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Threshold concepts in statistics and online discussion as a basis for curriculum innovation in undergraduate medicine

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Background

This paper is the first of two papers reporting on plans for implementation of statistical e-learning tools generated through the MSOR Network-funded project 'Statistics in medicine: a risky business?' and other funded development work. An emphasis is placed on the need for research in understanding threshold concepts in statistical learning within undergraduate medicine. Further, online discussion forums are promoted as a means of informing this process as well as enhancing student learning more generally. This will in turn form the basis in the follow-up paper for reporting on a larger educational project which is due to commence later this year through funding awarded by the Principal's Teaching Award Scheme (PTAS) at Edinburgh. As such, the current paper serves both as a project update and as the forerunner to a later paper on a more extensive project.

Conceptualizing approaches to learning

The categorization of learning styles into deep, surface and strategic [1] has proved to be a popular one in learning theory. However, when planning curriculum innovation across several years of a course, it is helpful to consider learning styles more extensively. Recent work exploring the notion of threshold concepts can help inform this process and encourage educators to evaluate "teaching contexts" from a fresh perspective. Within the literature on theories of student learning, a *threshold concept* has been described "as 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 ..." [2]

The sorts of transformations intended here may involve a eureka experience but are more likely to be protracted over a considerable period of time, with the transition to understanding proving troublesome. Either way, crossing the portal is a necessary step in empowering students to engage beyond the surface level with a range of areas within their discipline and appreciate their interrelatedness [3].

The transition brought about by threshold concepts may prove troublesome, since it is 'unsettling' due to exposure to new knowledge which is, for example, 'counter-intuitive', 'alien' or 'seemingly incoherent' knowledge. [4, 5] Through undergoing such a transition, the learner is perceived as acquiring 'a new status and identity within the community of practice' which is observable through a transformation in their 'use of language' within the discipline represented by that community [3].

In identifying possible threshold concepts which need to be acquired by undergraduate medical students if they are to have a sense of authenticity in the application of statistics, it is helpful to consider Baillie and Johnson's large-scale study involving engineering students. The findings of this study include a strong tendency of students to be uncomfortable with uncertainty and the recognition that this attitude towards learning is likely to have been acquired through exposure to comfort zones of precision in the learning of mathematics and physics at secondary school level. [6] From this perspective, it is likely that uncertainty is also a threshold concept in the learning of statistics and may prove as unsettling in this context as in engineering through requiring a reconstitution of the learner's values. Indeed, generally speaking, statistics is characterised by a tolerance of uncertainty and the possibility of this being troublesome is evident in the following remarks:

"Statistics is an exercise in coping with, and trying to make sense of, uncertainty, not in producing uncertainty. It is usually frank in admission of its doubt, and we should be more willing to [be] the same." [7]

If medical students are to tolerate uncertainty in their interpretation of what constitutes evidence in statistical reasoning, it makes sense to provide relevant learning opportunities. Moreover, exposing students to problem-solving activities involving uncertainty is supportive of Barnett's ideal for higher learning "as the formation of the human capacities to live without fear in an uncertain world" [8]. The need for this is illustrated by the findings of a recent qualitative study exploring junior doctors' experiences in their first year of practise, where learning to manage uncertainty is identified as a hurdle to be crossed. [9]

In the evaluation of clinical literature as a basis for clinical practise, medical graduates are especially likely to be exposed to methodological uncertainty through a plethora of competing statistical approaches to *estimating* patient risk, where the criticality of the clinical scenario is a potential driver for making uncertainty more problematic. I address this problem directly in the risk CAL, in keeping with the aims and objectives of the MSOR-Network funded work as expressed in [10], where 'CAL' is intended to refer to a sequentially arranged collection of Computer-Assisted Learning objects. However, in medical research, uncertainty is also encountered more precisely as statistical uncertainty through the concepts of p-value and confidence interval. Whilst these concepts may be thought of as fundamental to an understanding of statistics, they are problematic not only in requiring the learner to entertain uncertainty within a mathematical discipline, but also because they tolerate reasoning about unobservable and hypothetical instances: instances where there is a more extreme effect than that observed or where the sample has been derived from an unknown population. As such, they are challenging to visualise.

I believe that it is failure to grasp the concept of confidence interval in particular that is at the heart of a culture of infatuation with p-values and that this in turn has the potential to alienate medical students from a community of practise which a trained medical statistician would perceive as respectable and trustworthy. The decision to separate off the concepts of p-value and confidence interval and favouritism for the former, may rest in the apparent precision associated with the idea of pursuing a number – the p-value – which conforms to a preset rule (typically, that of being less than 0.05). Through the presence of a rule of thumb which forces a decision (*is or is not statistically significant*), students are duped by rigour into assuming the p-value to be the better choice for presentation of findings. The confidence interval CAL (a sister CAL to the risk CAL) has been developed to enable medical students to gain a better understanding of the notion of confidence interval through examples, exercises, normality plots and an interactive calculator and to appreciate the indispensability of confidence intervals in drawing valid conclusions from study findings. It is therefore intended that the notion of confidence interval will become less problematic as students are encouraged to use this CAL as well as the risk CAL in conjunction with their clinical learning.

It is anticipated that within the undergraduate medical degree (MBChB) programme at Edinburgh, those materials will conveniently integrate with problem-based learning (PBL). There is a call, however, for a more thorough integration of statistical and clinical learning beyond the confines of PBL. This call is to be met through a follow-on project to the MSOR-Network funded project. Details of this larger project, including the intended strategy for integrating statistical learning with clinical problem-solving and decision making, are to be provided in a later issue of *MSOR Connections*. Here, however, I wish to prepare an essential foundation stone by promoting the value of discussion boards as an effective support mechanism for enhancing statistical learning among non-specialists.

Online discussion boards should be integrated with the use of CAL materials

With the necessary information and communication technologies (ICT) training in place, the use of discussion boards can offer several advantages in the teaching of statistics within undergraduate medicine, some of which are discussed below.

The opportunity to encourage participation from less confident learners

At Edinburgh, EEMeC (the Edinburgh Electronic Medical Curriculum) is the standard virtual learning environment (VLE) for the formation of educational discussion groups for the MBChB course. EEMeC includes a discussion board system which allows individual contributions to be anonymized across students. Given this opportunity

for anonymity, it is anticipated that students will be more willing to expose their own opinions, disorientation and puzzlement to the benefit of all involved.



Fig 1 – Undergraduate medical students at work
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The MBChB course at Edinburgh is, as is the case with undergraduate courses at other UK medical schools, populated by students from contrasting cultures based on ethnicity, race and nationality. Variation in norms across these cultures can undermine the readiness of students in early years to participate in a more self-directed approach to learning (where knowledge is no longer transmission orientated). Provided group tasks are clear from the outset and all group members are delegated appropriate responsibilities with a view to achieving these tasks, discussion boards can challenge the misconception that self-directed learning is synonymous with learning in isolation.

The Edinburgh College of Medicine and Veterinary Medicine is also a participant in the programme *Pathways to the Professions* [11], which involves educational activities to attract students from all schools in the Lothian area to apply for places within the MBChB course and undergraduate courses in law, veterinary medicine and architecture. This programme allows the Student Recruitment and Admissions service to recognize and respond more proactively to the elevated problems which arise in recruitment of students from under-represented areas to professional undergraduate degree programmes. Priority in terms of educational and career support activities is given to potential applicants who do not have a parent or carer who previously attended university (*Pathways Plus* applicants). [11]

In terms of performance within courses, it has been recognized (personal communication, Kathleen Hood) that entrants via widening participation (WP) routes tend to outperform and require less support than students from independent schools. Nevertheless, there is still considerable scope for disintegration in early years as WP students seek to adjust to a predominantly middle-class student environment. Discussion boards can serve an essential role in early years as a means of validating

WP students' capacity to know and their sense of being respected within a learning community. This is achieved by allowing students to share in the construction of knowledge required in problem-solving activities and acquire a greater capacity for autonomous learning in more challenging learning environments in later years.

However, it is realistic to suppose that in some instances individual students may feel that they are not ready to contribute to a particular discussion. For example, based on their secondary school experience of working in small group settings with regular one-to-one tutor support, students from independent schools may initially feel overwhelmed by shifts in learning context experienced during their transition to university education. Even at these stages of the learning process, discussion forums can facilitate vicarious learning, whereby a learner's understanding is enriched by *observing* dialogue [12], thus allowing scope for less ready students to find their feet.

Learners evolve into tutors and thus acquire a richer form of learning

As learners begin to question their own and others' understanding of individual concepts, they are drawn into dialogues whereby deep learning becomes a social experience and as such, possibly more enticing. It is important to note here that the ultimate goal need not be to clone the learners' understanding with that of the expert but to encourage new insights into understanding through sharing of perspectives. However, it is likely that as students progress through CAL materials for learning statistics, such dialogues will encourage the practise of using the specialist vocabulary of the domain with a greater sense of ownership.

The statistician is alerted to new problematic concepts characterized by overlap between issues raised by individual students, to the enhancement of future learning experiences for students

Approximately one third of the students entering the third year of their MBChB course at Edinburgh will have already completed an intercalated honours course leading to a dissertation based on a short research project. Students who have been exposed to statistics through such courses have frequently reported various levels of incentive to disengagement, from having been told what to do without any sense of the rationale behind the choice of methodology to having had the statistical procedures performed for them (personal correspondence with 4th year MBChB students). Within such environments, where students are required to write up study findings, there is considerable scope for the development of misconceptions, particularly through over-simplified interpretations of findings, to the detriment of future learning. It is also possible that the development of misconceptions is reinforced by the nature of our intuition(s) and that, within the world of statistics at

least, threshold concepts, including *uncertainty*, are a special case of counter-intuitive concepts. Indeed, in a recent article, it is suspected “that much of the difficulty of statistics comes from its counter-intuitive nature.” [13] There is therefore a call for differentiating between intuitive and counter-intuitive knowledge (possibly including threshold concepts) in statistics using examples which clinicians in training and graduate clinicians are likely to encounter. Arguably, therefore, discussion boards can serve as a valuable medium, not merely for students to become unraveled from early misconceptions derived from prior learning, but also, for the identification of counter-intuitive concepts or ways of explaining these concepts which teachers of statistics may need to recognize as such. Findings could also be compared with claims from a recent study of 1st and 2nd year medical students that *sampling theory*, *normal distribution*, *statistical significance* and *effect size* all constituted threshold concepts in their learning of basic medical statistics and critical appraisal skills. [14]

The opportunity for space to contemplate

One learning attribute which I have highlighted in the context of designing resources which are inclusive for dyslexic learners is “[t]he need for space to learn alone and work through or create a personal cognitive representation of a given argument or process” – an attribute which may also apply to non-dyslexic learners. [15] Online discussion forums are valuable in meeting this need as they allow time for students to contemplate prior to presenting ideas more formally as a group in a classroom setting, as is typically required within the framework of PBL.

It is also important to acknowledge that there are a number of pedagogical challenges associated with the implementation of online discussion forums as a learning tool, particularly where students are *assessed* in groups. Problems such as reluctance to expose subjective inferiority in conceptual understanding and parasitic behaviour are included among the many possible explanations for the phenomenon, duped as *lurking*, whereby learners are present during discussion sessions but do not actively contribute to these sessions. Literature on group motivation losses (not specifically within e-learning) may prove informative here insofar as it has been recognised that increasing group size can be associated with an increased sense of dispensability of personal

¹Kerr and Bruun [16] identify disjunctive tasks as those permitting the group to choose a single member as the contributor, with there being an incentive for the group to choose the “most able” member. By contrast, they recognize conjunctive tasks as those permitting all group members to participate but with the ultimate effect that group output is defined by the performance of the “least able” member. Clearly, there is a continuum between these extreme categories of task which educators ought to be aware of in avoiding e-learner apathy at any one of a range of ability levels.

effort and a resultant *free-rider* effect. [16] Moreover, e-moderators ought to be aware that formative group feedback has the potential to reinforce such an effect and that the nature of the learning task – ‘disjunctive’ or ‘conjunctive’¹ – may be influential in determining whether it is less or more able learners, respectively who are likely to be susceptible to this effect. [16] As Salmon emphasises, however, not all lurking is negative and the e-moderator needs to exercise discretion and tolerance before challenging non-participatory behaviour, [17] just as is the case in relating to particularly dominant participants. Indeed, “Managing the interface between contributing and browsing is a key e-moderating task.” [17] To inform this task, it would be an interesting exercise to use retrospective student feedback to investigate psychosocial, logistic and other factors which might explain different types of online behaviour. First, however, I must face the challenge of driving curriculum innovation within a context where learning statistics is unlikely to be perceived as the *raison d’être*!

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