Statistics teaching in the light of statistics anxiety, anti-statistics attitudes and university drop-out rates of psychology undergraduates. Cole Davis. 2018.

Research overview

A substantive proportion of first year psychology undergraduates drop out; those who do almost invariably cite as the reason the statistical element of their courses (personal communication with the author, 2018). It is axiomatic that statistics be taught in psychology, at least on BSc courses and/or those courses which are accredited by the British Psychological Society. Statistics are integral to such courses not merely because psychology is the wellspring of much statistical invention, practice and lore, but because of a commitment to the evaluation of evidence as part of a scientific attitude to the discipline. Undergraduate sociologists and criminologists also learn statistics, at least in Canada and the USA (market research by the author, 2018).

As many behavioral and social scientists no doubt enter academia without expecting to learn statistics, the commitment to statistical testing is likely to unnerve some. It is no surprise that along with attitudes toward statistics as a discipline, failure in statistics courses over the last few decades has been ascribed to statistics anxiety. That this is neither purely a western concern nor restricted to psychology is made explicit in Khavenson *et al* (2012) who adapt western instruments for measuring statistics anxiety to a Russian context, with a sample of political science, psychology and sociology students.

The presenting problem is frequently considered to be statistics anxiety.

"Statistics anxiety is believed to be a multi-dimensional construct, comprised of six types of anxiety: worth of statistics, interpretation anxiety, test and class anxiety, computation self-concept, fear of asking for help, and fear of statistics teachers .. " Williams (2013).

Williams detects a relationship between intolerance of uncertainty and worry; worry was related to three types of statistics anxiety (interpretation anxiety, computation self-concept, and test/class anxiety). Baloglu *et al* (2017) take a similar approach to the problem of statistics anxiety, relating a variety of symptoms such as computational self-concept, classroom and test anxiety, and fear of the statistics instructor to constructs such as task value and self-efficacy. The latter concept is particularly pinpointed by Schneider (2015) as being negatively related with statistics anxiety.

These studies have in common a seeking out of relationships between statistics anxiety and students' prior and current attitudes and personal qualities. Macher *et al* (2015) are critical of a failure by some researchers to distinguish between statistics anxiety and factors such as attitudes to statistics and academic self-concept. Chew and Dillon (2015) refer to statistics anxiety and attitudes toward statistics as related but distinct concepts.

Another problem is the relationship between statistics anxiety and academic performance in statistics. In an experiment exploring the potential of instructor immediacy to reduce statistical anxiety, Williams (2010) finds that statistics anxiety is reduced in the form of affective learning, roughly speaking the emotional side of learning, but that this is not reflected in cognitive learning, as reflected in actual performance. Similar findings are found in other studies cited by Williams and in a later study by Hanna and Dempsey (2012), who are critical of the effects of statistical anxiety on performance as opposed to students' "perceptions of their competence".

Two studies which do provide evidence of a link between statistics anxiety and academic performance indicate a curvilinear relationship (Keeley *et al* 2008; Macher *et al* 2015). The earlier of the two studies makes mention of the Yerkes-Dodson effect: a great deal of stress has a debilitating effect on sports performance, but a complete lack of 'nerves' also leads to suboptimal performances. Mixing the metaphors, a modicum of 'match nerves' when it comes to topics such as interpretation of statistical tables may be no bad thing. This being the case, it is possible to criticise the idea that statistics anxiety is in itself the major villain of the piece.

It is also possible that the curvilinear relationship in the form described above does not in fact exist. The two bemusing ends of the spectrum could pertain to peculiar categories of individuals confounding the results. The over-stressed but not necessarily under-performing tail could be explained by a mixture of types of person – the initially over-stressed who lose their inhibitions when performing, or become familiar with the material or succumb to teacher wiles such as the use of immediacy techniques (Williams 2010) or humour, or perhaps are the individuals who typically annoy fellow students by making unlikely claims of poor performance in examinations. At the other end, perhaps low anxiety and under-performance could be the incompetence of the flippant.

Also potentially confounding, and more directly related to the literature, could be the existence of anti-statistics attitudes. While some of those who believe that 'therapies cannot be measured' could produce a self-perpetuating concept of statistics as unpleasant, perhaps developing a preternatural anxiety, others with a thoroughly dismissive attitude toward the subject could adopt an overly carefree attitude to a subject they see as unworthy of effort.

One study, contrary to hypothesised expectations, found that attitudes to statistics were the only direct influence on performance (Sesé *et al* 2015). The SEM model, when the cause of negative attitudes are considered, did find that attitudes mediated anxiety in a negative way, as did mathematical background. The latter relationship could pertain to a rather mathematically oriented syllabus, but this is not immediately in evidence from a (Google) translation of the syllabus from Spanish. It should be noted that, as is the case with some previously cited studies, a lack of longitudinal analysis renders the results somewhat tentative.

Statistics anxiety *per se* has been the subject of various practical approaches to overcoming its effects. Instructor immediacy, essentially a range of techniques to decrease distance from students and to increase warmth, has a substantive effect in reducing aspects of statistical anxiety, although there is generally a paucity of evidence of its effect on actual performance (Williams 2010). This also appears to be the case with that much bruited ameliorating factor, humour; see for example, Neumann *et al* (2017). One approach, the one-minute paper (Steadman 2005), a form of student post-class evaluation, was extended to the teaching of statistics by Chiou *et al* (2014), who reported both a reduction of statistics anxiety and an improvement in learning achievement. Ruggieri (2017), however, considers these results to be superficial, producing a marginal increase in grades.

Ruggieri writes disparagingly of a welter of 'bags of tricks'. "No first day activity, no single joke, no vivid anecdote is likely to address all issues faced in ensuring statistical literacy is gained by the greatest number of students." And yet he implicitly agrees with Chiou *et al* that practical solutions should be sought.

He recommends a fundamental rethink of statistics education. I cite in particular the first of Ruggieri's nine points: Statistical understanding ahead of the calculations; he cites in particular 'language, meaning and importance'. The concern about language is mirrored in Malik (2015), with its processing being a cause of feelings of inadequacy, problems in class and in tests and even physiological symptoms. Open notes and formulae sheets were the solutions offered.

Related potential problems are touched upon by Williams (2010). One particularly interesting point is not so much the obvious, that the teaching of statistics as mathematics may be problematic, but that statistics actually requires a form of logical thinking. Williams cites Zerbolio (1999) as explaining that "statistics is more closely related to verbal reasoning than it is to mathematical reasoning, and suggests that logical reasoning skills are utilized more than are mathematical skills in solving statistical problems." Interestingly, Williams cites the logical decision-making inherent in inferential statistics as intimidating even those students who are inclined to view statistics from a mathematical perspective; she cites a phenomenological study by Onwuegbuzie *et al* (1997): “I've never been frightened of math. In fact, I received an A in my last math class. Yet I am terrified of statistics.”

While some mathematicians and engineers may feel that statistical concepts are 'best expressed' through formulae (various personal communications with the author over the years), it seems that formulae are at best a distraction to the average social scientist trying to interpret statistical tables which represent the results of his or her quest for understanding. Those who advocate the use of formulae may do so as a replication of their own education in statistics or because they see formulae as representing 'deeper learning' (Popejoy 2015), as respect for tradition or a desire to retain respectability for the social and behavioral sciences in the face of mathematical orthodoxy.

Ruggieri's (2017) recommendations on how to teach statistics are reproduced here in précis form:

1. Statistical understanding ahead of the calculations... 'language, meaning and importance'.
2. Constant use of examples.
3. Balance formulae and decision-making.
4. Don't start with the calculator or software package.
5. Be engaging but not just with humour; 'laughter, tears or personal experience'
6. Statistics as a *tool.*
7. Don't design changes just to help 'strugglers'; implement for all.
8. "Focus on critical thinking instead of covering new chapters. Teach 'The New Statistics' .. before jumping to Bayesian cognitive modelling.. no matter how much the latter will be more likely to draw a keynote invitation…Wait til they've got the fundamentals. .. just because we don't teach it doesn't mean they won't learn it."
9. " Do not focus merely on teaching how to generate results. Teach how to identify patterns, infer from partial information, interpret ethically, and to illuminate insights."

Popejoy (2015) reported very favourable feedback for an adapted curriculum for graduates who are unlikely to become researchers or doctoral students. Similar recommendations are made by Forte (1995) for social work students.

There is a tradition, however, of statisticians who take a more fundamental view of the discipline.

> " Statisticians are convinced that statistics, while a mathematical science, is not a subfield of mathematics. Like economics and physics, it makes heavy use of mathematics, yet has its own territory to explore and its own core concepts to guide the exploration. Given those convictions, we would naturally prefer that beginning statistics be taught *as statistics*. " Cobb and Moore (1997).

Briggs (2013) considers mathematics to be one way, not necessarily the best one, of understanding statistics. And he does not see statistics as a branch of mathematics.

> " Statistics rightly belongs to epistemology, the philosophy of how we know what we know. Probability and statistics can even be called quantitative epistemology."

Even if it is agreed that formulae should play little or no part in the teaching of statistics, the evidence for which teaching methods are effective is fragmented in terms of statistics anxiety, attitudes toward statistics and learning performance. It should be noted that relevance to the students' main academic interest does seem to be agreed upon by most researchers.

Research positioning

It is the contention of the author that mathematical formulae represent the history of inferential statistics rather than its explanation. Some multivariate tests, although invented decades ago, only became practicable in the age of electronic computing; indeed, the centuries-old Bayesian analyses only became feasible as the twentieth century came to a close. That equations are often not physically usable beyond univariate analyses does rather suggest that they may not be completely relevant.

Another example of statistics being ruled by its history is terminology. Bonferroni can be corrected or adjusted; survival analysis confuses the true nature of what event duration analysis, or the time before events; criterion values jostle with alpha; and so on.

Paradoxically, statistics is also a fashion victim. The rise of computing makes it likely that students may become overloaded with potential tests before they have absorbed their import. And yet information about what they are doing is lacking; it has certainly been said to the author that students are told to use a default *post hoc* test such as the Bonferroni correction (adjustment) without any discussion of which tests might be used in different circumstances. As suggested by Ruggieri (2017), the internet is awash with controversies relating to Bayesianism and 'frequentism', which may be taken on board before the student is truly ready to make informed decisions.

The author is keen to adopt a pragmatic approach to the teaching of statistics: what works? Part of this requires an abandonment of statistics history, or at least an explanation of the history which promotes clarity in the learning process.

The author suggests a narrower, more radical, guidance list for teaching statistics:

1. Do away with formulae altogether.
2. Avoid complex language (n.b. statistical literature adds to problems by using multiple names for the same concepts – statistics is ruled by its history).
3. Return frequently to the basic logic of statistical concepts.
4. Be explicit about the adoption above three approaches.
5. Use examples judiciously, relevance being at least as important as humour.
6. Advance to Ruggieri's eighth and ninth points in your own time.

Having said that, any new approach may vary in its effects upon statistics anxiety, attitudes to statistics, academic performance and drop-out rates. The author considers it possible that statistics anxiety for many students may be largely rational, a manifestation of the student's lack of understanding of formulae or, even in courses without formulae, in the general belief that they are 'doing mathematics'. Even the anti-statistical stance as a point in principle could in part be a reasonable understanding on the student's part that the formulae are rather tangential to the issues under investigation.

Even if statistics anxiety and mathematical ability do have a role in generating negative attitudes toward statistics, attitudes seem likely to govern performance (Sesé *et al* 2015). Returning to anecdotal evidence, it seems likely that attitudes predominate in psychology undergraduates' failing to thrive. If students really do not see the relevance of statistics or otherwise feel overawed or overloaded by the subject, then there will be little desire to overcome related anxiety.

" People forget what they do not use. But attitudes stick. Positive attitudes keep us using what we have learned. They also encourage us to seek opportunities to learn more. It is for these reasons that students' attitudes are the most important and influential outcome from introductory statistics courses. " Sesé et al (2015)

The author believes that more positive attitudes could do much to reduce statistics anxiety as well as to improve performance. While it is clear that some reductions are likely to occur because of immediacy (Williams 2010) and other traits of gifted and dedicated teachers, this does not seem enough to stem the tide of disaffection with the subject.

Direct 'bolt-on' strategies for countering negative attitudes are available. Propaganda about potential career advantages and the likely enjoyment to be derived from the classes are nothing new and probably do not have a lasting impact. There are potential stratagems of despair, such as the self-screening of course applicants via online videos showing statistics being taught ('the horror, the horror'). However, the elimination of potentially gifted academics and practitioners because of something which – to be fair to those with negative attitudes – is rather secondary to their subject, is not something to be readily countenanced.

'To be fair to those with negative attitudes': this deliberately provocative statement was deployed because negative attitudes toward statistics are not necessarily illogical. The would-be therapist, action researcher and detective may see themselves in no more need of inferential statistics than the author has been of trigonometry throughout a long and varied life. Similarly, students who are ill-equipped with mathematical skills have reason to worry – in a context where they believe that they are essentially learning mathematics.

That statistics is not really mathematics is something that could be established early. Apart from the obvious recipients of such news, those with mathematical backgrounds may benefit from this knowledge (Williams 2010).

Beyond this, it is also possible that demonstrating the logic of statistical decision-making will assist understanding. By 'logic', the author does not mean a grasp of modus ponens, modus tollens and other philosophical concepts, but reference to asking fundamental questions of the research in hand. Ideas such as 'Is this an analysis of difference or an analysis of relationship?', 'Which type of data have we got?' and 'Are we looking at common factors or clusters of cases?', would be worthy of repetition throughout introductory classes. More practical questions such as 'How do we read this type of table?' may be regularly considered in order to reduce interpretation anxiety. The author's books are arranged with such structures in mind; this is a typical response:

" I .. find your style of writing easy to teach and the students don't get lost in arcane trivia about click a radio button to change the font in the graphs and other nonsense. Clear writing that gets the point across to them without me looking back at a class of blank faces. [A] rare quality in a statistics book. " (A personal communication, 2018.)

Returning to such issues regularly and perhaps punctuating lecture formats with exercises for individual students using relevant examples, may do much to keep the student calm as well as making an accumulation of understanding rather more likely. Other important factors are likely to be the format of teaching, such as whether or not the lecture is carried out by 'service classes' or by dedicated teachers; if service classes, are they taught to a single group with relevant examples? and whether or not there are clearly written resources to remind students of how to read a table for, say, multiple regression.

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