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Author:

Thompson, Rachel Elizabeth

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Title

Sexing up stats: dealing with numeracy issues and threshold concepts in an online medical statistics course.

Author

Dr Rachel Thompson, Learning and Teaching Fellow and Lecturer in Quality of Medical Practice, Faculty of Medicine, University of New South Wales (UNSW), Sydney, Australia

Abstract

Introduction/background:

Teaching statistics to medical students is hampered in two ways. Firstly, as a “Cinderella” subject, statistics is perceived to be less glamorous than other apparently more clinical disciplines. Secondly, as it involves mathematics students often view it as difficult, unpleasant or just plain boring. Since 2005, first and second year medical students, undertaking the new integrated undergraduate medical curriculum at the University of New South Wales (UNSW), Sydney, have been learning medical statistics and evidence-based medicine (EBM) through a mainly online learning environment (nine consecutive online modules supported by lectures and practicals).

Issues for exploration/ideas for discussion:

This paper examines numeracy issues and threshold concepts as impediments to learning medical statistics and EBM and shows how online learning and support activities can be adapted to target these problematic areas.

Purpose/objectives:

Early feedback on the online statistics modules revealed that there was a problem with student engagement and also poor understanding of the major assessed topic areas. In an attempt to improve the modules, the impediments to student engagement and learning were identified. Prominent among these problem areas were major threshold concepts and also any content containing mathematics or formulae. Further research aimed to find a more engaging and successful way to approach these problem areas from both teaching and learning points of view. Sections in the modules with major threshold concepts and statistical formulae were redesigned to present information using more than one teaching approach (visual and narrative as well as mathematical) and by targeting online exercises and quizzes, lectures and face to face tutorials on these more difficult areas. Several other changes were also implemented to support these initiatives, including a more comprehensive evaluation.

Results:

Subsequent evaluation using online evaluation forms, quiz and exam results revealed that the students' knowledge in the targeted areas improved and that student engagement in the course had increased considerably.

Discussion:

The significance of these findings for other "Cinderella" subjects and for online statistical courses is discussed and suggestions are made for the application of this process to other areas of learning. However, the overall impact of changes is difficult to assess as numeracy issues involve emotional responses that are difficult to gauge and the measurement of student understanding of threshold concepts is complex and maximal evaluation remains elusive.

Conclusions:

Medical statistics and EBM are areas of higher education where numeracy issues and major threshold concepts act as impediments to student learning. Teachers who identify and improve the teaching of these specific areas can increase student engagement and understanding.

Paper

Introduction

Medical statistics and evidence-based medicine (EBM) are often perceived by medical students (and graduates) to be difficult or boring as they include challenging concepts and mathematics (formulae, numbers and equations). These topics remain less exciting and attractive to students than the more seemingly clinically relevant subjects of anatomy, pathology and physiology (Altman and Bland, 1991). Sinclair (1997) in an anthropological study of a London Medical School in the 1990s found that statistics was "above all the subject most disliked by students". He concluded that statistics lacked the proper "hard facts" to engage students, and did not engender the expected sense of status that students associated with medical training. There is, however, a growing recognition of the importance of clinician competency in evidence-based medicine and interpretive medical statistics (Del Mar, Glasziou and Mayer, 2004). This is supported by the Australian Medical Council (2007) which targets EBM in two out of thirteen of the graduate attributes recommended for basic medical education. Despite the advent of an improved EBM profile in clinical and teaching arenas, a problem still remains.

In 2005 at UNSW, a curriculum design group launched nine online EBM modules teaching basic medical statistics and critical appraisal. The content and design of the modules were based on the guiding principles set out by the then current leaders in the teaching of EBM (Del Mar et al, 2004) and used various teaching practices including problem-based and integrated learning. The structure of the new integrated curriculum meant that about 500 first and second year students are taught together; the EBM online modules running through year B of an alternating A and B cycle. At the end of the implementation year (2005-6), over one third of students had not even logged on to all nine of the modules, and exam results indicated that one third of students did not appear to understand the key concept of statistical significance. Over the following year, an analysis and revision of the whole course was undertaken with the aims of identifying the key impediments to student engagement and learning, and to seek practical, implementable solutions. Early impressions suggested two key areas of concern: students had numeracy fears and also it appeared that there was under-teaching of key concepts. Other problems identified were: the online format, lack of alignment with assessment, and poor evaluation.

Issues for exploration/ideas for discussion

Lecturers of non-mathematical courses would acknowledge that showing an overhead or slide containing a formula or equation often provokes an audible intake of breath, communal sighs or even more vociferous complaints from the student audience. This highlights a problem of "numerophobia" (Ben-Shlomo, Fallon, Sterne, and Brookes, 2004) further defined as "a perceived and disproportionate fear of numbers and simple mathematical manipulation" (Ben-Shlomo, 2005). Other researchers have identified and investigated this further; finding that this is a common but not insurmountable problem (Klinger, 2004; Quinnell and Wong 2007; Moss, Greenall, Rockcliffe, Crowley and Mealing, 2007). At UNSW, early informal feedback from students and colleagues suggested that such "numerophobia" was a definite barrier to engagement in the online modules for a significant proportion of the first and second year medical students, despite most of them having taken higher maths at secondary school.

This possible numerophobic barrier was in spite of the original design of the modules which had aimed to reduce the emphasis on formulae and numbers in the teaching of the modules. The rationale had been that statistical concepts could be taught using a narrative, interpretative base rather than using traditional explanations with mathematical derivations. To this end, narrative techniques had been used to explain each key concept so as to allow students to bypass temporarily the maths and gain initial understanding, returning later to appreciate how the associated formula

represents the concept. Re-examining the explanations in the modules showed that minimal mathematics was employed and so it was concluded that while numerophobia might be a cause of poor initial engagement in the online modules, something else was affecting engagement and knowledge attainment as well. Threshold concepts as proposed by Meyer and Land (2003) seemed to fit this perfectly. As Meyer and Land state, a threshold concept:

"...represents a transformed way of understanding, or interpreting, or viewing something without which the learner cannot progress" (ibid, 2003, p. 1).

Further analysis of the modules elicited some key concepts that were problematic for students: sampling theory, Normal distribution, statistical significance, and the concept of effect size. They can also be classified as "troublesome" as Meyer and Land (2003, p. 7) describe because they constitute both "conceptually difficult knowledge" and "troublesome language" (in this case statistical and EBM language). These threshold concepts concurred with the designers' own learning experiences of statistics; these main areas were troublesome in their learning, but on gaining understanding this knowledge was perceived as "irreversible", "transformative" and "integrative" (Meyer and Land, 2003, p. 4-5). Without understanding sampling theory, Normal distribution, and statistical significance, much of inferential statistics would be inaccessible. To go further, one might speculate that these concepts are in fact linked or sequential threshold concepts. Essentially a transformative process occurs through gaining more than just understanding of each concept, and the next concept or threshold concept can be approached by the student with a different, enlightened way of thinking. This alteration in the way the student comprehends these fundamentals of statistics enables the next concept or threshold concept encountered to be understood at a deeper level. For example, when students fail to understand sampling theory, they have great difficulty with understanding the basics of inferential statistics.

Having recognised these as key to student learning, each threshold concept and other key concepts were analysed and unpicked (Bonner, Harwood and Lotter, 2004) to reveal the key theories and components that could guide a focused teaching approach. It was noted that numeracy issues were recognised as part of these threshold concepts but did not explain all of their "troublesome" nature. As a result of this analysis, the modules were adapted to concentrate more on the identified threshold concepts. This was achieved by expanding the explanation in these areas using visual, narrative and mathematical approaches with detailed examples, quizzes and exercises to assist learning by application (Ramsden, 1992). To support this, the number of lectures was doubled and all lectures were focused on the major threshold concepts whilst sexing up

the content with clinical scenarios and practical applications to show how understanding statistics is vital to clinicians practicing EBM.

Furthermore, feedback from 2005 emphasised the importance that students placed on discussion with peers and tutors, as the modules were initially designed as standalone. This married well with the course convenor's impression that the threshold concepts needed more concentrated teaching. As a result, practical sessions were increased and tutors supervise a large class of students who work through online exercises in small groups. Students now gain from peer, tutor and whole class learning, however this was not considered to be enough in itself to engage the students. Therefore, other changes were implemented to facilitate these initiatives, including: improving the readability of the modules; adding a brief evaluation after each online module adapted from Brookfield's critical incident questionnaire (1995); improving the alignment of assessment by including more questions in the formal integrated exams (Biggs, 2003); and making the online modules compulsory.

Results

Since the changes, the in-built, four-point scale evaluation has provided interesting interim feedback (both positive and negative). Students were most engaged in the earlier, easier topics (89.3% felt that they had a good understanding of descriptive statistics) compared to 57.9% expressing a good understanding of statistical significance which they also identified as one of the most confusing (41.7% compared to only 19.7% confused by descriptive statistics). Only 18.3% of students were confused by the module on bias and confounding (but 71.0% of students said that they needed "more time to grasp the key concepts" of the t-test).

A longer online evaluation form (Brookfield, 1995) has provided high quality qualitative feedback from those most motivated to reply; the most content, and the discontent grumblers. This has provided both useful suggestions for improvement and revealed interesting insights into how students learn. For instance, a few students want more maths (e.g. one student suggested "More maths-background behind each of the explanations!") but some want less and appear afraid of numbers; one student feels most distanced in a module "when numbers are brought in". There are both positive and negative comments on diverse topics such as the online format, module length, complicated concepts and the amount of face-to-face teaching. Students often felt most engaged when doing the online exercises and quizzes that followed explanations; others found the modules, the exercises and study appraisals "too long" or even "boring". Interestingly, the students have identified the same threshold concepts that the

designers identified as both areas of confusion and high engagement. Many students indicated that the exercises and quizzes helped them to understand the concepts better.

From another angle, monitoring showed that more students were logging into the online modules than in 2005, with the majority "signing off" with the concluding evaluation and quiz for each module. However, the most interesting improvement is the level of understanding of threshold concepts. Analysis of the formal exam questions (targeting threshold concepts) shows that less than 15% of the students failed the short answer questions after the changes, compared to over 30% in 2005, the mean average mark increasing by 7%.

In summary, responses to the online evaluations show that students are well engaged, quite confident and mostly not too confused whilst they recognise that they need more time to study the harder concepts. Supporting this improvement, informal feedback from tutors and students suggest that the majority of students are more content with the whole process and many are expressing an interest in EBM and statistics.

Discussion

It is hard to know whether the stick or the carrot has caused the improvement in student engagement and perceived understanding of the modular content. The compulsory nature of the re-designed modules may have achieved as much to improve engagement and knowledge outcomes as the changes in the way the content is taught. In a similar manner, following Biggs' (2003) manifesto to coerce the students into learning by aligning the assessment might well be the biggest driver here; rather than the teaching initiatives improving their understanding of the threshold concepts, the fear of exam questions may have forced the students to rote learn. If many students are in fact surface learning for the exams, then the apparent beneficial effects of the changes may not be as sustainable as we hoped. Following up these students in later years with a more detailed evaluation of EBM and statistical interpretation skills is necessary might shed light on this.

More immediately however, further analysis and evaluation will focus on clarifying the issues surrounding numeracy issues and how students approach the learning of threshold concepts in EBM and medical statistics. It is bothersome that some students are still left out in the cold, unable to understand the threshold concepts or unwilling to engage in the course. It is possible that remedial tutoring will assist the still failing students but little more can be done to assist those who do not want to learn. In contrast, the students who do want more maths will be directed to supplementary mathematical material.

To detect the subtler issues and learning outcomes of the modules, more should be done to align assessment and analyse a full two years' data (available 2009). Key elements from Brookfield (1990), Ramsden (1992) and other proponents of responsive teaching will be applied to the threshold concept areas identified as needing further attention. Moreover, students undertake an independent learning project in the third or fourth year that involves using the EBM and statistics learnt from these modules. Evaluation of how these students use their knowledge and skills in tackling their research project would be invaluable. Additionally, it would be interesting to do further research into how students might identify numeracy problems so that they can manage their "numerophobia" and initiate stronger engagement in the on-line learning (Quinnell and Thompson, 2008).

Conclusion

The results from this review of online EBM modules for first and second year medical students at UNSW suggests that medical statistics is yet another area with major threshold concepts that act as barriers to student learning. Identifying, analysing and addressing the teaching of these threshold concepts was key to improving the students engagement and learning, however, the more detailed factors that affect student learning in these modules are difficult to assess as the threshold concepts are complex and many changes were made simultaneously. Despite this, the teaching and student learning through these EBM and basic medical statistics modules appears to have improved and further evaluation should now assess whether teaching these topics at such an early stage of undergraduate medicine and in this particular manner is effective in the longer term goal of producing high quality EBM practitioners.

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