STATISTICS EDUCATION THAT INSPIRES LONG-TERM RETENTION OF LEARNING – A QUALITATIVE MODEL

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ABSTRACT

Statistical methods are an indispensable partner in all scientific work and in many other professional and commercial fields. So it is not surprising that statistics is widely studied at university. Yet most students never complete more than a single course in the discipline – and that is usually early in their studies. In this situation especially, it makes sense that teaching should aim at inspiring students to retain their learning for the long term. Here the author presents a comprehensive qualitative model of education designed for this goal. The model translates readily into practice and this is demonstrated by bridging it to a rich set of workable tools that are drawn from related papers by the author.

Keywords: *Qualitative analysis; Modeling the educational process; Principle into practice*

1. INTRODUCTION

Curiosity and enthusiasm are universal in young people but do not always flourish as people grow up. Stimulating youthful curiosity and strengthening youthful enthusiasm are among the ideals of caring teachers and mentors. For an intellectually demanding subject such as statistics, the effort required to maintain students' enthusiasm and build their engagement needs to be continuous across the school and university years. That effort is the midwife of the next generation of statisticians!

Here I am concerned with fruitful ways of teaching to enhance students' engagement with statistics at early undergraduate level. This is the stage of university studies where most students first encounter the technicalities of statistical analysis.

More fortunate students will already have discovered at school that statistics is the field of knowledge which helps us to find meaning in collected real-world data. They will also have had some experience with such searches for meaning, in contexts designed to excite their curiosity and to stimulate their appetite for more. Such experiences, however simple they may be, can be powerful motivators to finding fascination in statistics from an early age.

Less fortunate students will have followed a school curriculum in which the statistics topics were so thoroughly embedded in the study of mathematics that they believe (together with their teachers!) that statistics is simply a branch of mathematics. Consequently, though they may come to find elements of their curriculum exciting, they will not have discovered what it is that sets statistics apart from mathematics, namely a triple focus on data variability, on uncertainty, and on induction (Sowey & Petocz, 2017). Though such students will 'know' that statistics is a branch of mathematics, many will nevertheless sense that school exercises in mathematics and in statistics are 'somehow' essentially different. If this cognitive dissonance remains unresolved it may become, for some, a source of 'statistics anxiety', well-known in the statistics education literature as an obstacle to successful learning.

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Statistics anxiety is only one of several basic obstacles to learning that a committed teacher needs to recognise and respond to. But it is more important, I think, at this entry point to an education in technical statistics to ask 'what should be a committed teacher's *highest* ambitions for student learning?' I suggest these four: to enjoy the experience of learning; not only to learn, but also to understand the subject matter as the course proceeds; to understand how to apply it in practice; and to retain such understanding for the long term. Of these four priorities, the last is the most challenging to bring about. *The teacher alone cannot achieve it, but can inspire it*. I shall focus on paths to this end.

2. WHY TEACH FOR LONG-TERM RETENTION OF LEARNING?

Here is the setting. Most students who graduate with some academic knowledge of statistics have taken only a single course in statistics, commonly completed early in their studies. Since statistical methods are an indispensable partner in all scientific work and in many other professional and commercial fields, it makes sense that teaching in that course should aim at inspiring students to retain their learning beyond the graduation ceremony and into the early years of their employment – that is, for at least five years.

In the scholarly literature of education, by contrast, the expression 'long-term retention of learning' seems to be colloquially interpreted to mean 'extending beyond the semester of instruction for, perhaps, as much as a year'. There is a pragmatic reason for adopting such a relatively short period as the definition of 'long term', as will be clear from the following overview.

The conventional protocol for a statistically-based (and, implicitly, quantitative) experimental study of retention of learning is to give the class a test of what has been learned at the end of the semester of instruction, then to reconvene the student cohort, say, a year later and administer a similar test on the same subject matter. Any statistically significant drop in (average) test scores between the two tests is attributed to loss of learning over the 'long term'. Next, by devising a series of experiments in successive years, each time trialling an alternative teaching and/or learning strategy, it may be possible to arrive at a blend of educational strategies that will give the teacher significance-test-based confidence that the course produces students who still retain (much of) what they have learned *for a year* after they have learned it.

There are (at least) three problems with relying on the results of such a series of experiments to recommend authoritatively to teachers how they should teach. The first is that sequentially experimenting with new strategies can too easily become hostage to a search for ever more impressive statistical significance in a purely exploratory exercise, rather than being a search for what accords best with a model-based conception of teaching to inspire long-term retention. The second is that statistically-based studies of retention will be unreliable if only a part of the student cohort can be reconvened, which is very likely to be what will happen after more than a year has passed. The third is that the strategies which correlate highly with retention of learning for a year are not necessarily those that govern the retention of learning over the five years or more between the first (and, perhaps, only) statistics course and the early years of employment.

In today's world, funding for very long term statistical follow-up studies is routine only for a small category of vital issues related to community health and safety. Here are three examples: studies on the efficacy of new drugs, on the effects of heavy mobile phone use on the brain, and on the documentation of climate change. Unfortunately, statistical studies on the retention of learning in higher education are not in this category!

Specifically in statistics education, there are few empirical studies on retention of university learning. Consider two leading journals. Among all past issues of the *Journal of Statistics Education* there are just two papers on this theme (evaluated over one semester; and over about 20 months); among all past issues of the *Statistics Education Research Journal* there is only one (evaluated over 4 months). And in the extensive bibliography of Sahai, Khurshid, and Misra

(1996) there is none. All these three papers are, in fact, quantitative statistically-based studies. None reaches far into the long term.

If these formal studies, few as they are, offer little guidance on teaching to inspire long-term retention of student learning, what other ways of seeking reliable guidance might there be? One alternative is clear: try a qualitative and less-formalised approach.

Before advancing such an approach, I think it worth citing two kinds of objections I am accustomed to hearing – the first when I promote the value of teaching for long-term retention, and the second when I justify the aptness of a qualitative model of teaching and learning that makes for long-term retention.

The first objection is the 'who-needs-it-when-we-have-the-internet' argument. The gist of this argument is that there are countless sources online where people wanting to brush up their statistical knowledge can find what they need when they need it. There is certainly a kernel of truth in this claim; people who know precisely what they need can be well-served on the web. But those hoping to restore large chunks of forgotten knowledge from a web search will be bewildered – less by the large amount of information retrieved than by the scarcity of online explanations that will make that information intellectually coherent.

The second arises from claims by some researchers that qualitative studies flout scientific standards of controlled experimentation, rigour and generalisability, and so have nothing of worth to offer the scholarly literature. A careful appraisal of such claims by Groth (2010) suggests that the negative conclusion is unjustly dismissive. Petocz & Newbery (2010) make a broad and powerful complementary case for qualitative analysis.

3. ORIGINS OF MY QUALITATIVE MODEL

My qualitative model of the interplay of elements that empower teaching and learning for long-term retention evolved over more than 40 years from around 1970. I was drawn to this theme while teaching statistics and econometrics within the Faculty of Commerce at the University of NSW in Sydney. In the 1970s I saw that about 75% of the approximately 650 first-year undergraduate students who annually completed the mandatory one-year foundation course, Business Statistics, never took another statistics course. Only majors in Economics, Econometrics and Finance were required to take further courses in statistics. By 1990, the mandatory foundation course in statistics had shrunk to one semester and the proportion of students doing no further statistics was close to 80%. Though professional work in Accounting, Marketing, and Industrial Relations regularly calls on field-specific statistical knowledge and skills, the Faculty was graduating beginning practitioners in these fields with little more than a foundation statistics course in their career preparation. Between 1970 and 1990 I read widely on andragogy and reflected on how to help my students retain for the long term much of the statistical knowledge they had acquired in the foundation course. It was over this period that a structure for my model took shape.

Over the next two decades I had purposive informal conversations with many of my former students, both shortly after and long after their graduation. I wanted to understand, in retrospect, how they learned in my classes, whether their experience was different in classes taught by others, and most importantly, what they recalled of the subject matter of statistics they had learned with me. What this feedback revealed I constantly compared with what and how I was teaching, in line with the logic of my evolving model. These experiences naturally brought me new insights and led to many amendments and refinements of the model. After 1990 I began to publish facets of the structure of my model in the scholarly literature. I had two aims:

(i) to explain to my readers how important to long-term retention of student learning is a deep understanding of the teaching processes that populate my model – processes that are rarely explicit in formal statistically-based studies of education; and

(ii) to elicit commentary, whether supportive or critical, from colleagues in the statistics education community.

4. THE MODEL

Let me point out first that my model is not specific to statistics education. Expressed abstractly, the model offers a conspectus *in the broadest terms* over a set of entities and their interactions. As will shortly be clear, these interactions open up options for designing teaching that can inspire students to long-term retention of their learning. The model is relevant to teaching in *any* discipline and for *any* syllabus in that discipline. Moreover, it is adaptable to any configuration of the setting for learning; for instance, it can be effective in traditional class teaching or in the 'flipped' classroom. As well, it fits into settings where teaching is supported by educational technology (for example, in distance education) and also where technology is not a feature.

While the model is highly general in its applicability, my papers relating to it all focus on statistics or econometrics education. Its effectiveness in these areas is attested to by qualitative confirmation accumulated over more than 20 years. The model evolves from a straightforward proposition: in any educational context there are three fundamental entities, *the teacher, the learner,* and *the subject matter*. The educational outcome is essentially determined by the capabilities – or, in the case of the subject matter, the attributes – of these entities and their interactions. Even in a 'self-teaching' setting, the teacher has an implicit presence. It emerges in the content and educational design of whatever learning materials are adopted by the solo student.

A convenient way to elucidate the interactions of the three entities is by displaying them in a concept map. Simply described, a concept map defines a set of elemental concepts and traces out, in graphical form, directed causal connections among them. Schau & Mattern (1997) and Witmer (2016) provide statistical examples of such a map.

My concept map of the entities and their interactions is shown in the lower part of Figure 1. The diagram as a whole depicts my extensive model of the acquisition of a university education. Here is a quick orientation to the content of this map.

- On the far left is the segment of *the learner* as an entity and on the far right is the segment of *the teacher* as an entity.
- In the intervening space several interaction paths are laid out schematically. From left to right, with their colour codings, these segments are: *learner-learner* (pink), *teacher-learner-subject matter* (yellow), *teacher-learner* (green), *teacher-subject matter* (blue), and *teacher-teacher* (mauve).
- The yellow paths actually collapse two interactions into one. The two components are: 'the learner's engagement with the subject matter' and 'the teacher's engagement with *how the learner engages* with the subject matter'.

Note particularly that the wording in each oval and rectangle in Figure 1 describes *what* its (idealised) substance is but not *how* that substance is to be achieved in practice. The 'how' is at a level of finer detail than the map in Figure 1 displays and is most informatively explored one segment at a time. The upper part of the diagram depicts the potential progression of an individual learner from knowing, to understanding, to long-term retention of his/her learning and understanding, and ultimately to wisdom. This depiction should not be taken to suggest that learners will progress equally far, or equally quickly, along this continuum.

Nested within Figure 1, *the yellow segment is a map of my model for teaching to inspire long-term retention of student learning*.

Before focusing in detail on this segment, let us take a short tour of the other segments in Figure 1. The learner segment invites thought on how the learner can best prepare for the study ahead. Ways for learners to overcome obstacles, such as statistics anxiety, confronting them at entry will be among the 'hows' here. The teacher segment invites thought on how the teacher can best mature in his/her professional role. Note the importance of short- and long-term feedback from learners in this process.

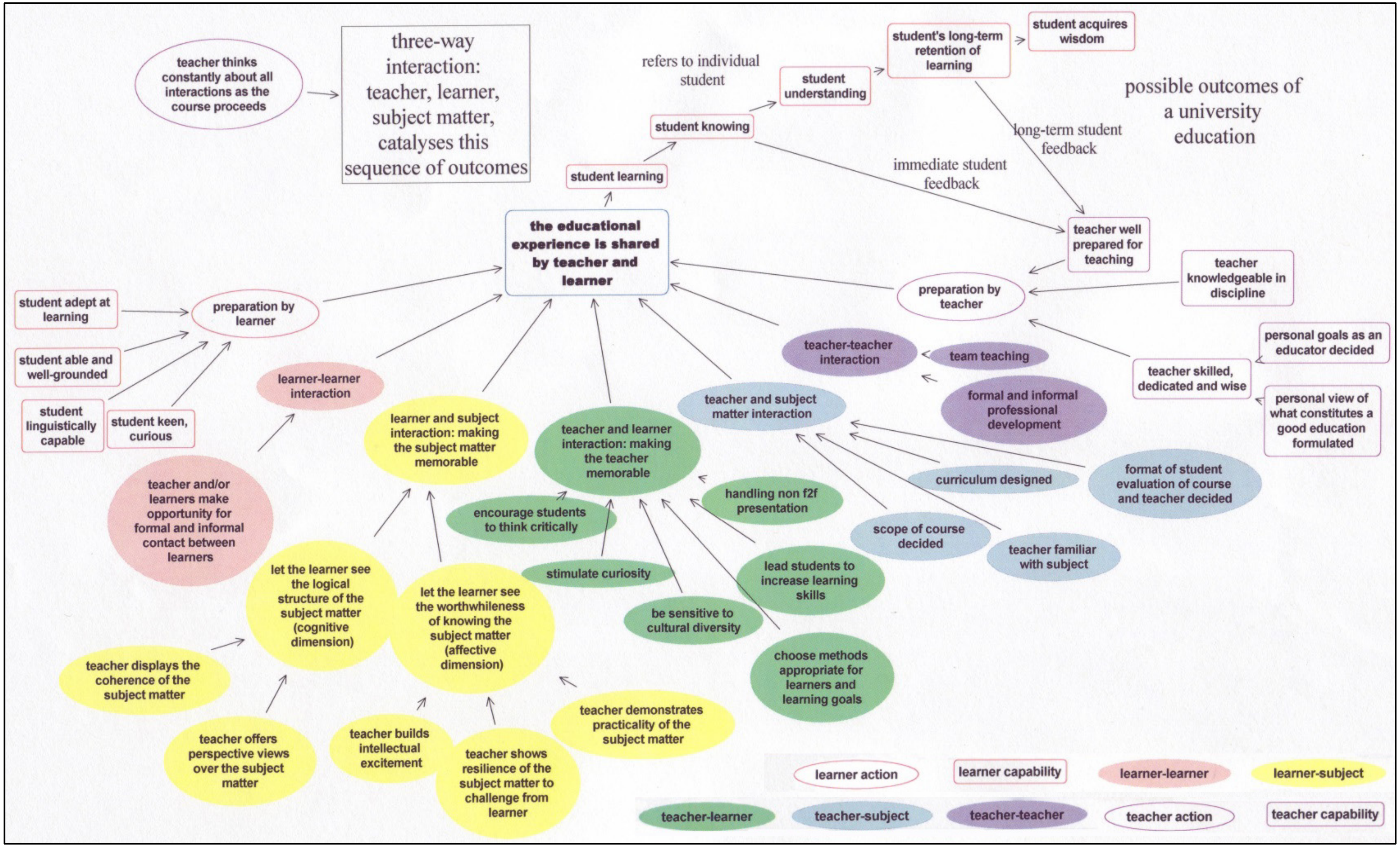

Figure 1. Concept map of my extensive model of the acquisition of a university education

The (pink) learner-learner segment invites thought on the benefits of peer-assisted learning, as promoted, for example, by Boud, Cohen, and Sampson (2013). The (green) teacher-learner segment suggests paths by which the teacher's nurturing of students' positive attitudes to learning, as well as his/her engagement with them intellectually and personally, can make the teacher memorable (in the best sense!). It would be a mistake, however, to think that being a memorable teacher is sufficient to make the subject matter memorable to students – though it could well contribute. Indeed, the paths to making the subject memorable – which is the theme of the yellow segment – make no assumption about whether the teacher is personally memorable to students or not.

The (blue) teacher-subject matter segment offers prompts for the teacher on planning the academic content of the course and associated student assessments, as well as on ensuring that all required administrative procedures are in place. The (mauve) teacher-teacher segment invites thought on two distinct aspects of a teacher's activities – the value of team-teaching in each particular context, and the value of peer appraisal in general professional development.

5. 'THE YELLOW PATHS': MAKING THE SUBJECT MATTER MEMORABLE

With the yellow segment we come to the model in this paper's title. The paths traced out in the yellow segment of Figure 1 identify the most directly influential processes by which the teacher may guide the student in his/her learning so that the subject matter becomes memorable to the student. If teacher and student engage particularly well with each other, retention of the student's learning can be expected to persist for the long term. Allowance must, naturally, be made for individual differences among students.

Other segments in Figure 1 may contribute to making the subject memorable, but their influence will be indirect, that is, via achievement of some intermediate goal.

Here is an overview of the fine-detailed workings of my model, and of what it suggests for the transition from principle into practice in the field of statistics education. To create this overview, I am bringing together systematically all my relevant published papers.

The model in skeletal form is found in Sowey (1995). Two directly influential teacher capabilities that inspire retention of student learning are identified:

(i) the teacher gives students a structured view of the discipline of statistics, and
(ii) the teacher's own conviction that statistics is worth the effort of learning it, for both its utility and its intrinsic interest, is conveyed to the student.

These capabilities are captured concisely (also in Figure 1) by the corresponding attributes of teaching, 'structure' and 'worthwhileness'. Here 'structure' encompasses the leading cognitive elements, and 'worthwhileness' the leading affective elements in teaching – it is well-accepted that teaching is most effective when students are engaged both cognitively and affectively.

What powerful cognitive elements are there in structure? The model highlights two: 'coherence' and 'perspective'.

Coherence has three senses:

(i) *continuity* – the exposition is a smooth traverse through statistical theory and into practice;
(ii) *unity* – the exposition unifies seemingly diverse statistical topics by revealing their latent commonality;
(iii) *integration* – the exposition shows how statistics integrates with other disciplines in the tapestry of all knowledge.

Sowey (1991) shows, with examples, how teaching that brings each of these three senses of coherence into view can make the subject matter memorable.

Pausing from time to time, in teaching, to offer a perspective view over what has been and what is coming helps students confidently chart their progress through the syllabus and promotes their understanding of the coherence of the subject. Sowey (1998) explores the many opportunities there are to introduce perspective views in teaching statistics. Sowey (2005) takes a single topic – explaining the logical basis of statistical inference – to show how a perspective view can provide valuable preliminary insights before this philosophically subtle topic is tackled more technically.

What powerful affective elements are there in worthwhileness? The model highlights three: ‘intellectual excitement’, ‘resilience to challenging questioning’, and ‘demonstrated practical usefulness’. Intellectual excitement can grow from students’ surprise when the teacher unexpectedly introduces something they find remarkable, such as an arresting example, a dramatically counterintuitive proposition, or a paradox that begs to be resolved. Sowey (2001) and Sowey & Petocz (2010) provide examples of this genre.

As students’ knowledge grows, the teacher can make two particular contributions that will let students feel how rewarding it is to master the subject. The first is to respond supportively to all thoughtful student questions, whether innocent or deliberately challenging – even when they raise controversial or advanced themes. Sowey (2006) gives more than a dozen examples of this kind, sourced from actual class experience. In this way, students come to appreciate how intellectually resilient statistics is, as a discipline.

The teacher’s second contribution is to excite students by showing how statistical methods are helping to solve important real-world problems. Such problems include how to ensure the safety of prescription drugs, how to reduce the number of road accidents, and how to discover risks to national security by analysing ‘big data’.

6. CONCLUSION

> “There are times when qualitative studies are valuable when not linked in any fashion to quantitative data. In some cases, qualitative studies, on their own, help challenge or modify existing theory.” (Groth, 2010, p. 16).

In the work of others on statistics education I have found, among the few relevant statistically-based experimental studies, nothing that qualifies as a general theory on teaching to inspire long-term retention of learning. I propose my qualitative model as the foundation for such a theory.

It is less demanding to describe the individual elements of my model than it is to realise them in teaching. That is because they can be reviewed here one-by-one at leisure, whereas in practice the teacher needs to keep *all* of them in play *all* of the time. Nevertheless, long experience of teaching in accord with the model gives me confidence that the educationally valuable end richly justifies the demanding means.

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REFERENCES

Boud, D., Cohen, C., & Sampson, J. (Eds.) (2013). *Peer learning in higher education*. Oxford, UK: Routledge.

Groth, R. E. (2010). Situating qualitative modes of inquiry within the discipline of statistics education research. *Statistics Education Research Journal*, *9*(2), 7–21.
[Online: iase-web.org/documents/SERJ/SERJ9(2)_Groth.pdf]

Petocz, A., & Newbery, G. (2010). On conceptual analysis as the primary qualitative approach to statistics education research in psychology. *Statistics Education Research Journal*, *9*(2), 123–145.
[Online: iase-web.org/documents/SERJ/SERJ9(2)_Petocz_Newbery.pdf]

Sahai, H., Khurshid, A., & Misra, S. C. (1996). A second bibliography on teaching probability and statistics. *Journal of Statistics Education*, *4*(3).
[Online: www.tandfonline.com/doi/full/10.1080/10691898.1996.11910516]

Schau, C., & Mattern, N. (1997). Use of map techniques in teaching applied statistics courses. *The American Statistician*, *51*(2), 171–175.

Sowey, E. R. (1991). Teaching econometrics as though coherence matters. In D. Vere-Jones (Ed.), *Proceedings of the Third International Conference on Teaching Statistics, Vol. 2*, 321–331. Voorburg: International Statistical Institute.
[Online: iase-web.org/documents/papers/icots3/BOOK2/B5-4.pdf]

Sowey, E. R. (1995). Teaching statistics – making it memorable. *Journal of Statistics Education*, *3*(2).
[Online: www.tandfonline.com/doi/full/10.1080/10691898.1995.11910487]

Sowey, E. R. (1998). Statistical vistas: perspectives on purpose and structure. *Journal of Statistics Education*, *6*(2).
[Online: www.tandfonline.com/doi/full/10.1080/10691898.1998.11910614]

Sowey, E. R. (2001). Striking demonstrations in teaching statistics. *Journal of Statistics Education*, *9*(1).
[Online: www.tandfonline.com/doi/full/10.1080/10691898.2001.11910647]

Sowey, E. R. (2005). From a logical point of view: An illuminating perspective in teaching statistical inference. *International Journal of Mathematical Education in Science and Technology*, *36*(7), 801–811.

Sowey, E. R. (2006). Letting students understand why statistics is worth studying. In A. Rossman, & B. Chance (Eds.), *Proceedings of the Seventh International Conference on Teaching Statistics*. Voorburg, The Netherlands: International Statistical Institute.
[Online: iase-web.org/documents/papers/icots7/3A1_SOWE.pdf]

Sowey, E. R., & Petocz, P. (2010). Enriching statistics courses with statistical diversions. In C. Reading (Ed.), *Proceedings of the Eighth International Conference on Teaching Statistics.* Voorburg, The Netherlands: International Statistical Institute.
[Online: iase-web.org/documents/papers/icots8/ICOTS8_4D3_SOWEY.pdf]

Sowey, E. R., & Petocz, P. (2017). How statistics differs from mathematics. Chapter 2. In E. R. Sowey, P. & Petocz, *A panorama of statistics*: *Perspectives, puzzles and paradoxes in statistics.* Chichester, UK: Wiley.

Witmer, J.A. (2016). Concept maps in introductory statistics. *Teaching Statistics*, *38*(1), 4–7.

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