one stand-alone flagship course environment. Hence, the findings of this action-research study have implications for other educators considering how to embed sustainability within course-work, particularly when there may be only one or a few sustainability 'champions' in the institution.

Using these results, it is intended that the course will be revised for 2012 to accommodate student feedback and contributions from conference peer review. Investigation will also be undertaken with regard to the selected threshold learning concepts based on the method described by Baille,[34] to check whether there are any hidden threshold concepts within these that may be hindering transformative learning. It is also intended that the 2011 cohort of students will be surveyed in May 2011 as a longitudinal study, to ascertain how well the five so-called 'threshold' concepts have been retained by the students.

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