

How can digital media enhance students' mastery of threshold concepts?

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SUMMARY

Mastery of threshold concepts is driven by students' expanding knowledge and experience. Threshold concepts cannot be taught via the simple transfer of knowledge, but instead 'emerge' for students via experience, conceptualisation and self-development (Meyer and Land, 2005). This can happen at different stages via different means and students may enter a liminal state whereby they oscillate between states of understanding and being (Cousin, 2006; Meyer and Land 2005). Teaching and re-teaching threshold concepts at set points adds to the teaching load and may not be an effective way to support students' mastery on what is a messy, unpredictable and personal journey.

The persistence of learning resources in the online space means that students can drive their own learning and development by visiting and revisiting interactive digital resources that demonstrate conceptually difficult or contradictory knowledge. Such troublesome knowledge is a feature of many fields of engineering. The transformative power of digital media can take students outside of the classroom and immerse them in other worlds.

By taking a focussed approach in this project, we will explore what transformative and troublesome knowledge means in the literature, and to a select group of students and staff at WMG. Using the findings, we will then propose digital media solutions informed by multiple perspectives.

INTRODUCTION

WMG, University of Warwick, is a department with strong industrial links. Its mission is: "To deliver the technology, knowledge and people needed by the industries of today and the future" (WMG, 2021). Its full-time masters' courses foster employability skills and

industrial awareness via classroom simulations, case studies and expert speakers. The aim of this research is to establish whether the use of experiential and immersive technologies, such as virtual and augmented reality and video case studies, could supplement these classroom experiences and enhance students' mastery of threshold concepts in the engineering leadership curriculum. Findings from a literature review, student focus group session and tutor interviews show that such technologies may be especially effective in helping students master threshold concepts relating to the practice of being an engineer in the workplace.

Meyer and Land (2006) describe threshold concepts as having one or more of the following characteristics: transformative, troublesome, irreversible, integrative, or bounded. This research focuses on troublesome knowledge – first identified by Perkins' constructivist approach (Perkins, 1999). In particular, *inert* knowledge; things that students know but do not actively experience, and *foreign* knowledge; which 'comes from a perspective that conflicts with our own' (Perkins, 1999, p. 10). It will also show that transformative knowledge is key to moving from student to professional to embrace new 'ways of thinking and practising', which Meyer and Land (2006, p. 15) identified as a threshold function in itself.

Full-time master's programmes at WMG are condensed courses taught over one year and, as such, opportunities for industrial visits or placements are limited. This research seeks to understand whether the use of rich media, such as video, augmented reality, (in which smart glasses allow users to see virtual objects overlaying reality), or virtual reality (in which users wear headsets that immerse them in a virtual environment), can create experiential and immersive learning that deliver more authentic ways of thinking and practicing – moving students beyond mere 'mimicry' to the transformative experience of 'becoming' an engineer (Meyer and Land, 2006).

LITERATURE REVIEW

Before we can identify how digital media can enhance students' mastery of threshold concepts, we need to understand the features of threshold concepts and how they apply in engineering, leadership and management education.

Flanagan (2017) describes threshold concepts as those that are: transformative, troublesome, irreversible, integrative, bounded, discursive, reconstitutive or liminal.

A review of the literature on threshold concepts in engineering, leadership and management has revealed that most relevant to 'becoming' an engineer or leader are the *transformative* and *troublesome* features of threshold concepts, those that transform the students' perspective and identity via a *liminal* process.

For a concept to be *transformative* it should change the student's ways of thinking and practising and be:

“... akin to a portal, opening up a new and previously inaccessible way of thinking about something. It represents a transformed way of understanding, or interpreting, or viewing something without which the learner cannot progress.”

(Meyer and Land, 2006 p.3)

Transformation is a theme that runs throughout the literature on threshold concepts in engineering and management (Baillie, Goodhew and Skryabina, 2006, Crispin et al., 2016, Donovan, 2017, Hibbert and Cunliffe, 2015, Hawkins and Edwards, 2015, Wright and Gilmore, 2012).

Male and Bennett (2015) identified the role of the engineer to be a transformative threshold concept for engineering students because once inhabited, it connects students' learning with their personal goals and future career. They become self-directed learners, who began to think like engineers rather than students.

Liminality is the process by which students transform. Liminality refers to the fluctuating state of learning or self. A process in which students oscillate between old and emergent knowledge and identities (Cousin, 2006). At postgraduate level, students traverse back and forth across the thresholds of student, scholar, and professional identities.

Hawkins and Edwards (2015) argue that a state of uncertainty is central to the study of leadership and that students occupy a liminal state in which they 'try on a variety of... identities'. (p. 39). Wright and Gilmore (2012) also focus on these states of liminality. In their study they found that pre-liminal students saw managing as 'common sense' and based this assumption on their own limited experience of being managed, whereas post-liminal students could contextualise case studies with appropriate theory allowing them to think like a manager.

Troublesome knowledge is sub-divided by Perkins (1999) into: inert (known, but unconnected to other ideas), ritual (routine and unquestioned) conceptually difficult knowledge or, most pertinently, knowledge that is foreign (that which comes from a perspective different from our own). This 'foreign' or 'alien' knowledge is a particular threshold for aspiring leaders who must understand the perspective of those they lead.

Hibbert and Cunliffe (2015) argue that students can be transformed into responsible leaders of the future through moral reflexive practice, a practice that not only focuses the student on their professional role but also creates 'authentic consideration of the interests of others' (p. 185). The need for managers to understand the perspectives of others is highlighted by Donovan (2017) who argues that accomplishing results through other people is a particularly troublesome concept for students who often see management as 'doing' rather than leading. Students must transform their view from seeing managers as control agents to managers as influencers.

In order to develop digital and immersive resources, a review of the current teaching methods and learning strategies employed by tutors and students to overcome thresholds can hold useful information. What is currently being practiced and how can digital and immersive resources enhance these teaching methods and learning strategies?

The literature in this review can be broadly divided into studies that focus primarily on a transformation of perspective and those that focus on transformation of identity.

When the teaching methods seek to broaden students' perspectives, dialogic methods are often utilised. Donovan (2017) used provocative statements as prompts to encourage debate and Wright and Gilmore (2012) used discussion to surface liminal states followed by peer and tutor feedback to encourage new perspectives. Baillie, Goodhew and Skryabina, (2006) encouraged students to enter into dialogue in order to see each other's perspectives.

In identity development, Male and Bennet's (2015) methods for connecting students with the identity of the engineer is to create passion for engineering by providing students with site visits, interviews with professional engineers and industry-based projects. Hawkins and Edwards (2015) ask students to reflect on their own experience of leadership and power via small-group experiential learning and Hibbert and Cunliffe (2015) take a social-constructivist approach whereby students are active constructors of their social and organisational reality. These approaches are all aligned to authentic leadership learning in which students are brought as close to becoming the subject (i.e. the leader) of their studies as possible.

The literature on the use of virtual and augmented reality in engineering leadership education remains sparse, which seems to be reflected in educational practice (Haber, Xu and Kanu, 2023, Snyder, 2014, Soliman et al., 2021). As Haber et al. explain: 'Virtual reality (VR) technologies have been gaining ... however, its adoption in management has been slow, and rigorous empirical research to understand its impact on learning and retention is scarce'. (2023, p. 93). Rather than examining the transformative potential of rich media and extended reality, most of the literature focuses on the affordances of the flipped classroom, which provides for enhanced threshold concept mastery in the classroom by transmitting theory via videos and quizzes online. (Khoo et al., 2015, Olaniyi, 2020, Gamez-MonteroPeña and Olmedo-Torre, 2021).

Although digital and immersive environments do not provide a truly authentic environment, they come much closer to authenticity than the traditional classroom. Findings from neuroscience have established the importance of authentic environments for creating authentic responses. For example, the high-stimulation environment of being 'on the floor' as a trader induces neurochemical changes resulting in 'reckless' decision-making (Snyder, 2014). Medina (2008) determined that being trained in the same location in which you will practice enhances memory and performance. This project proposes that these authentic emotional and cognitive responses can be made accessible via the use of virtual realities or interactive rich media experiences which mimic 'real-world' environments and practice.

CONTEXT: THE ENGINEERING EDUCATION PROBLEM AND INTERVENTION

By its very nature, digital media occupies a hybrid space – crossing temporal and physical thresholds (Davis, 2018). In this space, troublesome knowledge can be studied recursively (Cousin, 2006); visited and revisited at a time that is relevant to students and the stage they are at in their studies – allowing them to integrate new knowledge to concepts and make connections throughout their learning journey. When students are in a liminal state, oscillating between old and new perspectives and identities (Savin-Baden, 2006), the persistence of digital media and virtual spaces can act as a virtual classroom, always available to them at whatever stage they have reached.

Digital media can create a ‘portal’ to otherwise inaccessible places (Meyer and Land, 2006). New ways of knowing can be created when threshold concepts are presented in digital formats, and knowledge can be shared across disciplines or even communities, providing fresh perspectives on accepted norms.

By presenting ideas in multiple accessible formats, accessibility/inclusivity can be increased for students with restricted mobility, dyslexia, autism, English as a second language, or even shyness (Gilbert, 2019). Students’ study preferences can also be accommodated.

The aim of this research is to understand what threshold concepts have been experienced by students on selected courses and whether digital media and immersive resources can support students in their mastery of these threshold concepts.

From a more practical point of view, it is anticipated that digital media will be able to provide opportunities which the stuffed curriculum (Cousin, 2006) at WMG struggles to support. It will provide teaching staff with a greater understanding of what students find difficult in their course and so focus attention to those aspects without losing time for other teaching.

Site visits are limited, and industry speakers have restricted availability. The use of workplace video cases or virtual visits can plug this gap and enhance student engagement with their subject and future career. Simulations can be enhanced with immersive environments in virtual or augmented reality and dangerous environments can become (virtually) accessible.

DESCRIPTION OF INTERVENTION / PRACTICE

In June 2023, student members of the Staff-Student Liaison Committee were invited to take part in a focus group to gather opinions on threshold concepts teaching in WMG. A snowball sampling approach was undertaken where these students were asked to encourage

their course peers to attend. This was because there had been difficulty recruiting students up to that point and because we wanted students from WMG on a small number of courses.

The focus group ran with 13 postgraduate taught students on three courses: Engineering Business Management (EBM), Managing Business Excellence (MBE) and Programme and Project Management (PPM). Students were asked which topics or concepts had proved troublesome or transformative, which teaching methods had supported their threshold concept mastery, and which learning strategies had they employed to master threshold concepts. The session was audio recorded for later transcription and thematic analysis using NVivo.

Follow-up interviews were then held with tutors from two of the modules highlighted in the focus group to discover tutors' perspectives on students' mastery of threshold concepts. The tutors were asked about their teaching approaches, why they had chosen them and what responses they observed in students. Again, these interviews were audio recorded for later transcription and thematic analysis using Nvivo.

This was the first stage in identifying a possible benefit to developing online or immersive experiences to enhance students' mastery of threshold concepts in engineering education.

EVALUATION OF INTERVENTION / PRACTICE

A thematic analysis of the qualitative data from the focus group and interviews was completed. Comments relating to the threshold concepts were identified and coded. As expected from the literature review, comments relating to troublesome-ness and transformation scored most highly with 17 and 13 comments respectively (Baillie, Goodhew and Skryabina, 2006, Crispin et al., 2016, Donovan, 2017, Hibbert and Cunliffe, 2015, Hawkins and Edwards, 2015, Wright and Gilmore, 2012, Cousin, 2006, Perkins, 1999). Reconstitutive concepts (11 comments) (Flanagan, 2017) and liminality (eight comments) (Savin-Baden, 2006) also featured frequently. Analysis of the threshold concepts comments generated themes around students' learning experience, module design and group-work relationships. A sentiment analysis was then undertaken to look at whether comments related to the themes were negative or positive.

Discussions in the focus group that were most relevant to threshold concepts centred mainly around two modules from the Managing Business Excellence course, namely, 'Leadership and Excellence' and 'Reflective Practice for Managing Business Excellence'. These modules used simulations, case studies, feedback and reflection as part of their module teaching and learning strategy. The thematic analysis and subsequent sentiment analysis showed that these teaching and learning strategies were most effective in helping students to integrate theory and practice and make connections between their studies and the workplace. Most crucially, these strategies helped students to 'cross the threshold' and transform their perspectives and identities during their studies.

As discussed in the literature review, transforming students' ways of thinking and practising can be achieved by allowing them to try on new and varied identities (Meyer and Land, 2006, Hawkins and Edwards, 2015). Data from the student focus group supports this, one student described Leadership and Excellence as 'so transformative' in the way they 'thought about organisations' and 'dealt with situations'. The situations they describe were classroom simulations – but were viewed by the student in terms of professional settings. This transformative aspect was reinforced by Tutor 2 (Leadership and Excellence), who stated that the module was designed so that students would forget they were in the classroom.

In a similar approach to Hawkins and Edwards' (2015) Tutor 2 explains that he 'decided the only way for them to appreciate leadership was to experience it'. Students were asked to 'try on' a range of leadership styles in the simulation, from Authoritative to Laissez-faire. Often, those who didn't think of themselves as leaders performed well in a leadership role in the simulation, therefore changing their self-perception. Tutor 2 explains that one student felt that the module 'undid her completely' and that she had to 'rebuild' herself.

This trying on of roles was also experienced by students on the Reflective Practice module. Just like Snyder's (2014) findings that high stimulation results in reckless decision-making, students explored the impact of emotions on decisions by putting themselves in the shoes of decision makers in a video re-enactment of the Challenger disaster. Similar to the social-constructivist approach taken by Hibbert and Cunliffe (2015), this more authentic experience encourages students to be moral reflexive practitioners who empathise and understand the emotions involved in decision-making.

Connecting students to their own future professional identities is another method to help students cross the threshold from student to practitioner (Male and Bennett, 2015). Reflective Practice requires students to build a reflection on their master's study that will help them to look forward and see how they will apply their studies in a professional context.

Just as findings from both the literature and data suggest that learning that transforms identity is rooted in authentic experiences, there is also a match between the data and literature around the use of dialogic approaches to encourage new perspectives.

In a module review of 'Reflective Practice' one student commented that the feedback she received on the module helped her to "[grow] as a person and academically – I see everything differently". This change of perspective was noted by two other students. One described how their perspective 'changed completely', enabling them to take a holistic view of an organisation and team perspectives, another said that receiving feedback from other students provided a perspective she had not considered and that these new perspectives had enabled her to 'connect [her experience] to the theory concept'. The student's shift in perspective matched Tutor 2's intention, who explained that by receiving feedback from five other students on their leadership performance, students could see how it was perceived differently by each. A similar approach was taken by Tutor 1 (Reflective Practice) who built in feedback so that students could see the richer picture created via multiple perspectives.

In terms of transformation, it seems that receiving feedback is more transformative than giving it. Tutor 1 notes that active participants in discussions often have a confidence which 'acts as an insulator' from broadening perspectives. This is echoed by the Tutor 2 who talked about 'the importance of engaging with those who are quiet'.

The comments made by the student and the tutors suggest that receiving feedback not only encourages new perspectives, it also tackles the threshold concepts of integrating theory to practice (Wright and Gilmore, 2012) and the troublesome leadership concept of achieving results through others (Donovan, 2017, Hibbert and Cunliffe, 2015).

Further troublesome concepts reported by students in the focus group included self-reflection, group work, communication and timescales. The concepts were viewed as challenging, but not negatively. Students seemed able to connect the challenges they experienced to those that they would also face in the workplace. For example, one student explains the troublesome nature of his liminal state when trying on a professional identity: "I'm doing mistakes. I'm not doing the right way right now. I want to improve but this is the first, first step to improve it", but he rationalises these difficult emotions by countering "this is real life. This is what happens in industries."

Group work in both modules was intentionally designed to be challenging. In order to disrupt students' chosen roles, leaders were headhunted, and those who had avoided leadership were given the toughest role – going in as the new leader to an already established team. Three students reflected that case studies and simulations challenged them but they valued the 'real-life' application of theory to practice which they believed help them to understand better. Time constraints were viewed as positively challenging when designed into the simulations, but negatively in relation to the organisation of modules. For example, two students found the time constraint in the simulation 'helpful', but two others were frustrated by the amount of time it took to form new, well-functioning groups for each short simulation.

From the tutor perspective, troublesome concepts had been carefully designed into the modules to develop students as professionals. Tutor 2 described the sense of responsibility for outcomes that students felt as a positive challenge, this could be because the simulation made them *inhabit* the role of leader.

For Tutor 1 dealing with the emotions around giving and receiving feedback were a necessary challenge. He designed the module so that students would receive feedback from those he selected, so that they learned to dissociate the source of feedback from the content.

In terms of challenging theoretical concepts, Tutor 2 identified the difference between headship and leadership to be a threshold concept to students, who often thought of leadership in terms of positional power rather than leadership through influence. This aligns closely with Donovan (2017).

DISCUSSION

As stated in the introduction, the aim of this research is to establish whether the use of experiential and immersive technologies can supplement classroom experiences to enhance students' mastery of threshold concepts.

Both the literature and the qualitative data have shown that students' identity can be transformed via authentic learning experiences, such as Hawkins and Edwards (2015) small-group experiential learning, the Leadership and Excellence simulation and the Reflective Practice case study. However, as effective as these strategies are, they are still experienced in the classroom and can only be accessed once – when they are taught. As Snyder (2014) points out, neuroscience highlights the importance of environment for authentic responses. This paper asserts that the permanence of more immersive experiences, such as scenarios set up in the metaverse, enable students to inhabit and re-inhabit other identities and transport them at any time to more convincingly authentic environments. They can unlock the passion that Male and Bennet (2015) describe as key to understanding the role of the engineer.

Dialogic methods that allow students to understand new and broader perspectives is another theme that runs through the literature and qualitative data. Donovan's (2017) provocative statements to stimulate debate, Wright and Gilmore's (2012) discussions to surface students' liminal state, and the feedback students give to each other in the Leadership and Excellence and Reflective Practice modules all act as ways to surface and connect 'foreign knowledge' (Perkins, 1999). Online communities of practice can connect students with knowledge that is even more alien, knowledge that they source from beyond the confines of the classroom, their peer group or even their culture. The decolonisation of the curriculum is a key driver in higher education (Begum and Saini, 2019). Students are able to experience a greater number of diverse perspectives by connecting and interacting online with industry experts from across the globe and can embrace 'new ways of thinking and practising' via discussion with students from other disciplines (Meyer and Land, 2006, p. 15).

So digital resources open up access to remote places, diverse communities and authentic environments. Designed well they can also become inclusive, accessible resources that create a more equal educational environment for students with restricted mobility, dyslexia, autism, English as a second language, or even shyness (Gilbert, 2019). More research into these benefits (and limitations) will form the next steps for this study.

Of course, digital media has its drawbacks. The cost of developing bespoke virtual environments will be time consuming, resource intensive and costly.

It is also not suggested that these resources replace traditional teaching. Students in the focus group were keen to point out that they wanted contact time with tutors and that long periods of solo study via video were 'not fun'.

CONCLUSIONS & RECOMMENDATIONS

This study has explored the benefits of enhancing classroom study with supplementary digital resources. Simulations can be enhanced via rich media resources that tell a compelling story, or use of immersive learning such as augmented and virtual reality. Online communities of practice can allow students to cast their nets wider to share perspectives and ideas with peers or experts across the globe.

It is this study's finding that digital resources can enhance students' mastery of threshold concepts and we recommended that tutors explore the possibilities of adding digital media to their teaching strategies in order to enhance student experience, deepen understanding and provide equal access to all.

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