OPINION PIECE

Placing physics undergraduates into a state of confusion: why we must deliberately perplex learners during their degree course

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Abstract

In this opinion piece (based on personal teaching experience and independent study of the literature) I outline how we as teachers deliberately confuse our students during their physics degrees. I explain how the passing through this confused state can be thought of as a rite of passage for students, and suggest how a greater awareness of this can assist our teaching.

Keywords: threshold concepts, liminality, rites of passage

Background

The idea of the confused state

The transition from school to university learning is a difficult one. A student must get used to styles of teaching that are different from those provided in school and take control of their own learning in ways that have not been required before. The volume of work and rate of transmission of information may also be greater than at school, and this is tricky. The majority of students arrive ready for this challenge. They have developed a fledgling love of their chosen subject at A-level or equivalent and are keen to expand their knowledge and build on what they have learned before. But what many do not realise (and may never do so explicitly) is that much of their degree is not simply knowledge building and adding layers to what they already know: rather it must involve completely discarding

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cherished and comfortable frameworks on how they understand the world then going through a period of intense confusion to understand a new, more advanced, framework to emerge with a more advanced and enlightened view of the subject.

The confused state as a rite of passage

One way of considering the transition from eager fresher with simplistic ideas to complete graduand with a more advanced view of the world, and about to start knocking on the doors of the professional communities of practice as they embark on a PhD, is to consider the journey as a rite of passage, or, better said, a series of rites of passage, akin to those described in a broader anthropological context by van Gennep (1960). Recognising this concept is something that may potentially be used to our advantage in teaching and learning, especially in physics. Regardless of the quality of teaching within a physics department, the rites of passage a student goes through, three of which are outlined in this article, are not well delineated and I suspect this goes some way to producing low levels of student satisfaction. In my experience this does not occur in Earth Sciences, for example, where the rites of passage are clearly documented – the key part being field trips – where each and every student is aware of the journey they are embarking on, as are the teachers, and everyone knows that they are all in the same boat. Similar processes occur in dentistry and medicine leading to strong communities (recognised by those from outside as cliques) where all the learners are comfortable within their temporary state of confusion as they know their colleagues are at the same state. This is not so with Physics Departments, where the student often treads a lonely journey along the rite of passage with much less of an awareness of whether they're on their own with the confusion or whether others are experiencing the same.

The Liminal State

Liminal states

Following from van Gennep's work, Victor Turner was able to split the notion of rites of passage into that of liminal states (Turner 1964). These states involve three stages: the preliminal (the rite of separation as the student is required to leave a cherished notion behind as it no longer matches reality), the liminal (where the student learns a variety of new and initially bewildering concept ideas and (from the same etymological root) is in limbo, and the postliminal (where the newly initiated student is ready to take on the world and join the relevant communities of practice with confidence in their new and improved understanding). An essential part of teaching is to recognise how and when students are about to enter a liminal state and how best to introduce it. The best way to do this varies from person to person and from culture to culture, but if a teacher can anticipate the transition phase then they can potentially help the cohort.

When a novice leaves behind a comfortable framework to enter the uncertain phase, and ultimately reach the more elevated state of understanding, they change their way of thinking as a result. While in the liminal stage this can have interesting results, as eager learners attempt to try out new skills and techniques. A simple example is the way people at this stage will begin to try out the new lexica that inevitably come with any field of interest. They will often incorporate specialist words into everyday speech, sometimes in a clumsy fashion, gradually improving until the appropriate vocabulary becomes second nature. With this comes a change in outlook on the world, and thus a more refined mental state.

Threshold concepts

The idea of liminal states is closely tied to the idea of threshold concepts, which have been much investigated most notably by Meyer & Land (2003) and Land *et al.* (2010). They introduced the idea of the threshold concept when trying to differentiate types of learning. Some learning involves building on prior knowledge and understanding. This is easy learning. Other learning involves looking at familiar phenomena from a new perspective. This is what they define as a threshold concept, which they tie in with what they call "Troublesome Knowledge" an apparent misnomer as knowledge can be misinterpreted as recalling of facts, which is almost certainly not what the authors are referring to. In fact, Meyer and Land make clear that they are borrowing the term from Perkins (1999) and further split the types of Troublesome Knowledge into six categories. Of these, the 'ritual' and 'inert' knowledge types that relate to routine and passive thought could passably be declared as knowledge; the other four types ('conceptually difficult', 'alien', 'tacit' and 'troublesome language' are certainly more complicated than pure recall.

Threshold concepts in physics

Physics is awash with threshold concepts and rites of passage for the student to go through. I identify three major examples that most undergraduates ought to go through but not all fully negotiate.

First is an understanding of the way atoms behave, which is ultimately governed by quantum mechanics. This major undertaking is something students are relatively ready for, and is often the main attraction of the degree in the first place. Most

doi:10.11120/ndir.2014.00029

learners already know that the subject is counter-intuitive and underpinned by strange rules as they have read this in popular science books. What most are unwilling to do, however, is to check their current understanding of how atoms behave at the front door of the department and be ready for confusion while the lecturers bombard them with abstract mathematics whilst gradually applying this to increasingly sophisticated examples until finally they are in a position to understand macroscopic behaviour once again. This period of gradual liminality typically spans a few years. Many students fully emerge from this rite of passage, although some poor souls remain dejected and effectively in limbo, partly still clinging to their cherished, and, at graduate level, useless ideas of how atoms behave.

Second is an appreciation of uncertainty analysis in practical physics. The central tenet that the student must take on board is straightforward: when doing an experiment the uncertainty on the result is just as important as the result itself. This concept is something which hardly any undergraduates anticipate and it is unfortunate that contemporary A-level and IB exams do not emphasise it. There is no doubt that uncertainty analysis is recognised – it is often taught as one of the first things in the degree - however the freshers are thenceforth expected to recognise and use uncertainty analysis in all its sophistication throughout their degree. Wilson *et al.* (2010) recognise that with uncertainty as a threshold concept this is an inadequate way of preparing people for an important rite of passage. Many students in fact complete their degrees without ever fully reaching the level of maturity required for this subject.

Third is a practical knowledge of electronics, which, as with uncertainty analysis, is something that takes budding physicists by surprise and they don't recognise it as an integral part of the physics degree. This topic sees a more rapid liminality than the previous two examples but is one where students tend to feel a short duration of angst. It is also an area where students almost universally complete the rite of passage, finishing the course with a practical skill base they will use many times throughout their degree. (In my own experience I can add that many students end such courses skilled, though under-confident – they tend to surprise themselves later in the degree when asked to use their skills, saying things like "I'm rubbish at electronics", no doubt recalling the confusion of the liminal state, while simultaneously demonstrating a decent level of mastery.)

Mastering a Discipline

Punctuated learning

What students go through during a rite of passage is essentially a period of punctuated, episodic learning (Land *et al.* 2010). This can be further classified into three areas that are integral to the their understanding: that of content knowledge, procedural knowledge and epistemic knowledge (Kind *et al.* 2012). They also draws parallels with Kuhn's work (whose central thesis is that scientific advances in general occur in a start-stop fashion) (Kuhn 1962) that are beguiling though contentious. A realisation that learning is a non-linear process is, however, an important step.

Practice

Continual purposeful practice (i.e. the kind with no respite, where every time one seems to get the hang of technique the level of difficulty is increased) is a central route through the liminal state. University teaching is a guide to this purposeful practice and lecturers must train the students on which areas to practice next. As Matthew Syed points out in the scientifically flawed, though persuasively argued, Bounce (Syed (2010), which is a blend of educational theories applied to sports), the practice is going well not when students are succeeding but rather when they are failing. It is only when they metaphorically trip up that they are really learning. If a lecturer can recognise this then it can help with understanding student frustration.

Mastery

During a degree course students are aiming to complete the rites of passage necessary to finish with a mastery of the subject matter. How many do this could potentially be a measure of how well the degree course is working, and may be the key to student satisfaction. Some studies have revealed that while students in the UK start their degree courses intent on mastering the subject, this focus changes as the degree course proceeds (Lieberman & Remedios 2007, Remedios *et al.* 2008). In fact the shift in intention moves from a desire to master to a desire to perform by to displaying that ability to others. Looked at another way, this is a shift from depth to surface approach or even from intrinsic to extrinsic motivation. This is an undesirable state of affairs and once again, recognition of the problem and its source must be a step towards its solution.

Advice for Physics Lecturers

While most physics lecturers do have an implicit feel for the liminal states that students go through I feel that recognition and understanding of the phenomenon can explicitly help us in our teaching.

Preparing the student

Preparing the learners for rites of passage before they begin and helping them to understand that they are all in the same boat could assist with a

feeling that they are undergoing a journey together. Outlining the stages of the journey and the levels we expect the students to be at during the ongoing stages can be of use. Most of us do this already of course but there is a tendency to outline it in a glib format where each stage appears terribly easy. This can dishearten a pupil.

Embracing the confusion

A common part of a university course is to survey students to gauge their happiness with the course. While positive scores are a Good Thing and negative scores are a Bad Thing in general questions like this seem flawed. If a course is genuinely pitched at the correct level for students, it should be challenging the majority, putting them into a liminal state, and hence into a confused mindset. Some courses are standalone, and the end of the rite of passage should be at the end of the course (or rather several weeks later after the audience has consolidated its understanding by revising for the exam). Some courses dovetail with others (quantum mechanics for example) and while the end of one course may act as a milestone on the rite of passage it will really exist halfway along the route. I feel we need to anticipate and embrace this confusion and explain to students that it is a necessary and proper feeling that means they are learning.

Welcoming their arrival

And finally, if we can prepare students for the rite of passage and nurture them through it then it seems appropriate to welcome them to the other side with some sort of metaphorical red carpet. Like many of my points here this does happen implicitly to some degree already (allowing final year undergraduates to choose a project, or simply by congratulating someone in a tutorial for demonstrating understanding that implies they have reached a new level of maturity for example) but maybe we can take it further and formalise it somehow. In doing so we gradually permit those with a proven maturity to enter a community of practice.

In conclusion I feel that we can use the idea of the rite of passage to create a better teaching environment where students and teachers both recognise and appreciate the need for these liminal states. Too many learners fail to complete the rites of passage they are eager to conquer at the start of their first year and it is our duty as lecturers to ameliorate their journey.

Acknowledgments

Thanks to all staff at the EDU at Imperial College for assistance.

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