Using examples to promote statistical literacy

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Abstract: *Statistical literacy is portrayed by Gal (2002) as the ability to interpret, critically evaluate, and communicate about statistical information and messages. Effective teaching, which develops statistical literacy, is of prime importance for science undergraduates in diverse fields as many may become 'consumers' of statistical information rather than pursue further study to become statisticians. In this paper we present empirical data on why and how international university educators use examples to teach statistics in service courses, based on recent research (Gordon, Reid & Petocz, 2007). We outline Gal's (2002) model of statistical literacy for data consumers, activated by five related knowledge bases with supporting dispositions, and relate the empirical findings to this model. We conclude that examples can be instrumental in the challenging task of motivating students studying statistics and connecting their study with their chosen disciplines and future professions.*

Introduction

Teaching statistics to science undergraduates in diverse fields is a challenging and important task, as all these students will require some level of statistical knowledge for their future professional work. Some students will go on to become "data producers" (Gal, 2002, p.3) where they will carry out empirical investigations, interpret their own data and results and report their findings and conclusions. Many more will become "data consumers" where they will need statistical literacy, portrayed by Gal (2002) as the ability to interpret, critically evaluate, and communicate about statistical information and messages. An alternative characterisation of statistical literacy (Garfield & Ben-Zvi, 2007 p.380) postulates that statistical literacy "involves understanding and using the basic language and tools of statistics: knowing what basic statistical terms mean, understanding the use of simple statistical symbols, and recognizing and being able to interpret different representations of data". In this paper we explore ways that use of examples can promote statistical literacy for data users or consumers drawing on recent research (Gordon, Reid & Petocz 2007).

Growing numbers of research studies in statistics education reflect the shift in emphasis in statistics instruction from a focus on procedural understanding — statistical techniques, formulae, computations and algorithms — to developing the conceptual understanding that underpins statistical literacy and higher order statistical reasoning and thinking (Garfield & Ben-Zvi, 2007). Principles about student learning of statistics have been grouped into research-supported statements (Garfield & Ben-Zvi, 2007) including: students learn through active involvement in learning activities; students learn to do well through practice and learning is enhanced by having students become aware of and confront their errors in reasoning.

Although statistics teachers have routinely used examples as an integral component of their instructional repertoires, this use tends to be in the background of pedagogical knowledge. In the next section we summarise a research project investigating educators' views on teaching and learning statistics as a service course (described fully in Gordon, Petocz & Reid, 2009; Gordon et al., 2007) and report findings on why and how participants used examples in their teaching. We then adapt a model of Gal (2002) to discuss how examples can promote statistical literacy in undergraduate science students. Our data indicate the diverse ways that examples are used in teaching statistics and provide opportunities to improve this aspect of pedagogy in the many areas of science where students study statistics.

Data on statistics educators' use of examples in teaching

Method

The investigation consisted of a three-phase series of e-mail interviews with statistics educators. Participation was invited through an electronic request to the membership list of the International Association for Statistics Education (IASE) and Faculty bulletin boards of Australian universities. In all, 36 IASE members from twelve different countries and 8 other Australian statistics educators took part in the project. The research was approved by the Human Research Ethics Committee of the University of Sydney.

All participants were teaching statistics as a service course, with the majority (31 participants) teaching cohorts in one or more areas of science. These included biology, psychology, medical sciences, agricultural or environmental sciences, physics, information technology and/or computer science — an indication of the importance of statistics as a tool for students in diverse disciplines of science. The interview protocol consisted of an initial series of six questions focussing on educators' ideas about teaching and learning statistics. The second interview consisted of questions following up and probing each participant's responses. Finally, a third interview was sent with further questions to elicit clarification and in-depth explanations of the responses given as well as a request to evaluate the e-mail interview method. The methodology is critiqued in Reid, Petocz and Gordon (2008). We have also linked analysis of data to exemplification in mathematics (Gordon & Nicholas 2008).

Findings

Participants' reported goals for using examples in their teaching fell into three overlapping categories. In the first category, examples are developed and presented by educators for basic instruction in statistics. In the second category, students generate their own examples, under teacher direction, to aid learning. In the third category, educators present examples in order to connect statistics with students' future professional work.

The first category was expansive with educators suggesting diverse roles for examples in their instruction. These roles included engaging students (and oneself), illustrating ideas of lectures, grounding concepts, providing a template for students to follow and building conceptual complexity or developing critical thinking, as well as more unusual ideas, such as differentiating statistics from mathematics and personalising teaching. Expressions in the second category were sparse suggesting that statistics educators do not often engage students in this way. The third category provides evidence of the importance educators place on examples being relevant to and derived from practice in professional areas such as medical science. These categories are illustrated below with illustrative quotes from the e-interview transcripts. All pseudonyms were chosen by participants themselves and brief excerpts are reported under these self-chosen pseudonyms.

A. Examples as instructional devices used by educator

We summarise the varied uses of examples in this category with illustrative quotes in Table 1.

Educators' use of examples	**Illustrative quote**
To engage students (and oneself)	Ron Fisher: *I am constantly updating my examples, and looking for new applications that will interest my students. Not only do I do this for the students' sake, it also makes the class much more interesting for me, since I am interested in the world around me.*
Illustrate ideas of lectures	Andrew: *The large methods courses have a one hour tutorial each week where examples are worked on that illustrate the lectures of the previous week.*
To ground concepts	Joyce: *[How do real world examples help students to learn statistics?] To use an educational psychology phrase, it gives them "an anchor".*
As a template for students to follow	Natalie: *By giving students worked examples they can use these as a "template" until they are comfortable creating their own non-technical explanations.*
Develop skills	Margaret: *To develop good case examples for students to work on so that they develop their skills in a step by step fashion. To learn how to guide students and keep their interest as they go from simplistic examples to the more complicated.*
Extra practice	Kay: *(Struggling) students get extra worksheets with examples.*
Differentiate from mathematics	Primavera: *Students believe that Statistics is a branch of Mathematics. They change their mind with the use of real examples.*
Way into theory	Baz: *Even the students who can handle theory can learn from illustrative examples, and students who can't have no other choice.*
Develop critical thinking	Jane Johnson: *I sometimes use examples of incorrect analyses – as a warning to those who do not think critically.*
Build conceptual complexity	Despina: *I try to structure the problems I use as examples and as tutorial work so that we begin with a basic problem and slowly add complexity.* Kay: *We go over a number of examples, spread throughout the course – distributed versus massed practice, "spiralling" to repeat earlier concepts.*
Demonstrate the statistical process	John: *We will use an example reported in the media to illustrate how we can identify the statistical investigative process and understand statistical aspects of the study as reported.*
Explain terminology in everyday words	Annette: *… I just use examples from (imaginary or real) situations and try to explain the meaning of concepts using only these words which we use in our everyday conversation. And I ask students to do the same — to interpret the statistical results using the words which people who have never learned statistics would also understand.*
Indicate variation	Daria: *(We show students that variation is present in everything we do) by means of many "real" examples in the course of the lecture, and tutorials.*
Personalise teaching	Natalie: *Even though (many of us) use the same master resources, we each adapt these materials — add in our own examples, tweak to our preferences.*

Table 1: Ways that examples are used in instruction

B. Learner generated examples

There were few expressions fitting into this category.

Horace reported that if students could:

> draw a picture, give the definition, state an example, and show they know when to use something, then that's a pretty good operational definition of understanding?! (If they can write the formula, that's a nice bonus!)

Cara encouraged students "to find examples of misuse (of statistics) on their own and present them in class."

The few reports in this category indicated that student generation of examples helped students construct their own knowledge. As Janet Cole explained

> (The process) helps students put together/construct their own frameworks for learning. If a student can understand the process of constructing a confidence interval for a proportion (including checking conditions, mechanics, and presentation of results), then it should ideally be easier for that student to transfer this process to the construction of a confidence interval for any other situation. The student is not learning something entirely new, but is rather doing what I call a "variation on a theme."

C. Examples presented to demonstrate applicability of statistics as a methodological tool in future professional work

In this category educators used examples to indicate the work of statisticians, or relate to students' disciplines and future professional work.

Andrew:

> It is important to convey to students the view that what they learn in a preparatory course on statistics is going to be essential for their future work in their major subject, something that many first year students do not appreciate. Therefore, the statistics teacher must be able to access appropriate examples from the areas of application. It is with these types of applications that students suddenly realise the greater picture of statistics. Such examples abound but they must be chosen very carefully. They must not be artificial class exercises in my view.

Glee added that from his experience

> students respond very well to the statistics if the examples given in class relate to their specific disciplines. The motivation is that when they leave University they will be relevant and employable in their respective job markets.

In turn, Johanna found that starting the semester by asking students why they think statistics has been made a compulsory unit in their degree program, led to discussion about the role of statistics in their particular field—how, when and why it would be used.

> I use many examples that relate to the degree program that the students are enrolled in but also ask them to consider examples from different areas (highlights the diversity of statistical applications).

Statsboy:

> So, in teaching statistics to medical students you MUST use medical examples – show me how the authors have analysed their data and what it means. Don't write a regression model with alphas and betas without giving me a relevant example of how this works in real life.

Henry VIII:

> What I try to show medical students is that, even they don't ever intend to do any research, they still need some basic knowledge of stats in order to be able to fully understand the concepts of "statistical patterns" and "typical values", and the probabilistic nature of the decisions they have to make every moment during their practice. I try to do this by highlighting, through examples, the probabilistic nature of the patterns and decisions, and by trying to steer them away from the sort of deterministic thinking they are exposed to during most of the other courses they attend at college. // My most successful lecture on the Probability subject, for instance, is the one in which I discuss the interpretation of sensitivity, specificity and predictive

> value of diagnostic tests — these are very practical application of the rather abstract Bayes' theorem, and the students love it.

The reports about examples by participants indicate that the majority of them used examples, chosen by themselves, for a range of instructional goals. A few participants reported that they encouraged students to generate examples as part of learning activities, while many educators used examples to indicate the utility of statistics in the student's own discipline. In many of the above excerpts we see educator's goals for using examples that fit with principles (Garfield & Ben-Zvi, 2007) on how students learn statistics — including developing conceptual knowledge, practising skills, and confronting misconceptions. The excerpts suggest ways that examples play a central role in enhancing science students' statistical literacy. We develop this idea below starting with an overview of Gal's (2002) model of statistical literacy for adults.

Discussion: enabling statistical literacy

A model of statistical literacy

Gal (2002) argues that, for data consumers, statistical literacy is enabled by five inter-related knowledge bases: literacy, statistical, mathematical, context and critical, together with essential supporting dispositions and beliefs. While Gal's focus is on statistical literacy for adults in everyday life contexts, his ideas extend to essential knowledge foundations for university students and graduates who are potential users of statistical information in their work.

Literacy skills, as the first component of the model, go beyond skills in reading, writing, listening and talking that are essential for comprehending and processing information and interpreting or discussing documents. Literacy skills for statistical literacy — essential to scientists — encompass an awareness of the meaning of basic statistical terms and an ability to make sense of graphical and tabular information, as well as a range of text and media messages.

Requirements for statistical knowledge, the second element of Gal's (2002) statistical literacy model, depend on the context and hence cannot be prescribed by a definitive list of topics. However, reviews of the literature indicate agreement on the importance of including basic notions such as variability, key terms and ideas relating to producing and describing data, a basic understanding of probability and some knowledge of how statistical conclusions are reached.

Mathematical knowledge, Gal's third component or knowledge base, appears to be more controversial (Gordon, Petocz and Reid 2009; Moore 1997), with some statistics educators arguing for less emphasis on mathematical derivation and theory in introductory or service statistics courses, while others insist that at least basic quantitative skills and some formal mathematics are needed to appreciate statistical concepts or to understand the meaning of statistical findings on more than a superficial basis.

The fourth knowledge base, an ability to place statistical information in context, is considered essential by Gal (2002). Context knowledge is the main determinant of sources for variation and error. Without this knowledge:

> it becomes more difficult to imagine why a difference between groups can occur, what alternative interpretations may exist for reported findings about an association detected between certain variables, or how a study could go wrong (Gal, 2002, p. 15).

Finally all these knowledge bases support the fifth component of critical evaluation: students' abilities to interpret statistical information critically and make informed decisions and judgments on the basis of data.

Statistical literacy, in this model, is not a passive possession of skills and knowledge but includes the dispositions that enable a person to access and use the five knowledge bases. Gal (2002) uses the label "dispositions" (p. 18) to refer to related concepts about stance, beliefs and attitudes. Firstly, critical stance is required — that is, a willingness and confidence to question statistical messages. This stance needs to be accompanied by beliefs and attitudes that support statistically literate behaviours — so that learners will invest effort and engage critically with statistical tools and concepts.

Using examples to promote statistical literacy

We now consider how the use of examples in teaching, reported in this paper, relates to Gal's (2002) five inter-related knowledge bases and accompanying dispositions. Firstly, many respondents indicated using examples in instruction to enable students to build up skills and understand basic statistical concepts and processes — to develop the statistical knowledge base. Our participants' reports illustrate many aspects of this, such as Kay's "spiralling" examples to develop concepts, John's illustration of the statistical investigative process and Margaret's guidance of students' skill development. Annette's insistence that students explain statistical terminology in plain English is one of many ways examples can be used to develop students' literacy knowledge base. We do not have evidence in the data presented of how, or whether, teachers use examples to promote the mathematical knowledge basis. However, Henry VIII arguably spoke for many participants in reporting that little mathematics was needed for the statistics courses he taught as "they are not courses on mathematical statistics" and "we usually avoid doing mathematical demos of theorems".

Perhaps foremost of the five knowledge bases, our data show that examples provide context for statistical information. This is most evident in the responses that link examples to students' future professional work as exemplified by Statsboy, who considered it essential to use medical examples when teaching statistics to medical students, so that students have relevant examples of how statistics "works in real life". By drawing on examples from their own practices, such as psychology, biology or medical science, educators demonstrate the relevance of statistical information to science disciplines, and enable students to see the "greater picture of statistics" (Andrew). There is also evidence that educators are alert to developing students' critical thinking skills. Jane Johnson's "warning" examples of incorrect analyses and Henry VIII's goal of highlighting "the probabilistic nature of the decisions they have to make every moment during their practice" are two examples of this. The findings show that teachers seek to develop both literacy and critical thinking through discussing and critiquing examples from the media or research.

Finally, and perhaps most importantly, examples can help engage students and motivate them to understand the power and limitations of statistics. Respondents' expressions in Category C (relating statistics to the discipline or profession) are at heart about making statistics personally meaningful to students. In this way using examples in teaching can enhance the affective components of learning statistics, which, Gal (2002) stresses, support the knowledge bases of statistical literacy.

There are many challenges in teaching statistics (Onwuegbuzie & Wilson, 2003), motivational and cognitive. Our findings show that examples can be used to help meet these challenges. In science education examples can promote active learning, enable students to work with statistical concepts and procedures and begin to think critically. Generating their own examples would assist students to construct their own knowledge. Our data suggest that this aspect of statistics pedagogy needs development. If statistics educators reflect on how examples can be used to help teach and engage their science students, this could promote statistical literacy as an essential aspect of students' future professional lives and help develop students' capabilities to be effective and competent scientists.

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