A Threshold Concepts approach to curriculum development in Physics at the University of Kent.

Abstract

This article presents a recent study at the University of Kent’s School of Physical Sciences. The study uses Threshold Concepts theory (Land & Meyer 2003) as an approach to curriculum development in the School of Physical Sciences. Threshold concepts theory aims to discover the parts of the curriculum that transform students’ understanding of their subject. This article argues that by identifying the transformative parts of the curriculum tutors can support students Personal development planning through a series of targeted subject related reflective questions. The aim is to enable students to see their development and appreciate how their understanding of the subject is constructed.

Introduction

Threshold Concepts theory was introduced into the context of curriculum development in higher education by Land and Meyer (2003). They describe threshold concepts as the ‘concepts that bind a subject together, and that are fundamental to ways of thinking and practicing in that discipline’ (2005 p1). Threshold concepts are the parts of the curriculum which open up a new way of seeing a subject, hence the word threshold as in doorway into the discipline. Central to the theory of Threshold concepts is the idea that in order to pass through a threshold students must spend some time in a ‘liminal’ space (this can be thought of as a temporary stage or waiting space) until they have fully understood and can move forward. Threshold concepts differ from core concepts (a more familiar term in curriculum design) which are better understood as building blocks that progress understanding of the subject but do not necessarily lead to a qualitatively different view of the subject. Threshold Concepts are the parts of the curriculum which qualitatively change the students’ understanding or transform their view of the subject. Meyer & Land describe threshold concepts as having particular features four important features are:

• **Transformative**, they open up new ways for the student to see the subject
• **Irreversible**, once learned they are not easily forgotten
• **Integrative**, they provoke students to ask new questions of the subject
• **Troublesome**, they are difficult to understand and often counterintuitive

To help to illustrate their ideas Land and Meyer give a number of examples of threshold concepts in different disciplines such as; opportunity costs in Economics, the state in Politics, metabolism in Sports Science and heat transference in Physics. Their work has led to a number of interesting studies to identify threshold concepts in different disciplines such as in Computer Science (McCartney & Saunders), Economics (Davis & Mangan, 2007), and Cultural Studies (Entwistle, 2005).

Aims

This project has three central aims; firstly to find out more about how Physics students learn and what can be done to enhance that process. Secondly to see how useful a threshold concepts approach is as a way in to discussing the curriculum with students. Thirdly to develop a subject based approach to PDP by formulating reflective questions structured around the threshold concepts or as Land terms them the ‘Jewels in the curriculum’. This may have the potential to turn PDP from a generic, bolt-on activity to one which is grounded in the discipline, subject-specific and responsive to individual students’ learning styles.
Literature review

The idea of Threshold Concepts emerged from a research project into the characteristics of strong teaching and learning environments for undergraduates. It builds on Hounsell’s work on ‘ways of thinking and practising’, and Perkins’ (1999) description of ‘troublesome knowledge’ i.e. the parts that are alien or counter-intuitive. The potential result of a curriculum constructed around threshold concepts has parallels with other theories on learning in HE such as Brookfield’s focus on students becoming critically reflective, Gibbs’ (1992) emphasis on deep learning and Barnett’s suggestion that HE should seek to provoke anxiety in students in order to shift their thinking. It is the transformative aspect of learning which is of interest in this study because it is this which is often most challenging for students. PDP puts emphasis on students’ reflection on their learning but many students and tutors have difficulty with this seeing it as a bolt-on approach which does not really help students to develop in their learning. Reflection is a natural reaction to challenging situations we all replay difficult situations in our minds and think through ways that we could have done things differently. Therefore the aim of this study is to use the Threshold concepts that exist in Physics to ‘hang’ PDP reflective questions on in an attempt to make PDP more subject specific and timed to help students see the process of their learning.

Methodology

The methodology for this project took the form of a series of focus group discussions. First Ray Land presented his theory to a group of about 30 academic staff from across the University. From that a staff meeting in the School of Physical Sciences was organised in which the theory of Threshold Concepts was outlined and colleagues were asked to suggest threshold concepts from the curriculum. This was only partially successful as colleagues tended to focus most on the areas of the curriculum that are most troublesome such as quantum physics, relativity special and general, thermodynamics and calculus, this is only one feature of threshold concepts. However the discussion did provoke two interesting observations; firstly that perhaps each person’s threshold concepts might be different i.e. what opens up questions about the subject for one person may not be the same for everyone and secondly that it is difficult always to remember what you once found troublesome or what it was that motivated you because this changes over time. We therefore resolved to ask the students about threshold concepts.

In preparation for student focus groups it was useful to read Cousins (2005) recommendations on consulting students. In the light of that the outline of threshold concepts theory was substituted for 5 questions which aimed to break down the theory and get at all the features of threshold concepts as identified by Land and Meyer. The questions were as follows:

1. Can you identify any area of learning that has enabled you to see new aspects of the subject?
2. Has there been anything that has changed the way you think about the subject?
3. Is there anything that you have learnt which really sticks in your mind?
4. Has there been any aspect of your study which you have had to go over and over again before you have been able to understand it?
5. Have you encountered anything in the programme that you have found troubling, counter-intuitive or alien?

Three student groups were consulted; Y2 (40 students), Y3 (15 students) and FY (6 students). Questions were asked to the group as a whole, students discussed in small
groups and were provided with the questions on paper and then allowed thinking time (Stahl 1994). We requested responses and facilitated discussion which was recorded. This approach was much more successful as it enabled students to think about different aspects of the curriculum as well as to identify and form some consensus in answer to the 5 questions.

**Responses**

Foundation stage

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| Can you identify any area of learning that has enabled you to see new aspects of the subject? | • Calculus and how it applies to the real world – maths for a reason  
• The properties of matter |
| Has there been anything that has changed the way you think about the subject?         | • The course has enabled us to understand physics related stories in the newspapers which students found motivating |
| Is there anything that you have learnt which really sticks in your mind?          | • Physics modules are more memorable because they are applied to something real that we can relate to  
• Remember 'Avagadro's number' |
| Has there been any aspect of your study which you have had to go over and over again before you have been able to understand it? | • Calculus  
• Bragg equation which was difficult to learn  
• Trigonometry  
• Avagadro’s number |
| Have you encountered anything in the programme that you have found troubling, counter-intuitive or alien | • Pure maths, e.g. logarithms, calculus |
| Do you have any other comments?                                            | • The importance of links, need someone to help you to see links  
• Repetition is useful |

Stage 2

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| Can you identify any area of learning that has enabled you to see new aspects of the subject? | • Practical lab sessions, reading publications on the space sector which made the theory more relevant, medical physics because it shows how physics can be applied to real situations  
• Maths is essential, new ways of applying theory within areas of mathematics, calculus  
• Quantum mechanics leading to an understanding of atomic physics, Newtonian mechanics |
| Has there been anything that has changed the way you think about the subject?         | • The technique of visualisation – visualising what’s physically happening  
• Applications of what we have learnt such as electromagnetics, forensic science, medical physics, spacecraft design and rocket science, building a bridge between concepts and real life examples  
• The idea that things don’t happen perfectly |
| **Is there anything that you have learnt which really sticks in your mind?** | • Rutherford scattering – the theory of the atom  
• Mass, momentum, force etc  
• Newtonian physics and electronics  
• Schrodinger equation, SUVAT equations |
| **Has there been any aspect of your study which you have had to go over and over again before you have been able to understand it?** | • Quantum numbers  
• Maths, calculus  
• Differential equations  
• Electro-magnetism |
| **Have you encountered anything in the programme that you have found troubling, counter-intuitive or alien?** | • Atomic physics because it is hard to visualise  
• Quantum mechanics, quantum physics  
• Optics |
| **Do you have any other comments?** | • Just studying one area of the course doesn’t allow develop a deep insight into the entire subject  
• Realisation that there many different jobs that you can do with a degree in physics  
• Realisation that there is so much to learn about the physical world  
• Every time we start a new subject we are told the stuff we were taught earlier was wrong, in particular learning new models for existing entities e.g. learning new ways to describe an atom  
• You have to know it all as it all builds on itself, need to learn how everything links up, need to connect all modules to get a complete understanding |

### Stage 3

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| Can you identify any area of learning that has enabled you to see new aspects of the subject? | • Maths – calculus, trigometric functions, algebra  
• Wave theory  
• Quantum physics, quantum mechanics  
• Relativity |
| Has there been anything that has changed the way you think about the subject? | • Quantum mechanics, quantum physics  
• Relativity, special relativity  
• Electrical magnetism |
| Is there anything that you have learnt which really sticks in your mind? | • Space craft section because it was fun and practical  
• Equations |
| Has there been any aspect of your study which you have had to go over and over again before you have been able to understand it? | • Electromagnetism  
• Optics |
| Have you encountered anything in the programme that you have found troubling, counter-intuitive or alien? | • Relativity  
• Quantum mechanics |
| Do you have any other comments? | • A lot of what we have learned we have since found out was wrong it is frustrating |
Discussion

1. What can be done to help students learn?

Enabling students to see new aspects of the subject: The responses from students revealed a surprising degree of consensus; they all seem to recognise that there is a ‘tool kit’ for successful learning in Physics which is the maths, particularly calculus, trigonometry and algebra, without this students did not feel they could make progress in the subject. Therefore it is maths that opens up learning for physics students and enables them to interrogate the subject further. Foundation year students were the most acutely aware of this which is unsurprising because they tend to come from non-traditional routes into Physics and therefore have a steep learning curve to understand the maths content necessary for higher study of Physics.

Motivation: From the students’ responses it is very clear that practical and applied physics motivates them. Students said that they want to start from the applications or context of real Physics to the theory that underpins this rather than the other way around. This could really change the way in which the programme is taught and will present some challenges for lecturers in helping students to navigate a programme structure of this nature.

Epistemology: the epistemological basis for physical sciences is based on a positivist approach to knowledge i.e. that the truth is out there it can be tested and known. This approach to knowledge seems to make it particularly hard for many students to accept that there are different ways of looking at theories. In all three groups students expressed frustration that what they had learned previously was frequently replaced by a new way of understanding. It seems likely that if students were introduced to the constructivist approach to knowledge they might be more accepting of new ways of understanding theory.

Memorable: the responses from students to this question came in two forms; either they thought about the aspects of the programme which they had learned by rote such as particular equations which stick in their minds because of the way in which they have been learned, or they thought about the things that had had the greatest impact on them because they were motivational or had ‘real world’ application such as medical physics and space craft design.

Teaching troublesome knowledge: Students in all three groups identified similar things that are troublesome. An approach to teaching troublesome knowledge based on Threshold concepts theory has been developed by Pace & Middendorf (2004). They have termed this approach ‘Decoding the disciplines: 7 steps to overcome obstacles to learning.’ This puts a focus on the liminal space which Land and Meyer talk about this is a time for practice feedback and more practice before students can pass through a new threshold. This emphasises modelling how an expert approaches the problem and giving students practice and feedback on their practice. This seems to be what the students were asking for so it would be interesting to teach one the subjects listed in the troublesome category in this way.

Less is more: Students emphasised their need for the fundamentals of the subject to be repeated and represented often to enable them to feel confident to move on. This endorses Cousins (2006) view that there is ‘a tendency among academic teachers to stuff their curriculum with content’ she says that ‘a focus on threshold concepts enables teachers to make refined decisions about what is fundamental to grasp of the subject’.
2. Can threshold concepts be used to structure students’ reflection on their learning?

**Review, repetition, reflection:** Students in foundation year discussed the benefits they gained from repetitive learning. They felt that some of the more difficult concepts on the curriculum should be repeated so that they had more chance to really understand before moving on. They also talked about the importance of understanding the links between things and the need to be helped to perceive these links. This approach to learning is emphasised by PDP which through reflective learning claims to help students to record their work, review it and reflect on it in order to see their learning process and perceive links. This is termed by Moon (2003) as ‘cognitive housekeeping’ suggests that this needs to be done regularly in order for students to be able to see the most important things that they have learned.

Related to this is Perkins’ (1999) view that reflective learning enables students to get to the ‘attics of their brains’ again suggesting that students need to be given time and support to arrange their knowledge, put in place, index it, and make links and even throw out bits that are no longer useful. One thing that came across strongly from all three groups was unease about being told by tutors that what they had learned last year about x was no longer quite right and needed to be replaced by further information. Students found this unsettling, there seems to be a need to prepare students better for this aspect of learning perhaps by introducing the habit of regular reviewing and reflection, ‘tiding-up’ of their knowledge.

Threshold concepts theory lays emphasis on troublesome knowledge i.e. the things that students find counterintuitive or alien. There are parallels here between troublesome knowledge and other educational approaches which emphasise the importance of deep learning Gibbs (1997) ‘provoking anxiety’ in students, (Barnett, 2000) or asking them to identify ‘critical incidences’ discussed by Brookfield (1987). It is the troublesome knowledge, the critical incidents that provoke anxiety in students that are the points at which a critical educator must allow for a pause in instruction i.e. waiting at the liminal/portal stage and structure reflective questions for the students to help them to see the process of their learning and understand how what they are learning is transforming the way in which they understand their subject.

Allowing students to identify threshold concepts pin-points times when the reflection on learning and PDP advocated by (Dearing 1997) makes sense in a discipline based approach to PDP. There is no point reflecting on the mundane everyday learning. It is only really useful to reflect on things that have challenged or even things that seem to have gone badly critical reflection at this point can really help the student to learn more about their learning and develop their own strategies to overcome challenges. Therefore creating learning experiences which deliberately target points of resistance are likely to be most powerful in provoking critical reflection or what Gibbs describes as ‘deep learning’.

3. Does Threshold Concepts theory help to facilitate a discussion with students about the curriculum?
Having worked with student groups on similar projects for many years the threshold concepts approach does seem to be a useful way to structure curriculum discussion with students. It enables students to talk about their subject but does not give them the answers. In general students did not use it as an opportunity to moan about the subject or about the teaching but instead they mostly engaged with the questions from a subject perspective and they seemed to enjoy the opportunity to share their experiences of learning. This was especially true of Y3 students, the size of their group and the stage of learning they are at also probably predisposed them to have the most productive discussion.

Conclusion

The idea of threshold concepts advanced by Land and Meyer is useful for a number of reasons. First it facilitates a new framework in which to discuss the curriculum with students. Second it offers a theoretical explanation of why some students emerge from 3 years studying at higher level having been successful in gaining a qualification but without having ever really engaged with the subject. Finally it provides a link between the subject knowledge and transformation or personal development in the student.

Questions:

- Which bits of the curriculum can be left out to create space?
- Give examples of PDP questions that can be scaffolded into the curriculum

References


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