Profoundity in the obvious and simple, in teaching statistics at tertiary level

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Abstract

Learning to teach and to assess statistics in tertiary level courses is an iterative process. The new tertiary teacher has knowledge of the content to be handled in courses, especially introductory courses, and associated confidence in material. The challenge lies in the major purpose of teaching, namely that the students learn. The students are the principal agents of a course. The teacher orchestrates and serves their endeavours. Students are generally diverse in cultural background, motivation, academic orientation, learning sophistication and stages of emotional maturity. They may have home or first languages other than the language of the tertiary classroom. The levels of mathematical fluency they bring to the first year Statistics course will vary from brilliant to absent. Students will also vary in previous access to and prior experience of technology that enhances the learning environment. The tertiary teacher must respond creatively to this initial diversity and to its various ongoing manifestations in the progress of learning.
The teacher has to assess learning and self-assess the teaching. She must empower the students to adopt similar critical processes by which they can assume responsibility for their own levels of engagement with statistics. Some strategies will be presented, and some examples of threshold concepts and scaffolding. Their key roles in teacher practice and reflection, and in learning development and assessment, are discussed.

Keywords: motivation, conceptual field, threshold concepts, scaffolding, assessment

1. Context

This paper envisages the predicament of the new teacher of an introductory course in statistics. It seeks to address the whole learning environment and the complete challenge into which this teacher is inserted. We make various assumptions that modify the understanding of what is appropriate and useful and important in teaching of year one courses. These assumptions will cover curriculum elements and structure, the diversity of course participants, and ways in which the goals of developing learning and competence are monitored by the teacher.

The rationale for this approach is the belief that a competent practitioner of statistics can emerge as an outstanding teacher by orchestrating an array of strategies to suit and extend her or his various interactions with students. We acknowledge that some of these strategies may appear to be indirect, but we hope to argue their pertinence.

The motivation for the paper is the belief that new teachers need to be fully supported in the enormous challenge that confronts them, if we are to assure that they have a fair chance to achieve excellence and be recognized for that achievement.

2. The teacher

The new teacher is likely to be a newly appointed academic, have recently completed a PhD in statistics and have a personal research agenda, in Statistics or in Statistics education. S/he has been appointed by a Statistics Department that may have both a theoretical stream of courses leading to higher degrees, and an applied stream leading to workplace competences. Teaching is a constrained part of the working day.

We presume that the new teacher will usually be taking over a role in a course that already has a history. The fixed nature of the curriculum structure may have consequences and the new teacher will need to be alert its strengths and the weaknesses.

While processes that make our teaching accountable to both our institutions and our clients, the teacher serves her or his self-interest far better by avoiding a narrow focus for teaching. It is possible that the new teacher is strait-jacketed by narrow expectations. Departments have a responsibility to empower the teacher, in particular by encouraging and valuing planned and considered experimentation as part of an innovative approach.

3. The student

At the beginning of an introductory course, the students may know nothing or very little of the intended curriculum, other than a formal list of topic names, in a course outline. The whole purpose of teaching is that the students learn. All else is subsidiary. All students, whatever their motivation, must progress to competences or proficiency in the material and the tasks of the course.

One useful view partitions motivation around three poles, taken as distinct for simplicity: extrinsic to the person (e.g. meeting an imposed requirement of a curriculum or degree), instrumental (e.g. attaining an achievement that will support a personally meaningful objective) and intrinsic (e.g. seeking within a course to resolve meaningful questions and explore associations by mastering and using the knowledge and skills a course promises).

These motivational levels are substantially associated with the frequencies of surface, strategic and deep levels of engagement and enquiry in the learning process, and hence associated with course performance outcomes, and the attainment of proficiencies.

We argue that it is useful for the teacher early in the course, to open up the matter of motivation so that students can explicitly address their initial orientations to the course. The teacher may achieve this objective in both direct and indirect ways.

Direct approaches might request students to diagnose or identify their initial or current motivation for the course, and to consider ways by which they choose that motivation. Indirect approaches include the display by the teacher of authentic enthusiasm for the challenge, usefulness and advantages that arise from mastery of the curriculum.

The pertinence of the teacher addressing motivation in some way is a consequence of the claims that it is the whole person who learns or fails to learn, that the person is the fundamental agent of her or his own learning, and that learning involves a deliberative focus and effort which the person must summon from within. The more intensely personally relevant the motivation applicable to the course, the easier we expect it to be for the student to bring their cognitive processes to bear upon the material and tasks.

Thus we infer that the student who has articulated and taken inner control of the level of motivation and learning applied to the material, is in a better position to benefit from the teacher's efforts to ensure that material and its associated skills are cognitively accessible.

This conscious addressing of student motivation is an investment into a holistic teaching effort, whose final purpose is both student learning and its vindication by assessment. It is justified on the basis that it seeks reduction or removal of impediments to learning.

4. Cognitive dilemmas

We concede that insight may arise from or involve cognitive processes that are distinct from languages, or do not require language. The recognition of pattern by the senses may address features that the perceiving mind does not initially necessarily express in words. However we argue that the ability to describe explicitly in words is a tool for developing, harnessing, exhibiting and communicating an understanding.

Any well-designed applied or theoretical first course in statistics will have contents that necessarily involve language challenges. We shortly exhibit several problematic words and concepts. The new teacher may usefully formulate his or her own list, before offering the first learning session, lecture, or activity.

The teacher of statistics will do well to convince students of the efficacy and the necessity to articulate precisely in spoken language, their current versions of understandings and dilemmas. Students must make the essential distinction between following a sequence of steps in an argument as the evidence of existence of a pathway to a conclusion, and the quite different process of being able to re-enact that sequence of steps, in language.

The achievement of language and fluency by the student involves an iterative process of current attempt, internal critique, diagnosis of inadequacies, and revised verbal attempt. This process of diagnosis and revision becomes more efficient if the student is made comfortable about speaking out loud to herself or himself while engaging course material. Hearing is harnessed as a tool for identifying pauses and um's and ah's associated with as yet unarticulated steps to fluent comprehension and report.

We claim these considerations apply to first language users of the medium of instruction. In some contexts there may be large numbers of students who have home or first languages other than the language of the tertiary classroom.

For these students any multiplicity of meanings for an English word used in a special sense in statistics (such as random, occurrence, certain, and others discussed below) will generally cause greater impediments to progress than for first language speakers.

5. Concepts and constructs

Learning involves the acquisition of concepts and relationships between concepts, together with modes of use of concepts and relationships. In the mathematical sciences these elements can be presented in a definitional form. In some circumstances such definitions may be sufficient to engender learning, but usual processes are more complex.

Vergnaud (1998) suggests that problem-solving is a universal medium for concept acquisition in mathematics. Invariably a problem will involve more than one concept and possibly more than one relationship between such concepts. Conversely, any concept or relationship will be involved with whole sets of problems, apparently of distinct kinds. He argues that in these many-to-many relationships, incomplete acquisition of concepts occurs, and that students continuously form and revise what he calls concepts-in-action and theorems-in-action as they address problem contexts. Gradually, better and better approximations to tight underlying mathematical structures emerge.

Astute selection of problems by a teacher enables subsets of students to engage with problems that match their current zones of proximal development (Vygotsky, 1978). Such matching is predicated upon teacher observation or use of test outcomes.

For the discipline of mathematics, Vergnaud (2009) envisages that natural clusters of concepts and relationships, which he labels conceptual fields. His exemplars include additive (number), multiplicative (number), algebraic and geometric conceptual fields. In effect we claim Statistics too has a pre-existing structure, a stochastic conceptual field, related to conceptual fields of Mathematics. It pre-exists any construction.

Like Mathematics, Statistics has analogues within the real world as we experience it. Thus we expect, in parallel with Vergnaud's insights into the teaching of mathematics, that the role of problem-solving will be vindicated as an iterative pathway to acquisition of the concepts, relationships and tools that constitute the stochastic conceptual field.

It is the challenge of the gifted teacher to recognize a teachable moment, and to harness that recognition by reconstructing the elements of such moments within the repertoire of exposures planned for the students. This strategy is a scaffolding for key ideas.

The notion of the teachable moment is complemented by the idea of a threshold concept. Meyer and Land (2005) argue that all disciplines may be characterised by a set of core concepts. They reserve the term threshold for troublesome concepts that are initially very difficult, but once mastered are retained irreversibly, perhaps because they open up transformed thinking or a shift of perspective within subsequent material.

The new teacher does well to identify such concepts and to develop ways of exposing students to situations and contexts seem likely to create the a-ha experience.

6. Assessment

Student proficiency will presumably be tested and then attested by the course assessment processes. Usually these assessment processes set a highest contributing summative value on the final examination of a course, though perhaps incorporating interim formative assessments and project outcomes, to some degree.

The new teacher is likely to have to marshal evidence of teacher efficacy, to contribute to any annual review moments and processes within a Statistics department. Demonstration of teaching efficacy will include having to account for the profile of student performance outcome in the course.

The first issue to be addressed is what goes into any assessment instrument. The implemented curriculum up to a testing moment can be specified, and material selected for items. Coverage and balance of material may be easier objectives to achieve, than selection of the concepts and skills that really matter most and also track progress.

Within the variety of curricula in first courses in statistics there are some well-agreed sets of troublesome or threshold concepts. It is arguable that item material for formative or summative tests should focus upon the salient sets for the current teaching purpose.

The concepts whose penetrability should not be assumed, include: random, representative, sample, possible, probable, outcome, event, occurrence, certain, population, statistics, parameters, distribution, frequency, order, expectation, variance, significant, association, contingency, correlation, confidence, hypothesis, test, odds, odds ratio, and experiment. Some basic notions of cause and effect belong in every first course of statistics. Their inclusion is necessary because common confusions about their meanings lead to widespread nonsense inferences, allegedly based upon data.

These less penetrable elements will have had the new teacher's special attention in interactions with the class. If the associated marking memo is to serve as a teaching device, it needs to demonstrate which understandings were most valued by the teacher, and that message needs to be clear to the student using the memo.

Implicitly any test is targeted for a particular cohort of students. Each test has to be fit for the purpose intended, which is to assess proficiency and to eliminate or suppress any effects on scores from sources other than the proficiency itself. Inter alia, this objective requires attention to the language and the construction of the instrument, including the possible provision of hints, formulae or other resources.

This view of the whole test suggests that coherent expectations of a sound instrument include that each item contributes systematically to an overall differentiation of students on the basis of the total score. It is our intention that total score is a sufficient statistic for student proficiency. It is therefore important that the extent to that intention is realized by the item composition of our test instrument is subsequently explored in data analysis.

All such findings can be orchestrated into subsequent test design and construction. We need to support the new teacher in a journey towards insights and practices that bring us to coherent, appropriate and reliable assessment of differences in proficiency.

Multiple-choice questions (MCQs) can make marking and test feedback in large classes more efficient. The challenge with a good multiple-choice item is that the so-called distractor options for which no credit is given cannot be arbitrary. Ideally they should represent either a common misconception the student is expected to avoid, or be drawn from a sequence of emerging but incomplete mastery of the item content.

Well-structured MCQ items permit evidence for diagnostic insights into student progress. It is merely a convention that items have the same number of options per item. An item for which no plausible alternatives to the correct choice is either inane or has no real value in differentiating levels of student knowledge.

Assessed projects, tests and examination may readily serve as norm-referenced modes for distinguishing between students within a course, on the basis of an implied ordination of proficiency, in marks and grades. There may well be a need for criterion-referenced distinctions about which of the student performances meet external quality specifications of some kind, and which do not meet them.

Accountability of teachers and accreditation of student progress require pertinent, valid and reliable instruments or processes of evaluating student performance and distinguishing between various ordinal classes of achievement. New challenges arise in ensuring that instruments focus upon and distinguish between levels of performance on the basis of the course material *per se*, and substantially unconfounded with features of the context that are incidental to the main purpose of the course and its curriculum.

The continuity of learning throughout any course requires the teacher's ongoing processes of formal and informal assessment to be sensitive to the broad spectrum of understandings and misunderstandings that emerge and change in the class. This requirement of sensitivity has to be grounded in an appreciation of the discontinuities in student learning that occur in consequence of incorrect or incomplete mastery of concepts and of the perceived relationships between concepts.

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