Embedding a Threshold Concept in Teaching and Learning of Product Development Management

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This paper uses insights from the literature on threshold concepts to develop a structure for understanding teaching and learning in the area of managing product development. The paper defines the threshold concept, outlines pedagogic principles and describes learning activities that seek to enact these principles. The paper is based upon experience of an established final-year university undergraduate course.

Introduction

> [A] CAS (complex adaptive system) framework is capable of facilitating interpretations of NPD (new product development) reality that maintain a fit among descriptive stance, system behaviour, and innovation type (McCarthy et al., 2006, p. 441).

The research reported upon by McCarthy et al. proposes and supports the notion that a CAS framework of NPD has descriptive value in terms of studying, classifying and defining the attributes and relationships that govern adaptive behaviour and outcomes in NPD processes. This paper accepts that proposition and explores the implications for curriculum development and teaching. In addition, recognizing that the process of product development involves multi-disciplinary activity, the paper explores these implications in the particular context of teaching business and engineering students together. Here the challenge facing teachers of such groups can be captured in the following two statements:

- To the business student: I am not trying to make an engineer out of you, but I would like you to be able to talk to one.
- To the engineering student: I am not trying to make a business manager out of you, but I would like you to be able to talk to one.

Figure 1 illustrates this challenge. Our paper examines this challenge using the two related concepts: *threshold concepts* and *troublesome knowledge*. It illustrates a response to the challenge, drawing from an undergraduate course, titled 'Managing New Product Development', to move from learning theory, to teaching principles, to learning activities. Course documentation, student survey data, student and company communications were used in the description and analysis of the teaching-learning environment presented in this paper.

Encouraging Student Learning through Threshold Concepts

Meyer and Land (2005) suggest that within each discipline, field or profession there are threshold concepts which integrate and define the scope of the academic community with which a student is engaging. These threshold concepts can be considered like passing through a portal, or conceptual gateway, thus opening up a new and previously inaccessible way of thinking about something (Meyer & Land, 2003). Such concepts lead to a transformed way of understanding, or viewing something that may represent how people 'think' or how they perceive, apprehend or experience particular phenomena within a discipline. A single discipline-based threshold concept may be nested within other concepts and students may have to progress through these in order to develop (Davies & Mangan, 2006). Such concepts have five attributes: they are *transformative*, *irreversible*, *integrative*, *bounded* and *troublesome*.

doi:10.1111/j.1467-8691.2009.00524.x

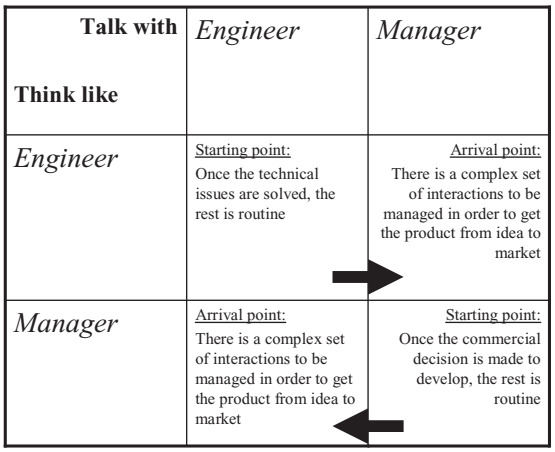

Figure 1. Thinking and Talking: The Educational Challenge

- The transformative character reflects how threshold concepts can change a student's perception of themselves and the subject.
- Irreversibility makes it inconceivable that (the student) would return to viewing, not only the world around them, but also the subject and themselves, in the way they did before (Davies, 2006).
- The integrative quality is critical to the transformative and irreversible attributes. Once the ideas and procedures of a subject make sense, it becomes possible to bring together different aspects of the subject that previously did not appear to be related.
- A threshold concept helps to define the boundaries of a subject area because it clarifies the scope of a subject community.
- Finally, a threshold concept is likely to be troublesome, not only because it operates in an integrating way, but also because it is taken for granted by practitioners and therefore rarely made explicit. Knowledge is troublesome when it is alien or counter-intuitive (Perkins, 1999).

Where did the troublesome knowledge concept come from? Perkins (1999) described different types of troublesome knowledge including tacit, alien, conceptually difficult, ritual and inert. Troublesome knowledge, troublesome language and the various threshold concepts that sit within disciplines create disjunction in the mind of the learner. The resultant effect has been described as similar to 'hitting a brick wall' in their learning. Some of this troublesome knowledge is predictable and well known to business or engineering academics as challenging areas of subject matter, and some is unique to each individual based on their previous knowledge, experience and aptitudes.

As part of the British Government's Teaching and Learning Research Programme (TLRP), the Economic and Social Research Council (ESRC) funded a major research project focused on the development of university teaching and learning in five subject areas: biology, economics, engineering, history, and media and communications (Entwistle, 2003). An outcome of this research has been the development of a set of concepts in respect of the quality of learning, focusing on the pedagogical concepts of troublesome knowledge and threshold concepts.

It was during their work as part of the team gathering data within Economics that Meyer and Land (2003) realized that certain concepts were seen by both faculty and students as being difficult. This in itself was nothing new! However, these difficulties were recognized by faculty as presenting a predictable and an ongoing challenge when creating a teaching-learning environment to facilitate the students' ontological shifts. Over the succeeding years, the concept has been embraced by many disciplines outside of economics.

In summary, threshold concepts and troublesome knowledge are central to encouraging students to engage in deep rather than surface learning. This paper now examines a university undergraduate degree course, linking subject theory to teaching principles and to learning activities with a view to provoking reflection on curriculum and the art of our teaching in this area.

The Managing New Product Development Course

The Managing New Product Development (MNPD) course has run each year at Trinity College Dublin since 1997. The course objective is to enable final-year undergraduate students to understand the contributing factors to shorter lead times when developing marketable and manufacturable new products, choices in structuring the development process and the integration of differing functional capabilities during the process.

The students are drawn from two separate disciplines, each with their own unique 'ways of teaching and practicing' (Entwistle, 2007): business and manufacturing engineering. In bringing these disciplines together in the same classroom, the course creates an opportunity to combine curriculum content and cross-disciplinary teaching-learning. It also provides an opportunity for students to work in the cross-functional environment they will experience in their professional careers as graduate engineers, accountants or marketers.

Table 1. The Four Stages of the MNPD Project

Project Stage	Objectives
Stage I	Describe the innovation process at the level of the firm, identify gaps relative to 'best practice' and identify emerging issues using 'Innovation Your Move' (Voss, Coughlan & Chiesa, 1993)
Stage II	Describe the development process in a recent product development project as key informants experienced it, reflect upon that experience and identify emerging issues using a protocol (Coughlan & Brady, 2002)
Stage III	Compare and contrast the insights emerging from Stages I and II, develop action plans to improve the development process in specific areas and present these to the firms
Stage IV	Consolidate Stages I–III, incorporating lecturer feedback, new information from the company and new insights from the course material

The course is designed to allow each student, as an individual and as a group member, to learn about the application of product development theory to complex case studies and to a major strategic issue in a real organization. The cases challenge students to analyse such product development issues as:

- success and failure
- the strategic dimension
- the product development process
- organizational interfaces
- incorporating industrial design
- design for manufacture
- evaluating and improving the new product development process.

Briefly, the year-long course is taught using a combination of case studies, readings and group project work. Some 14 cases challenge students to analyse product development issues in different industries and countries. The readings provide a conceptual and theoretical underpinning for discussions of those issues. As such, having prepared the readings and case material before the 22 weekly two-hour classes, discussion is open and helps to advance understanding of the issues.

The group project (Coughlan, 2002) runs over the entire year and details are summarised in Table 1. The overall mark for the course is made up of a combination of marks for the project and the end-of-year examination.

Working in groups, students assess product development practice and performance in a firm of their choice and develop recommendations for management. Their reports reflect the issues and concepts which have been addressed in the course.

Viewing Product Development as a Complex Adaptive System: A Threshold Concept

Viewing product development as a complex adaptive system (CAS) has the potential both to provide a framework for helping managers and engineers to manage and to improve this area. Three related but different perspectives on product development used in the MNPD course together lead to the embedding of CAS as a threshold concept. These perspectives are illustrated in Figure 2 and each is discussed below.

Product Development as a Linear Conversion Process

The first perspective in Figure 2 sees product development as a (relatively) simple transformation process, converting inputs to outputs. Using the language of Slack and Lewis (2008), the inputs are in two forms: *transformed resources* and *transforming resources*. The transforming resources (such as staff and design equipment) act on transformed resources (technical, market and time information) to convert an idea into a finished product, ready for release onto the market. Recognizable process attributes, drawn from Operations Management, fit within this perspective. For example, the task of converting ideas into specifications, prototypes and finished products requires the flow of people, information and materials. The information and materials may be held in storage in raw or semi-processed states as the process evolves.

On reflection, this perspective on product development as a linear conversion process

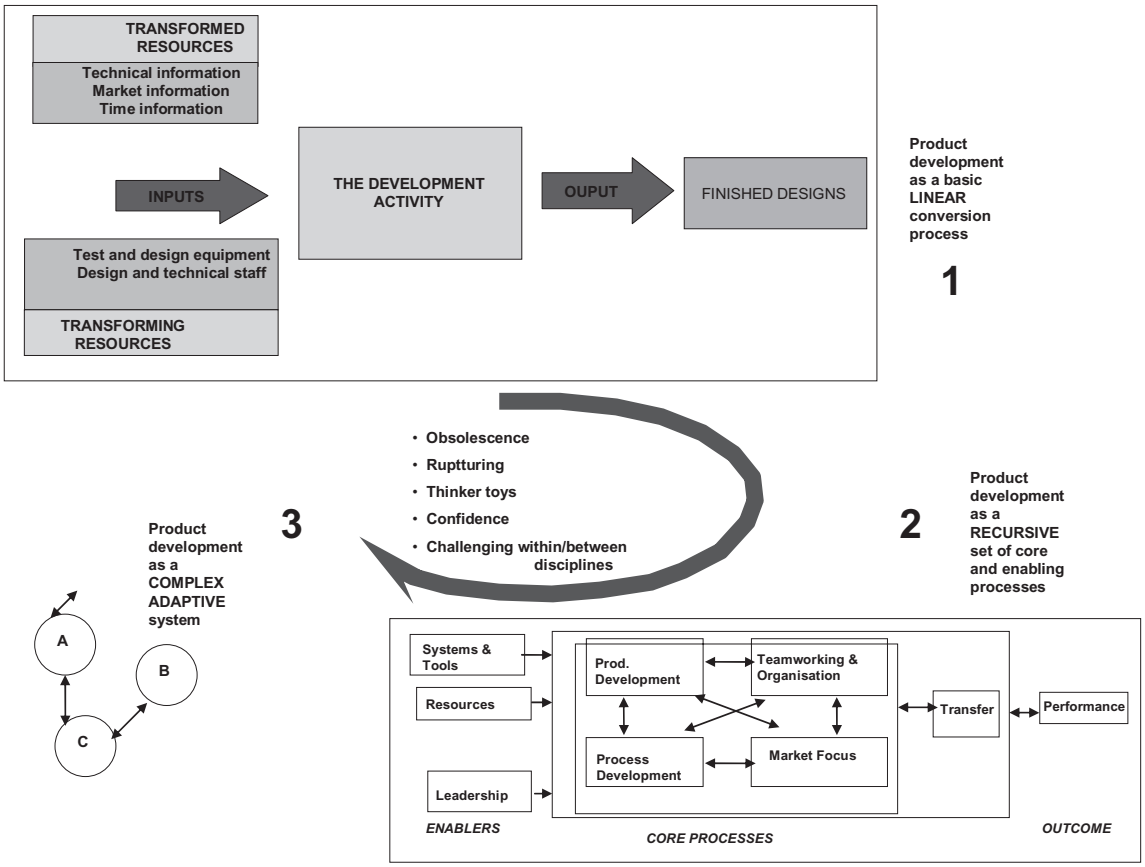

Figure 2. Three Perspectives on Product Development

is based upon relatively fixed, discrete and sequential stages where the flows and outcomes are relatively deterministic (McCarthy et al., 2006). From the perspective of the student, it provides a simple and effective representation of the structural logic and flows associated with a stable product development situation. However, it leaves undeveloped the dynamic behaviours and relationships associated with the notion of product development as a process of discovery and translation into tangible and marketable outputs.

Product Development as a Recursive System

The second perspective in Figure 2 sees product development as a process with concurrent and multiple feedback loops that generate iterative behaviour and outcomes that are more difficult to predict (McCarthy et al., 2006). This perspective builds on Chiesa, Coughlan and Voss (1996) who proposed an underlying process model at the level of the firm that included core and enabling processes of innovation. These core and enabling processes should result in improved innovation performance, which in turn leads to increased competitiveness.

Coughlan and Brady (1996, 2002) developed a related process model, replicating the structure of the Chiesa, Coughlan and Voss model at the level of the product development project. As earlier, the concept of product development is defined as a process rather than a function. This process encompasses the activities, decisions and responses required to take a product from concept to market. In order to explore product development as a process, the framework defines its scope in terms of core and enabling processes. The core process of product development consists of five areas: product development, teamworking and organization, process development, market focus, and transfer to manufacturing. Again, leadership, resourcing and the use of appropriate systems and tools enabled the core process of product development. A successful product development process leads to improved development performance, which is evaluated in relation to goals set for product launch, and measured both in

Table 2. Product Development as a Complex Adaptive System (CAS) – A Threshold Concept

Attribute	Product Development as a CAS
Transformative	The concept of product development as a CAS, defined in terms of core and enabling processes which are non-linear, self-organizing and emergent, rather than a function or a linear technical design task challenges the students' perception of themselves and of the subject
Irreversible	Seeing product development as a CAS, the student does not return to viewing the area as a function, a linear technical task or, even, a simply recursive process, as they might have done before
Integrative	The scope of the adaptive core and enabling processes brings together a variety of discipline and functional areas to be managed that are now understood to be related
Bounded	Depending upon the context within which a new product is being developed, the detailed management task will differ. However, the scope of the adaptive core and enabling processes at the levels of the firm or of the development project helps to define the boundaries of the subject area and clarifies the scope of the communities of research and practice
Troublesome	Seeing product development as a CAS is taken for granted (if even intuitively) by many practitioners. The associated knowledge is tacit, alien to disciplinary-bounded students, and conceptually difficult

terms of product performance and customer satisfaction.

From this perspective, product development is a dynamic and fluid process and radical innovations are possible. However, even though the perspective allows for two-way flows of communication, it does not explicitly allow for structural or behavioural instabilities in the process as the development activity proceeds.

Product Development as a Complex Adaptive System

The third perspective illustrated in Figure 2 sees product development as a complex adaptive system (CAS). From this perspective, product development is non-linear, self-organizing and emergent (McCarthy et al., 2006). The feedback loops in the process produce sensitivity and potentially disproportionate outcomes seen in terms such as development time, product quality, product cost, manufacturing dependability or manufacturing flexibility. The process, as a whole, self-organizes, independently adapting and developing new configurations. Correspondingly, emergence occurs because the process allows experimentation, rule breaking and exploratory actions.

For example, for a new development, the sequence of tasks and the associated relationships between key players/actors may be unpredictable, particularly in an open innovation environment. Creating a climate, within which development tasks and priorities can be changed internally to match market forces and innovation expectations, can be easier if there is an appreciation that the complexity is manageable. To manage in this area requires process managers who can span and integrate a variety of areas of expertise. As proposed by McCarthy et al. (2006), the benefits of the CAS perspective are that it assumes that overall process configurations and behaviours are malleable.

CAS as a Threshold Concept

The MNPD course introduces students to all three perspectives sequentially, ultimately embedding the concept of product development as a complex adaptive system. This CAS concept may be characterized in terms of the five attributes of a threshold concept noted earlier and now presented in Table 2.

The next section of the paper describes how, in the MNPD course, the three perspectives on product development described are combined to help learners to identify CAS as a threshold concept.

Table 3. Product Development as a CAS – Pedagogical Issues and Principles

Pedagogical Issues	Pedagogical Principles and Associated Types of Activity	Application to the MNPD Course
The threshold concept acts as a keystone	Highlight variation to ensure that there is sufficient foundation of basic concepts to make it possible to work towards acquisition of the threshold concept	Product development as a CAS brings form and robustness where previously there was a collection of ideas
The threshold concept is distant initially from direct experience and can only be experienced hypothetically	Help students to integrate their understanding through re-working their understanding of previously acquired concepts in the light of the threshold concept	The hypothetical experience of product development as a CAS is experienced through the comparative case analysis
The threshold concept becomes visible through engaging in a new way of practising and of thinking	Expose the way in which scholars in the discipline use procedural thresholds by highlighting variation in the use of key procedures	The concept of product development as a CAS becomes visible through engaging in the field project
The acquisition of a threshold concept transforms understanding of previously acquired subject knowledge	Help students to regard their understanding as provisional and to tolerate uncertainty.	The sequential presentation of each of the linear and recursive perspectives illustrated in Figure 2 develops provisional subject knowledge which is subsequently obsolete when the CAS perspective is embedded

Helping Learners to Acquire a Threshold Concept

Davies and Mangan (2006) have identified some key pedagogical issues and principles when supporting the students' acquisition of threshold concepts. Table 3 summarizes the expression of these issues and principles in the MNPD course.

Making a threshold concept explicit in this way for students poses an immediate problem unless they have acquired sufficient subject knowledge to develop and to practise an integrated understanding. The transformative nature (Mezirow, 1981) of the learning experience involved forces the student to re-evaluate their previous 'ways of knowing', based on prior learning, constructions of reality or perspectives that have served them very well to date, so triggering a new learning cycle. Following Davies and Mangan (2006), the MNPD course undertakes three types of activity: *reflective exercises*, *problem-focused exercises* and *threshold network exercises*.

Reflective Exercises

As noted earlier, the formal content of the course includes concepts, theory and frameworks designed to assist in understanding organizations, their environments, their product development processes, their performance and the role and responsibilities of management. The readings are drawn from journals and from the EIASM International Product Development Management Conference papers.

Problem-Focused Exercises

Students are assisted towards acquiring deeper subject knowledge through analysis of some 14 case studies. These problem-focused exercises provide a basis for conceptual analy-

sis of practice and linkages among these practices in differing industries and countries. Here, students develop a more extensive understanding of the underlying complex system through analysis of the case situation rather than just through review and reflection on theoretical papers. The class discussion includes a description, detailed analysis, evaluation and development of a plan of action. There is appropriate and creative use made primarily of course material, and also of some additional material relevant to the issues. Recommendations for action are of a specific nature and include consideration of cost, time, responsibility, impact and outcome.

Threshold Network Exercise

The readings provide the concepts and theory relevant to describing and explaining the world of organizations and their management; the case studies and class discussions provide practice in aligning theory with practice. These reflective and problem-focused exercises are complemented by the major field project – a threshold network exercise – which runs throughout the year-long course and involves the students in a number of company visits.

The *central objective* of the project is to assist students in the course to apply theory to understanding practice with a view to making recommendations to management. The *second objective* is to develop holistic competencies in the conduct of diagnosis and the making of judgements in relation to the management of the product development process. The *third objective* is to support, in so far as is realistic, the process of organizational and strategic development in the firms in which projects are undertaken. The *final objective* is to act as a feedback mechanism, internal to the course, through which both students and faculty can observe the extent to which coursework is and can be applied to thinking and practising. The projects are not consultancy projects. They are clinical educational endeavours with which firms co-operate based upon an interest in the content and outcome of an analysis of strategically significant products.

Examination

The overall mark for the MNPD course is made up of a combination of marks for the project and for the end-of-year examination, each accounting for 50 per cent of the overall mark.

The end-of-year examination consists of a case study and a question paper. The case study is available to each student individually ahead of the exam in order to facilitate familiarization with the issues. The examination is closed book. The questions require the student to use the case study as a basis for their answers. In addition, the student is encouraged to apply concepts, techniques and illustrations from the course in the development and presentation of their answers. There are four main criteria for evaluation of the examination:

- an *understanding* of management issues
- *substantiation*, primarily by course material
- critical evaluation and *insight* into the management situation
- *clarity* in structure and presentation.

Feedback

Feedback on the achievements of the MNPD course comes from a number of sources. First, student feedback is gathered systematically and independently at year-end by the university's Centre for Academic Practice and Student Learning (CAPSL). The survey invites students to rate and to comment on course planning, content, evaluation and delivery. The survey administered in May 2009 is illustrative of the feedback received. A total of 68 out of 80 students responded. In brief, 92–95 per cent indicated that the lecturer stimulated them to think critically about the subject. All 68 students rated their satisfaction with the assessment approach highly (90%) or very highly (10%). Some 99% found the course good or excellent. Additional anonymous comments included the following:

- 'Overall, this [course] has been one of the most enjoyable and worthwhile in a practical sense, not just this year, but in my entire college career'.
- 'The course is trying to give the students something no other business course offers'.
- 'Liked the project because it gave [a] practical dimension to the theory'.
- 'I found the assessment a positive challenge which allowed us to use our knowledge in a different manner than previous years. I also feel it worked well doing the project over the course of the year'.

Second, the project also provides a source of feedback. For example, two of the 27 projects completed in May 2009 noted:

- 'The project enabled us to gain tremendous insight into the practical application of the theory we had studied throughout the course. Many of the issues that we identified within (the company) were similar to those we had seen in the case studies in class and the experience complemented our

learning greatly. Likewise, it was helpful to have covered cases beforehand which aided us in understanding the kinds of issues facing [such companies]'.

- 'In completing this project, we have managed to apply theory to practice and in doing so have gained a more complete understanding of new product development and innovation within firms. Through our interviews and analysis of the information gathered in these, we have developed competencies in formal methods of conducting research and auditing companies'.

A final source of feedback comes from the project companies. Company support for the course is evident in the ease with which students gain access, the incidence of repeat projects, and management comments. The following comment from one of the 27 projects completed in May 2009 is illustrative:

- 'The management team are very impressed with the assessment of the company by [the students]. They showed a great understanding of our Company and provided us with detailed and accurate feedback. . . . Certainly as the company grows the recommendations could enhance our New Product Development. [F]ormalized methods could greatly improve NPD by getting more input from a wider group. Benefits would also be reaped by others learning from [named manager] if they were brought into the development process'.

Reflections and Recommendations to Others Responsible for Teaching and Learning of Product Development Management

The ability of teachers and faculty to create effective teaching-learning environments is critical to student success. However, in order for students to develop to their true potential they must have a solid understanding of both their own learning strategies and style, and the challenges their chosen course poses for them. Given the identified difficulty of this type of course, the challenge for faculty is to consider how and in what ways we can create teaching-learning environments that enable and empower students to deal with the stress and anxiety these difficult areas of curricula engender in them.

There is nothing special about the readings, case studies or project tools used in the MNPD course to facilitate a useful learning experience for students. Such elements have been in existence for years. In addition, the project-based approach to enhancing the learning experience of students is not new. What is of note, however, is the way these elements are combined within the course to embed a threshold concept. Stated differently, the course creates particular conditions of learning and implements pedagogical principles to support students in their understanding of the threshold concept and in arriving at the kind of transformational thinking aimed for.

From a pedagogical perspective, embedding a threshold concept requires that it becomes visible through engaging in a facilitated way of practising and of thinking where students accept that, at each stage in their learning, their understanding is provisional. While threshold concepts pose difficulties for students, they can spur their learning interactions with fellow students (Marton & Tsui, 2004; Entwistle, 2007). They also beg a learning space which facilitates a process of meaningful understanding and learning in a deeper way (Graham, 2008). In this space, the student's 'taken-for-granted' nature of their own experienced ways of knowing is challenged. In the particular learning space of a course, the student takes a journey within a relatively 'safe zone' created by the facilitation of a scaled learning experience.

In the MNPD course, the sequence of learning and the iterative nature of the process have developed particular 'conditions of learning' described earlier. These conditions include the combination of the core disciplinary and cross-disciplinary reflective exercises and course materials, the use of particular types of case work as problem-focused exercises, which consolidate the connections between knowledge and practice, and the project which challenges students in an iterative cycle to link knowledge, experience and practice. This 'learning space' offers the required safe zones where the supportive teaching-learning environment is consistent with the traditional pedagogical orientations of the university as a whole.

Summary and Conclusions

New product development management practice continues to move towards a multi-functional and cross-disciplinary focus which means that university graduates need to be able to deal with non-linearity, emergence and self-organization. Expressed differently, they need to be able to practise with the benefit of an embedded threshold concept of product development as a complex adaptive system. Such a concept integrates a way of thinking and operates at a high level of abstraction.

From a pedagogical perspective, a threshold concept has potential to encourage students towards deep rather than surface learning and is best introduced when students have acquired sufficient subject knowledge to develop and to practise an integrated understanding. Embedding the concept requires that it becomes visible through engaging in a facilitated way of practising and of thinking where students accept that, at each stage in their learning, their understanding is provisional.

This paper has examined how students of product development come to understand and cope with a threshold concept and troublesome knowledge. Further research opportunities exist in the identification of further threshold concepts and the nature of the 'learning space'. For example, what level of prior subject knowledge is required by students in order to be capable of acquiring a threshold concept? Further, how might we measure empirically the acquisition of a threshold concept in relation to product development teaching and learning at third level?

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