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One in a Million: An Alternative Transformation of the First-Year Statistics Course

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Abstract

This paper describes the continuing development of a first-year statistics textbook, which is written with a primary focus on statistical ideas and statistical thinking and a secondary focus on statistical techniques. Such a "second-generation" transformed approach to statistical education has a number of practical benefits in terms of student engagement with statistics, and aligns with theoretical research on students' ideas about the discipline. As well as describing and exemplifying the content of the text, colleagues' and students' reactions to (earlier versions of) the book are presented, the challenges they raise are addressed, and future plans for the project are indicated.

Keywords: Conceptions of statistics, Reformed courses, Statistics education, Statistical thinking, Transformed courses

1. A new approach to the first statistics course

A central aim of an education in statistics is the development of "statistical bravery". Statistics is a practical discipline and any course should help the student to have "an intelligent go" at statistical problems which arise. Here are two examples of how the approach described in this paper has encouraged statistical bravery.

A student of a course based on the approach was consulted by two former bank managers who were running a grocery warehousing operation in the South Island of New Zealand. They wanted to know the cost of processing a pallet of goods. Knowing nothing about warehousing, but armed with statistical thinking and some simple tools, the student produced a satisfactory solution to the problem. Another student, a marketing employee, became brave enough to question the weekly company performance analysis. The conclusion was being drawn that a salesperson was performing poorly due to laziness; the student pointed out that this person was working a difficult sales region – more than likely the reason for poor sales figures for that individual. In teaching such outcomes should be our aim.

Here is the opening of the first chapter, to provide just a flavour of the text.

We all seek knowledge. Why? Knowledge turns mere observation of the world around us into understanding and understanding is a prerequisite for control. Francis Bacon (1561-1626) put this succinctly around 400 years ago when he wrote in Of Heresies in his Religious Meditations, "For knowledge itself is power". Knowing more about the world has lead to many of the improvements and comforts and pleasures which we now take for granted – from car paint to plastic toothpaste tubes, from computers to digital watches, from ATMs to stump cameras. The science of statistics assists in turning observation into understanding.

2. Theoretical background

In the early 1980s a section of the statistical community became increasingly dissatisfied with the traditional approach used in first-year university statistics education. This approach had served well since the 1950s, but had begun to reveal inadequacies. The traditional approach begins with an introduction to probability and distributions, followed by an introduction to inference and estimation, often taking a mathematical view of the material. A second approach, the so-called reformed approach, emerged as a consequence of this dissatisfaction in the mid-1980s. The reform consisted of a broadening of the syllabus, to include such topics as exploratory data analysis, time series, index numbers and an introduction to Deming-based ideas of continuous improvement. Students' reaction to such courses, however, was often, "How do I know which technique to apply in a new situation?".

Reflection in turn on the inadequacies of the reformed approach lead to a call in the 1990s, primarily by prominent statisticians in the United States (such as Box, Joiner, Snee and Hogg, see for example Hogg, 1991), for a transformed approach to teaching statistics. Such writers argued that even the reformed course was not conveying the essence of the discipline. It was failing to put across to students the power of the thinking which should become second nature through a study of the science of statistics (for a retrospective view, see Garfield, Hogg, Schau and Whittinghill, 2002). The aim of transformed texts (such as Hoerl & Snee, 2002) was to teach statistics in the context of the need for problem solving; "improvement is necessary" was the starting point in that text.

The transformed approach has merit, since it sets the tools of statistics within the framework that motivates their use. This framework, however, can be broadened beyond the business context, the aim of the work described in this brief paper. The mantra of the text that has been developed is not that "improvement is necessary" but rather that "learning is necessary". Effort is then made to show how statistical thinking is relevant not only in the world of business, but also in the worlds of science, engineering and day-to-day life. The key differences between the three approaches are summarised in Table 1 (below).

Table 1. Characteristics of different approaches to teaching a first statistics course

Approach	*Characteristics*
Traditional	Mathematical focus, initially on probability and then inference
Reformed	Focus on displaying and investigating data, using computer packages
Transformed	Focus on statistical thinking and literacy, power of the statistical approach

Recent research in statistics education (Reid & Petocz, 2002) affirms the validity of this approach. Student conceptions of the discipline can be described using three hierarchical levels: the most limited consists of a focus on techniques (the "formulae and equations"), a broader level focuses on using data (analysing data and building models) and the most inclusive level is a focus on the broader meaning and its impact on life (the connection with personal and professional life). A course (and a textbook) that incorporates the broadest level is ultimately more successful at helping students learn. Garfield (2002) discusses the general topic of how students learn statistics, incorporating findings from psychology and pedagogy. She lists several "principles of learning statistics" that include the importance of active involvement in learning activities, a feature of the current textbook. The American Statistical Association's (2005) GAISE report also recommends the use of active learning and emphasises the development of statistical thinking and conceptual understanding rather than mere knowledge of procedures.

3. The project – a second-generation transformation of statistics education

The aim of this project was to push forward the development of a textbook, *One in a Million* (by Wood, Wasimi and Noble) to answer this call for a second-generation transformation of statistics education. The primary focus is on ideas and statistical thinking, consistent with the recommendations discussed earlier; the secondary focus is on techniques. For most students, their first university course in statistics is their only course in statistics, so the aim in such a course must be to create an awareness of the power of statistical thinking and techniques. This is more likely to occur if the course conveys the statistical way of thinking and applies it to real problems, demonstrating the power of the subject.

Hallmarks of this second-generation transformed approach, which comprise the overall philosophy of the text, are:

(1) "Outside-in" teaching, ever emphasising a unifying framework for the pattern of thinking in statistics. This is reassuring to the student, since whenever a new problem is encountered the framework of thinking provides a systematic initial approach to its solution, whether it be dealing with a difficult staffing problem or the scheduling of rubbish trucks. It begins with careful definition of the problem and proceeds according to the standard learning cycle.

(2) Use of real problems in a "question-theory-answer" pattern. One of the authors, in 1987, experimented by running a first-year university statistics unit based totally around real and current problems. The outstandingly positive reaction of the class provided convincing evidence that this must be a major component of any transformed approach to teaching (Wood, 1988).

(3) Introduction of traditional material only after the need for it is made apparent through the study of real problems. More traditional material (such as probability theory, distribution theory, confidence intervals and simple linear regression) is introduced in the second half of the course, and used to provide further insight into the real problems encountered earlier.

(4) Instructor accountability. If you only had 30 seconds to tell somebody about the essence of statistics, what would you tell them? Then suppose you were given an hour, what would you tell them? Then a day, what would you tell them? Thinking this way forces us as instructors to consider what is most important about our discipline. Surely this is the

order in which we should teach our students!

(5) Instructor honesty. Many statistical problems can be solved with disarmingly simple statistical tools. We should tell our students this and not pretend otherwise. We should amaze them about the power of simple methods, not impress them with the power of less-used sophisticated methods, at least in the first stages of the course.

It is important that students be given the confidence to “have a go” at whatever comes along – not only if it boils down to an application of the t-test. This is the payoff, for example, of the “30 second – what’s most important” approach. In practice, every statistical problem has its own character and challenge, so is best tackled by an individual who sees the subject of statistics in a broad light. The approach aims to open the student’s mind to the big ideas, but necessarily has to leave some of the details found in traditional courses for later study. In the authors’ view, this is a liberating approach, not a stultifying one, and results in a brief text which is long enough to convey the important ideas.

4. The project in more detail and the Plan-Do-Check-Act cycle

Now we turn to more detail concerning the material developed. Central to statistical thinking is the use of the scientific method or Plan-Do-Check-Act (PDCA) cycle; this is discussed in the opening chapter and reappears like a chorus throughout the text. To quote from the text:

Believe it or not, you are quite familiar with the PDCA cycle. For example, special occasions often require us to wear a tie. Let's pause for a moment and contemplate the process of putting on a tie.

First we plan. We decide it's necessary to wear a tie and select the right one from our extensive wardrobe. Then we do something, we tie the tie – perhaps an elegant Half Windsor. Assuming a certain minimal vanity, we then check up on ourselves by glancing in the mirror to see if we are looking alright. Uh oh, we don't. The long piece is far too long and looks ridiculous. So we act, we decide to go around the cycle again. This time, with an intelligent adjustment, it looks great. Success is ours, thanks to almost unconscious PDCA activity on our part!

The central irony is that although we use the PDCA cycle routinely in trivial matters, we often don't use it in important ones. We all have a strong tendency to leap into the Do phase – keep a close eye on yourself in future! We also have a reluctance to use the Check and Act stages. Using the cycle once carefully is the first sign that you are learning something from reading this text. You should aim to make it an unconscious way of operating in all that you do.

Despite its apparent simplicity, the PDCA cycle can be a challenge to move around successfully – it takes a lot of effort, but the effort is well worthwhile. In order to make it easier to go around, it has been amplified into seven steps:

(1) Clarify the problem

(2) Understand the current situation

(3) Analyse causes – develop hypotheses to be tested or quantities to be estimated

(4) Formulate and implement a plan to test the supposed cause

(5) Check the results

(6) Act by standardising new knowledge

(7) Conclusion - project review and future plans.

The first three are subdivisions of the planning phase. For an excellent discussion of these seven steps see Kume, 1985.

It has surprised even the authors to see how well the PDCA cycle unifies the activity of statistical problem solving. Many, many problems are solved with simple tools, so Chapters 2 and 3 are devoted to the basic tools of statistical problem solving. Chapter 2 handles the snapshot tools for process improvement, while Chapter 3 introduces the tools for handling processes over time. In this way, Chapters 1-3 form a micro-book. By the time these ideas are digested the student will have a rudimentary collection of statistical tools that will go a long way towards solving problems in the real world.

This thinking is summed up in the learning cycle of Figure 1, which summarises the essence of statistical thinking. When we are confronted with a problem, we are concerned with learning about a situation (always part of some process, symbolised by the sequence of rectangles) in the PLAN stage of the learning cycle. We gather data at some critical point in the process, during the planning stage, and take it around the DO (often modelling) stage, the CHECK (is the model useful?) stage, and finally the ACT stage (where we decide that we have either learned enough for now and stop, or continue the learning cycle).

Modelling is a fundamental statistical activity. This is introduced as a way of thinking, in the context of estimating tourist arrivals, in Chapter 4. Experimentation is also a fundamental statistical activity. This is introduced, in the context of “hotting a Cortina” (modifying the engine so that the car goes faster), in Chapter 5. Sample surveys are introduced in Chapter 6. These second three chapters, together with the first three, create a mini-book. By the time all these ideas are digested, the student will have a repertoire of some of the most-used techniques in statistics (and, our experience indicates, the desire to learn more).

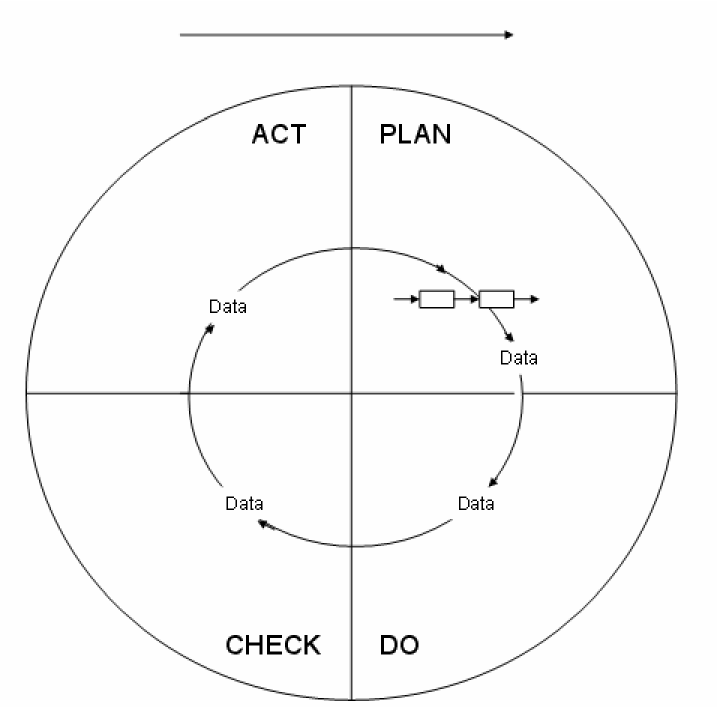

Figure 1. The essence of statistical thinking

The appetite is now whetted, through a practical, and largely unthreatening, arithmetic first half of the text, for more traditional material. The need has been seen for an understanding of probability, probability distributions and further modelling. This material makes up the latter, more conventional, half of the text.

The basic toolkit of exploratory techniques is extended in Chapter 7, to include stem and leaf plots, boxplots and more. Sample spaces, probability, random variables and distributions, the language of variation and the means for building statistical models are introduced in Chapters 8 and 9. Traditional model fitting is discussed in Chapters 10 and 11, first for questions about single populations, then for questions about two populations. Analysis of variance is left for a second course! Straight line relationships are discussed in the concluding chapter, Chapter 12.

In this way, quantitative confidence is developed rapidly. Chapters 1 to 3, thoroughly understood, create the rudimentary statistician. Chapters 3 to 6 add more sophisticated ways of thinking, while Chapters 7 to 12 introduce the foundations upon which the early chapters are built, together with some traditional material. The complete chapter summary is given in Table 2.

Table 2. Outline of the textbook's chapters

Chapter	Title
1	The Framework of Statistics
2	Basic Tools
3	Statistical Process Control
4	Time, Models and Prediction
5	Experimentation – Forcing the Pace
6	Sample Surveys
7	Exploring Data – The Beginnings of Data Mining
8	The Language of Variation – Sample Spaces and Probability
9	The Language of Variation – Random Variables and Distributions
10	Questions about a Single Population
11	Questions about Two Populations
12	Straight Relationships

The earliest version of the material was used as a basis for the main first-year statistics unit at Central Queensland University (CQU) in 1995. A revision was then used for the main first-year statistics unit at Massey University in 1998.

In order to solve substantial real problems, it is essential that students be introduced to a statistical package. Minitab has been used to date for data analysis and the presentation of results in versions of the course.

This book is devoted to ideas, not the usual array of techniques. At present the book is a draft only, available on request from the first author, and constructive comments (from typos to earth-shattering revelations) that might lead to improvement of the text are keenly sought. The text itself has already undergone a number of trips around the Plan-Do-Check-Act improvement cycle, and will doubtless do a few more before it reaches a publisher!

5. Evaluation, future plans and summary

Student evaluations of earlier versions of the textbook were conducted at both CQU and Massey University. Reactions were mixed, ranging from complaint that the material was too 'wordy' to expressions of relief that the course was sufficiently engaging to allow success. The emphasis on real problems received general approval, although some students found the emphasis on the fundamental nature of the PDCA cycle a too-much-used chorus. These evaluations have informed the development of the revised version of the book, although key features (such as the PDCA cycle) have been kept.

In addition, comments have been sought over the development period from statistics teachers, statistics practitioners and interested readers from the general public. It appears clear that no single text will ever satisfy the taste of all! These received comments, however, have been noted and the text revised periodically in an attempt to take them into account. Essentially, the development of the textbook itself has been based on a PDCA cycle (or actually, several cycles).

A secure website is being set up at Macquarie University that will make available the chapters to interested readers; feedback will allow ongoing development of the materials to take place, with a view to the future use of the improved material. It is also planned to make updated data sets available at this site, together with additional (solved and unsolved) problem sets and PowerPoint presentations. But of course the ultimate goal of the development is to allow a revised version of the textbook to be used with students at Macquarie University, and at that time further evaluations will be carried out to capture the views of students who are using the book to enhance their learning.

To summarise, the approach developed presents a transformed first-year tertiary statistics course, aiming to prepare students for statistical problem solving. It emphasises the purpose of statistics at all times: to solve problems, in context, using the ideas and methods of the science of statistics. A student should leave the course confident that a new problem can be approached with a way of thinking, not just a basketful of techniques.

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