Troublesome concepts in statistics: a student perspective on what they are and how to learn them

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Introduction

The notion of threshold concepts (Meyer and Land 2002; 2004) has sparked renewed interest in examining what is important for students to learn, and the challenges they may encounter whilst learning (see for example Meyer and Land 2006). Most of these discussions have emerged from the perspective of disciplinary academics, many of whom nominate and exemplify the 'threshold concepts' within their discipline or field of study. We felt that the student's experience of what is 'threshold' (Davies 2006) and equally of what seems troublesome (Perkins 2006) was also of significance, and would be potentially informative for the design of teaching, assessment and feedback.

In this modest study we sought to take an initial step in this direction. The study is focused on an introductory statistics course, which typically attracts between 300-500 students each semester. Our primary concern was to gain access to the student's view of what constituted significant learning within the course, and the concepts they found particularly tricky or challenging. We were particularly interested to see if the concepts nominated as 'important' or significant in some way by the students aligned in any way with those nominated by the PASS (Peer Assisted Study Session) leaders and the lecturer. We were also keen to consider the types of difficulties students indicated they experienced, as this could inform future course design and teaching strategies.

Research design and analysis

This project was conducted with a class of 555 biology students (most in their first year) undertaking an introductory statistics course. At the end of each semester the students are invited to complete an online evaluation of the course and the lecturer, similar to the teaching evaluations used at most institutions. We added the following three questions into the middle of this evaluation:

1. Describe one or two important concepts or principles you learned, or deepened your understanding of, during this course.
2. What was the most difficult or tricky aspect of these concepts to learn?
3. Imagine that you are teaching this concept or principle to a friend. What would you do to help them with the difficult or tricky part?

Each question was open-ended with a textbox available for typing the response. A total of 294 students gave responses to at least one of these three questions.

A grounded analysis of raw responses was conducted to devise response categories for further thematic collation. This approach yields analytic categories that derive from, and hence closely reflect, the thoughts and experiences as expressed by the participants in the study (Denzin and Lincoln 2005, Evans 2002). Categories for each of the open format questions were created in the following way:

1. Each student's response to the question being categorised was read by one researcher.
2. Based on this initial reading of the students' responses, the researcher created preliminary categories to reflect thematically similar clusters of responses.
3. The researcher then read each response again and placed it into one of the preliminary categories.
4. At this point it became evident from the students' responses that some categories needed to be broken down into two separate categories and so that was completed.
5. It was also apparent that a small number of students made responses that did not fit into any of the previously created categories. If a number of these students' responses were similar a new category was formed. If the student's response was dissimilar to others it was placed in the 'other' category.
6. This procedure was conducted for questions 1, 2 and 3 for both the students' survey and the same survey administered to the 10 PASS leaders.
7. For the student data, the number and percentage of students whose response made up each category for each question can be seen in the sections under each question heading.
8. Throughout this process, the analytic categories being developed were presented, discussed with reference to the raw data, and vetted by the research team (authors).

The percentages of each category may not add up to 100 for each question due to the fact that on a number of occasions, one student's response could be placed in more than one category. As the PASS leader cohort was very small, the responses were categorised using the grounded approach described above and clustered according to thematic similarity of responses. This provided two data sets for comparison, which we anticipated may vary: i) the students' responses to the survey; and ii) the PASS leader's responses to the survey.

Lastly, we also conducted a correspondence analysis (Everitt and Dunn 1991) of students' responses. This analysis was based on the more frequently occurring categories from each question.

The study generated an array of data captured within tables, descriptions of categories with examples, and graphs to illustrate responses. Word limitations preclude the inclusion of these in this paper, but they can be obtained from the authors. The following section provides a summary of significant results.

Results (1) – What did the students think?

Question 1

The first question asked students to name one or two important concepts which they had learned or had deepened their understanding of during the course. The majority of students responses centred around specific statistical techniques. More specifically, confidence intervals (27.6%), the concept of significance testing (p values) (20.5%), hypothesis testing (14.8%) and analysis of variance (19.5%) were the statistical techniques which the students mentioned most often. A category which was not related to the specific techniques, 'Articles' (7.1%) was made up of responses which described how the understanding of statistics had assisted students in their interpretation of scientific articles. The category, 'Tests' (4.0%) included responses that discussed knowing which test to use with different data sets.

Question 2

Question two of the student survey asked students what aspect of the concepts they found most difficult to learn. As was the case with question 1, the majority of students named a particular statistical technique which they had difficulty with. Almost half of the students' responses (45.1%) mentioned at least one technique. There were two other major categories which a number of students talked about: these were 'Maths/Formulas' (12.5%) and 'Tests' (11.8%). The Tests category referred to the same ideas as were mentioned in question 1 (i.e. students found it difficult to know which test they should use with different data sets). The ‘Maths/Formula’ category referred to students who had difficulty understanding or completing the formulas and calculations associated with statistical techniques.

Question 3

The last question which students were asked referred to what they would do if they were to teach the difficult concept to a friend. Two major categories were evident from the students’ responses; these were ‘Examples’ (24.2%) and ‘Explanation’ (23.6%). In the ‘Examples’ category students mentioned giving their friend a number of examples to help them understand the concepts. In contrast, in the ‘Explanation’ category students discussed the need to provide their friend with clear, precise and simple explanations. Two other categories that received a number of responses from students were: ‘Practice’ (8.8%) and ‘Text/Web/Lectures’ (8.1%). The ‘Practice’ category included responses that mentioned telling their friend to do lots of practice. The ‘Text/Web/Lectures’ category centred around instructing their friend to either read the textbook, look at specific websites or make sure they go to the lectures.

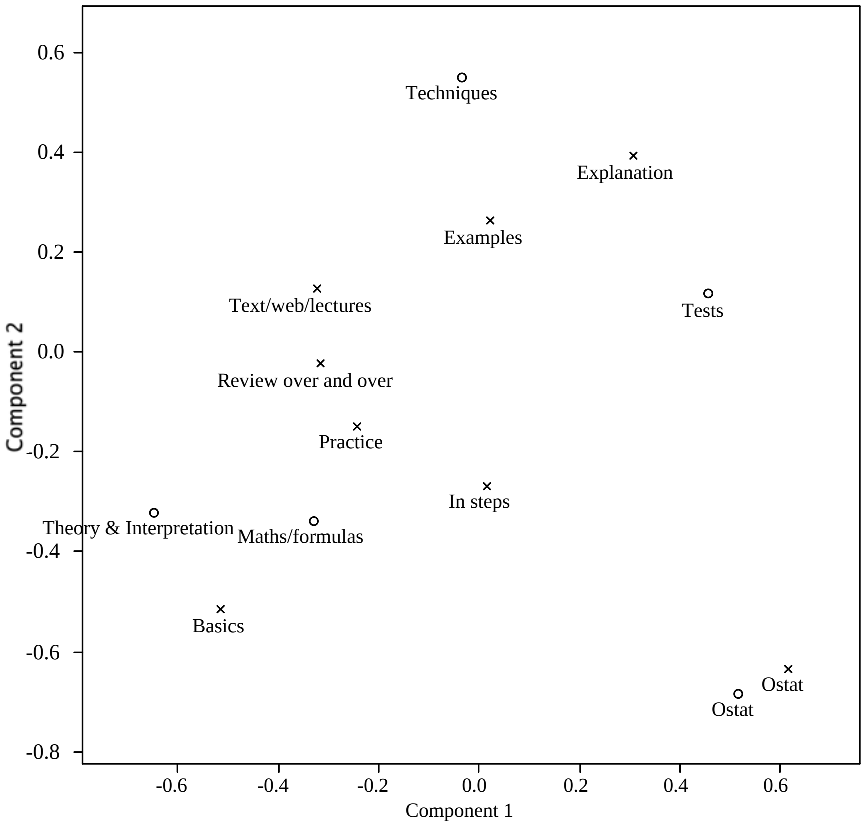

Figure 1. Correspondence plot for Questions 2 and 3

Figure 1 shows a plot of the first two components from a correspondence analysis (Everitt and Dunn, 1991) of concept (‘o’; Question 2 category) and teaching approach (‘x’; Question 3 category). This analysis was based on the more frequently occurring categories from each question. Although some of the categories are still based on small numbers of observations, the overall picture here is interesting. For example, the ‘Ostat’ teaching approach is placed close to the ‘Ostat’ concept. The more theoretical concepts (‘Theory & Interpretation’ and ‘Maths/formulas’) are surrounded by teaching approaches with a focus on ‘Basics’, ‘In Steps’, and ‘Practice’. The more applied concepts (‘Techniques’ and ‘Tests’) are nearby teaching approaches based on ‘Explanation’ and ‘Examples’. The ‘Review over and over’ category arose from students using those exact words in their responses.

To simplify the categories it was noted that this was actually similar to the 'Practice' category and indeed these two concepts appear close to each other in Figure 1.

Results (2) – What did the PASS leaders think?

The questions that the PASS leaders were asked were designed to be similar to the student questions, however they differed slightly in that they were asked from the PASS leaders' perspective. Question one asked the PASS leaders what important concepts they had learned when they did the introductory statistics course. For some PASS leaders, it may have been a number of years since they completed the course. Question two asked PASS leaders not what they found difficult when they did the course but what their students had found difficult. Lastly, question three referred to what PASS leaders did in their sessions with the students to help them with the difficult parts of the course. The PASS leaders responses covered the same categories which the students mentioned for each of the three questions. The following are quotes taken from the PASS leaders responses which correspond to the aforementioned students' responses.

Question 1

Significance testing – 'Understanding what is required for something to be statistically significant and what statistical values actually mean.' (Response #9)

Articles – 'Definitely helped with understanding the results in journal articles! Before, reading those numbers meant nothing, now it is actually applicable and understandable.' (Response #4)

Tests – 'I learned many important concepts and one important basic concept was that there are different statistics tests suited for different types of data. It is important to select the appropriate test when it comes to analysing data.' (Response #3)

Question 2

Technique – 'T-tests, ANOVA etc. where a P value is obtained. It seems a little unclear in the textbook as to what the P-value actually means.' (Response #2)

Maths/Formulas – 'I find that most people just seem to find the lectures so heavy and the maths a little overwhelming. I know this is a vital part of the course, but for some I think it's just a little difficult and they find that once they learn the practical skills that the course is not as difficult as they first assumed. I'm not brilliant at the maths myself so this is where I focus.' (Response #1)

Tests – 'Some of the students struggled to know what all the different tests were and what their purpose was. They knew about the t distribution and attempted to use that for every question possible. They couldn't understand why it failed for a question that required them to use a binomial distribution.' (Response #3)

Question 3

This question was worded slightly differently to the survey administered to students. Instead of asking what they would do to teach a difficult concept to a friend, the PASS leaders were asked to describe they actually ***did*** do when trying to teach the concept to their students. The following are examples of the responses to this question provided by PASS leaders.

Examples **–** 'I mostly work through examples, particularly the ones you provide on the web and some of the ones in the textbook, step by step. I remember from when I did maths you'd just not comprehend one step, then you would be lost. I guess pass [sic] is good because you can sit down, identify the step where they don't understand, and rework through it...' (Response #1)

Explanation **–** 'Talk them through it – doesn't usually take them very long to understand.' (Response #6)

Practice **–** 'Practice with Normal distribution problems until they understand how to do them.' (Response #7)

Text/Web/Lectures **–** This category was not directly addressed by any of the PASS leaders.

What could have been done…? **–** One PASS leader not only discussed what they did but also what they thought they could have done to assist their students: 'We helped the students to understand these different distributions by highlighting what information they needed to use the distribution. We also worked through various examples with them, examples that showed where only one particular distribution could be used. On one question in particular, we let them attempt to use alternative distributions only for them to discover that it didn't work. By doing this we got them to reflect on why their choice did not suit the data supplied. What we didn't do, which would have been helpful, was as a class, write a summary about each distribution and when to use them.' (Response #3)

Discussion

As the results in the preceding sections illustrate, there is close alignment between the students' responses and those of the PASS leaders, across each of the three questions.

Question 1 asked both cohorts to nominate and describe the concepts or principles they considered important, or to have deepened their understanding of statistics during the course. Both cohorts nominated specific statistical techniques (such as confidence intervals, p values, hypothesis testing and analysis of variance), all of which could be considered to be conceptually difficult aspects of statistics at the introductory level. This is particularly encouraging from the lecturer's point of view, since each of these techniques could themselves be considered 'threshold' in nature, and transformative for students' learning.

Further alignment is revealed in Question 2, which asks both cohorts to nominate the most difficult or tricky aspect of these concepts for learning. Here the responses appear focused on *techniques*, but with specific reference to a particular kind troublesomeness that students grapple with, and that PASS leaders are aware of. In this small sample the main difficulty was in knowing *how or when to apply* the tests or formulas students had learned. This issue appears to stem from learning that is confounded by ritual knowledge, which Perkins describes in terms of '*the routine that we execute to get a particular result*' (2006, p37). So while the students do not find the underlying mathematics knowledge to be challenging or particularly 'threshold' in nature, the conceptually difficult bridge to traverse appears to be in the selection and application of statistical techniques within relevant contexts.

Lastly, in considering how best to assist their peers or future introductory statistics students in learning these concepts, the student-nominated approaches provided an interesting clue for teaching and feedback patterns. This observation is drawn from the correspondence analysis, which illustrates that students felt that difficulties with theoretical concepts were best supported with a focus on basics, small steps and opportunities for practice. In contrast, the students noted that teaching was based on explanations and the provision of clear, concise examples were the best ways to support the learning of applied concepts.

The PASS leaders also valued the use of practice and teaching of small steps for theoretical concepts, and used examples and explanations to support applied concepts.

Implications

This simple study prompted much pedagogical reflection. In the first instance, the findings are immensely valuable to future iterations of the introductory statistics course, providing an empirical basis from which to anchor further course design and feedback approaches to better support student learning, and will inform the training of our next cohort of PASS leaders.

Beyond this iteration, we feel there is much value in undertaking a 'tricky concepts' and 'troublesome knowledge' focus as part of a holistic action research framework within this and any other course for three significant reasons.

First, the framing of this evaluation brought the nature of what must be learned, and what may be difficult or challenging about this for our students, clearly into view. Like others, we feel this is an essential basis from which to plan curriculum and teaching in ways that directly support learning (Land, Cousin, Meyer and Davies 2006). We have found this activity to be a valuable impetus for reflection and discussion. As one study of university teachers' pedagogical knowledge indicates, many academics have limited understandings about the nature of difficulties their students face in learning challenging concepts (O'Brien in press). This study offers a simple method that seems transferable into most disciplinary contexts.

Second, as we reflected upon the data and the outcomes, we decided that implementing the survey earlier in a course would be a useful way to engage students in reflection on their own learning, perhaps even signalling areas in need of consolidation or further revision.

Finally, the design of this study could be used as a basis for further professional development of teaching staff (e.g. PASS leaders, tutors and lecturers). The kinds of challenges that students experience in learning are variable and highly contextual. Generalised approaches to effective teaching don't directly address the conceptual, procedural or epistemological impediments students can find themselves grappling with. Because the method within this study engages teachers in the investigation of the kinds of difficulties students within specific course or disciplinary contexts are facing, teaching, feedback and assessment can be modified accordingly; and student learning will be more directly supported.

References

Davies, P. (2006) Threshold concepts: how can we recognise them? In J.H.F. Meyer and R. Land (Eds) (2006) *Overcoming barriers to student understanding. Threshold concepts and troublesome knowledge.* London: Routledge.

Denzin, N.K. and Lincoln, Y.S (2003) *Collecting and interpreting qualitative materials.* Thousand Oaks, California: SAGE.

Entwistle, N. (2005) Learning outcomes and ways of thinking across contrasting disciplines and settings in higher education. *The Curriculum Journal*, **16**(1), 67–82.

Evans, L. (2002) *Reflective Practice in Educational Research.* London: Continuum.

Everitt, B.S. and Dunn, G. (1991) *Applied Multivariate Data Analysis*. London: Edward Arnold.

Land, R., Cousin, G., Meyer, J.H.F., and Davies, P. (2006) Implications of threshold concepts for course design and evaluation. In Meyer, Jan. H. F. and Land, R. (Eds). (2006) *Overcoming barriers to student understanding. Threshold concepts and troublesome knowledge.* London: Routledge.

Meyer, J.H.F. and Land, R. (2005) Threshold concepts and troublesome knowledge: epistemological considerations and a conceptual framework for teaching and learning. *Higher Education*, **49**, 373–388.

Meyer, J.H.F. and Land, R. (Eds) (2006) *Overcoming barriers to student understanding. Threshold concepts and troublesome knowledge.* London: Routledge.

Meyer, J.H.F. and Land, R. (2006) Threshold concepts and troublesome knowledge: issues of liminality. In J.H.F. Meyer and R. Land (Eds) *Overcoming barriers to student understanding. Threshold concepts and troublesome knowledge.* London: Routledge.

O'Brien, M. (in press) Threshold concepts for university teaching and learning: troublesome knowledge and points of liminality. In J.H.F. Meyer and R. Land (Eds) *Threshold concepts in the disciplines.*

Perkins, D. (2006) Constructivism and troublesome knowledge. In J.H.F. Meyer and R. Land (Eds) (2006) *Overcoming barriers to student understanding. Threshold concepts and troublesome knowledge.* London: Routledge.