REACTING TO QUANTITATIVE DATA: TEACHERS' PERCEPTIONS OF STUDENT ACHIEVEMENT REPORTS

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As part of an investigation into statistical literacy for the teaching workplace, this research paper uses a framework for professional statistical literacy to examine teachers' perceptions of the complexity and value of such reports. Although teachers identified aspects of the data as useful for their work, many features were described as being difficult to understand. Even tertiary educated adults may not be well prepared for dealing with quantitative data in their workplace. There are lessons, too, for the presentation of statistical information.

Introduction

Since the 1990s there has been increasing recognition of the importance of statistical literacy, or the statistical understanding needed for everyday life as an informed citizen. However, statistical literacy for the workplace may mean more than this. The project reported here focuses on the needs of the education workforce and presents some preliminary work examining teachers' perceptions of the complexity and value of one statistical report of the kind received by teachers. The report was chosen because it has elements typical of those prepared by the Victorian NAPLAN Data service and provided to schools. In reporting our findings we will first review key literature related to statistical literacy and then propose a framework for "professional" statistical literacy. This is followed by details of the current study and the results for the chosen data report. Finally we consider the implications of these findings for both school mathematics and for pre-service and in-service teachers' professional learning.

Background

In education—as in other workplace sectors—quality control, accountability, and forward planning are informed by statistical data. The technological revolution has supported the collection, analysis, and sharing of vast quantities of data. Australia, for example, has developed a *Measurement Framework for National Key Performance Measures* (Ministerial Council on Education, Employment, Training and Youth Affairs, 2007) to monitor and advance outcomes from school education. Governments expend significant resources on collecting such data from the education sector via, for example, the National Assessment Program: Literacy and Numeracy (NAPLAN) involving students in Years 3, 5, 7, and 9 from all states and territories, with these intended to

inform planning and practice. In Victoria the Victorian Curriculum and Assessment Authority (VCAA, n.d.) provides reports to schools. Despite the expectation that performance data be used to improve teaching and learning (e.g., Boudett, City, & Murnane, 2005), the extent to which this occurs is not clear. A pilot survey of Victorian mathematics teachers (Pierce & Chick, in-press) found low engagement, but never-the-less an expressed desire for guidance on using data well.

Statistical literacy for the workplace

Reading and interpreting statistical reports requires more than conventional literacy: it requires statistical literacy. Analysing and interpreting quantitative data in the context of a school setting—or any workplace—is not a trivial task. The concept of statistical literacy has been well encapsulated by Gal (2002) as the ability to interpret and evaluate statistical information from diverse contexts, and discuss the meanings of, implications of, and concerns about such data and conclusions. For the education workplace this definition encompasses the expectation that teachers should be able to interpret national testing data (being data "encountered in diverse contexts").

Issues surrounding teachers' capacity to interpret and use statistical reports have been noted internationally, as illustrated by three examples. Matthews, Trimble, and Gay (2007), writing from their Georgia, United States experience, expressed concern that teachers need to be able to interpret data in terms of the local context. An Organization for Economic Cooperation and Development (2004) report on the improvement of education in Chile discussed the introduction of national testing in that country. It also found that constructive use of data seemed to be restricted by teachers' lack of capacity to interpret the reports they received. Finally, and locally, a pilot study with junior secondary mathematics teachers and junior secondary English teachers (Pierce & Chick, in-press) suggested that some of these Victorian teachers felt that Australian testing data were difficult to understand.

Framework

In order to analyse "professional statistical literacy" generally, and for education settings in particular, we propose a framework for considering the elements of statistical thinking that are important for those who must engage with workplace data. Other frameworks already exist that address parts of the issue, but they are focused on children's learning rather than the tasks faced by professionals. Curcio's 1987 study of graph comprehension in Year 4 and Year 8 students highlighted the ideas of "reading the data" (read direct factual information on the graph), "reading between [or within] the data" (attend to two or more data points on the graph, often for comparison), and "reading beyond the data" (extend, predict, and infer from the data). More recent work of Shaughnessy and colleagues (1996, 2007) suggests an additional category, "reading behind the data", which addresses the context from which the data arise. Watson (2006) also emphasised the place of context in the interpretative process. The first tier of her three-tiered statistical literacy hierarchy involves understanding of basic terminology, and then the second tier requires "an understanding of probabilistic and statistical language and concepts when they are embedded in the context of wider social discussion" (p. 16). The third tier concerns the ability to challenge and question statistical claims. The statistical knowledge base posited by Gal (2002, p. 10) also

indicates the importance of knowing why data are needed, having familiarity with basic terms, and understanding how statistical conclusions are reached.

Our proposal for a framework to encapsulate *professional* statistical literacy is shown in Figure 1. The professional—the teacher in the case of this study—needs to be able to examine the data at several levels, each more complex than and dependent on the lower levels (indicated by overlapping circles). *Reading values* requires a technical understanding of labels, scale, data type (e.g., numerical, categorical) and things like percentage versus percentile. *Comparing values* requires an awareness of relative and absolute differences, early informal inference, and low-level statistical tools. *Analysing the data set* involves being able to consider the data as a whole: observing and interpreting variation, observing and interpreting trends, observing and interpreting changes with time or other variables, and attending to the significance of results.

All statistical data are numbers in context, represented here by the surrounding context that impacts on the data and which should be considered in the teachers' interpretation of the outcome of their examination of the data. First, the *Professional Context* involves knowledge of information recognised within the whole profession and needed for the data set (e.g., meaning of special terms such as "band", "like schools", "VELS level"). Finally, the *Local Context* comprises contextual understanding that may be known by individuals about the specific data set but is not evident in the data set alone (e.g., knowledge of local school situation, knowledge about timetabling issues affecting class composition). The boundary between the two context components may not be distinct, as indicated by the dashed line.

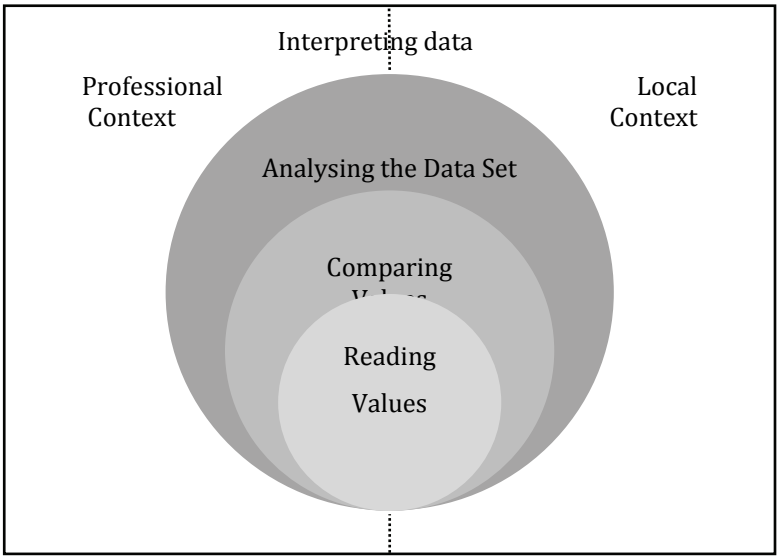


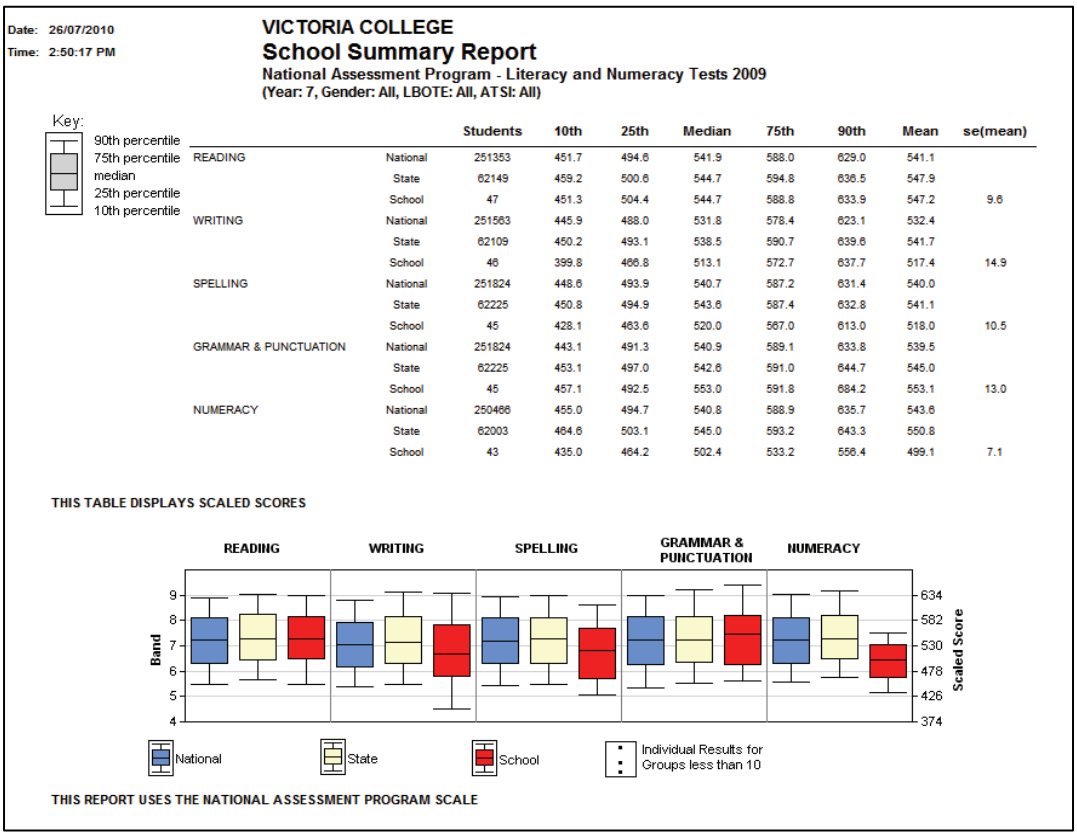
Figure 1. A framework for considering professional statistical literacy.

The study

This study was conducted with teachers from Victorian government schools. The Department of Education and Early Childhood Development (DEECD) operates through a structure of regions. A cluster sample of 20 schools—10 primary and 10 secondary—was obtained by first randomly selecting one network from each of the 4 metropolitan and one of the 5 non-metropolitan regions, then randomly selecting 2 primary and 2 secondary schools from those networks. The school principal (or their

"data expert" nominee) together with 7 randomly selected teachers from each school were asked to participate by completing a questionnaire. The first part of the questionnaire probed demographic background, information about the use of statistical reports in each school, and attitudes and beliefs about statistical reports. The second part examined statistical literacy.

This paper reports data from part of one item in the statistical literacy section of the questionnaire, concerning the NAPLAN report shown in Figure 2. It was chosen for this study because it presents both graphical and tabular information, showing school, state, and national data. Three prompts (see Figure 3) probed teachers' affective and cognitive responses by asking about the aspects of the report that teachers thought they would make *use of* and those that were *hard to make sense of*. These prompts focus on teachers' perceptions of the usefulness and difficulty of the NAPLAN report; the resulting data set provides indirect information about the teachers' statistical literacy.



		Students	10th	25th	Median	75th	90th	Mean	se(mean)
READING	National	251353	451.7	494.6	541.9	588.0	629.0	541.1	
	State	62149	459.2	500.6	544.7	594.8	636.5	547.9	
	School	47	451.3	504.4	544.7	588.8	633.9	547.2	9.6
WRITING	National	251563	445.9	488.0	531.8	578.4	623.1	532.4	
	State	62109	450.2	493.1	538.5	590.7	639.6	541.7	
	School	46	399.8	466.8	513.1	572.7	637.7	517.4	14.9
SPELLING	National	251824	448.6	493.9	540.7	587.2	631.4	540.0	
	State	62225	450.8	494.9	543.6	587.4	632.8	541.1	
	School	45	428.1	463.6	520.0	567.0	613.0	518.0	10.5
GRAMMAR & PUNCTUATION	National	251824	443.1	491.3	540.9	589.1	633.8	539.5	
	State	62225	453.1	497.0	542.6	591.0	644.7	545.0	
	School	45	457.1	492.5	553.0	591.8	684.2	553.1	13.0
NUMERACY	National	250466	455.0	494.7	540.8	588.9	635.7	543.6	
	State	62003	464.6	503.1	545.0	593.2	643.3	550.8	
	School	43	435.0	464.2	502.4	533.2	556.4	499.1	7.1

Figure 2. Victoria College's School Summary Report created by VCAA for NAPLAN Data Service.

A. Please identify any aspects of this report which you think *might be of use to you as a teacher* by *circling it/them* and annotating the relevant aspects to indicate what is helpful and why.

B. Please identify any aspects of this report which you think *are hard to make sense of* by *drawing an arrow* to it/them and annotating the relevant aspects to indicate what may cause difficulties and why.

C. Any other comments about this particular report:

Figure 3. Excerpt from survey questions.

The teachers' responses were pooled, with annotations in some cases to capture key points and any highlighted material, and the resulting data were examined to identify

major themes associated with the teachers' views of the value and accessibility of the statistical information in Figure 2. The themes were analysed in the light of the "professional statistical literacy framework". Although statistical skills were not directly examined by prompts A to C, the data provide evidence of how the participants' statistical literacy might drive their reactions about the usefulness of the data. For the purposes of this analysis, no distinction is drawn between principals (or nominees) and teachers.

Results

Data were received from a total of 150 teachers: 41 males and 109 females. The professional and statistical backgrounds of those in the sample were diverse. The secondary teachers came from the full range of disciplines and the primary teacher participants included language and music specialists. Subject, year level, curriculum, and student welfare co-ordinators were also present in the sample. The teachers' mean number of years of teaching was 13.7 (SD=11.2). Their statistical backgrounds also varied widely, with 23.3% claiming never to have studied statistics formally as a subject or topic, 13.3% only having such study prior to or in Year 10, 26% having studied some statistics at Year 11 or 12, and 37.3% having done statistical study beyond Year 12. Sixty percent of respondents indicated they had attended professional learning program(s) related to student achievement data/school system data.

There were two versions of the questionnaire, the second reversing the order of most of the statistical literacy items. This structure meant that our focus report (Figures 2 and 3) was one of the last items on the questionnaire for about half of the teachers, and so not all teachers may have had time to attempt it. Of the 150 teachers in the study, 143 responded to at least one part of the item that included three statistical literacy questions and prompts A, B, and C (Figure 2). Thirty-eight teachers did not respond to any of the A, B, and C prompts, so the data here are from 112 primary and secondary teachers.

Four major themes emerged from the data: (i) technical, statistical issues related to tables; (ii) technical, statistical issues related to graphs; (iii) knowledge or understanding of statistical terms and measures (notably lack of knowledge of "bands", "scaled scores", and "se(mean)"); and (iv) reactions based on personal preferences. The first two themes relate largely to reading and comparing values; the third theme relates largely to the professional context, but also incorporates understanding of the more advanced statistical skills required to analyse the data set; and the fourth theme is influenced not only by technical issues but also by local context. Rather than organise the discussion by the themes themselves, we have incorporated them within the categories of the framework for professional statistical literacy, along with a section on "reactions". The details will be discussed below, illustrated by quotes from the teachers' responses to prompts A, B, and C. In general it will be clear from the content of the quote whether the teacher was responding to A (useful aspects of the NAPLAN report) or B (difficult aspects of the NAPLAN report).

Reading and comparing values — Dealing with graphs and tables

First, it was clear from the data that the teachers wished to be able to read the data to gain some idea of the spread or variation in the scores of the students they need to cater for in teaching. Many of them wrote about the school data and what that meant for the

individuals within the school's classes. Second, it was evident that they wished to make at least broad comparisons in order to assess their school's results with those of the state and note differences in the students' performances on different tests.

Turning now to specific aspects of the report deemed useful or difficult, the graphs were commonly mentioned as helpful and easy to read (e.g., quotes 1-3) while the table was more commonly associated with difficulties (e.g., quotes 4-8)

1. [Graph] Graphical representation [is helpful]. It's good to be able to compare the different areas and see the spread of results.
2. [Graph] Boxplots makes it much easier to make comparisons when compared to tables.
3. [Graph] Easy to compare school with state and national results; mean as well as "spread" of student results. Easy.
4. [Table] Hard to make sense of — too many numbers, don't understand layout.
5. [Table] Unsure of 10th, 25th etc [percentiles]; too many figures.
6. [Table] I could not understand the table. I would need someone to explain it to me.
7. [Table] Too many figures and comparisons.
8. [Table] These statistics don't make sense to me.

However, these views were not held by all respondents. In contrast, some found graphs difficult (e.g., quotes 9-10) or tables helpful (e.g., quotes 11-13).

9. [Graph] Hard to read this type of graph [boxplot]. I don't get it.
10. [Graph] I find this report a bit difficult to interpret as I struggle to decipher boxplots.
11. [Table] Good for specific info [Graph] Quick.
12. [Table] Good to show mean here where it is not shown in the graphs below.
13. [Table] The median and mean scores are helpful for determining how our school is performing in comparison to other schools.

There were two difficulties related to reading values that were commonly mentioned, associated with not understanding a specific technical term. The standard error of the mean (appearing in the table of Figure 2 as se(mean)) was specifically highlighted by 17 of the teachers in response to prompt B (e.g., quotes 14–15), and the "scaled scored" or "bands" on the graphs were also mentioned frequently (e.g., quotes 16–18). Although se(mean) is a standard statistical term, it is a concept that might not be considered a necessary part of statistical literacy for good citizenship and is not covered in the compulsory years of schooling. Here, however, understanding se(mean) is necessary for these teachers' "professional statistical literacy". The "scaled scores" and "bands", in contrast, are not so much technical statistical terms, but arise from the professional context of the way in which the NAPLAN test results are processed. This will be discussed further below.

14. [se(mean)] Not sure what this column is?
15. What is se(mean)?
16. Scaled scores or bands - these numbers mean nothing to me.
17. "Bands" aren't descriptive. What classifies a band?
18. [Scaled scores] I'm not exactly sure what these scores mean.

Other issues related to reading the data were noted by the researchers but not by the teachers, and reveal aspects of the teachers' statistical literacy. It is of concern that, while many teachers noted that having a key was useful not all teachers noted the details in the key. The boxplot, as is usual and as the key states, shows the median, not the

mean mentioned by some teachers (see quote 19). The key also reveals that the boxplots being used in the graphs are not typical of most boxplots, with the whiskers truncated at the 10th and 90th percentiles. Consequently it does not show the top or bottom students' results (see quotes 20 and 21). Some teachers also have difficulty understanding that boxplots represent percentiles of the student cohort not numbers of students (22).

19. [Graph] The means and range of student outcomes in all graphs gives me a general whole school indication.
20. The whisker showing how top and bottom students are performing [is useful].
21. [Graph: top and lower tails] Highest 10%, lowest 10%, tell us they may need support ...
22. [Graph - school writing] the long tail means that there is a big group of students who need extra support.

Analysing the data set

Most analysis was at the simple level of noting the variability or spread of students' results. Several teachers commented that they would like to be able to see trend data, with one teacher actually trying to get a better picture of the whole data by deriving some additional information (quote 23).

23. [The teacher created a new row in the table noting increased differences between the school and state results for the 10th, 25th, etc., percentiles] As we went up the scale the difference between us and the state became greater—weaker children catered for, top half not?

One teacher wondered if the size of the school group should be taken into consideration when analysing the data. While the teacher's question highlights some lack of statistical literacy, it also reveals appropriate thinking about issues that may need to be considered when analysing the data.

24. Do the huge difference in numbers for each group skew the results? How can 251353 [State] be compared to 47 [School] as sample numbers?

Considering local and professional contexts

Some teachers expressed difficulty or lack of familiarity with details that are part of the Australian education context, i.e., their own professional context. The vertical scales on the graphics show "bands" at the left and the related "scaled scores" on the right. The table shows statistics (to one decimal place) based on "scaled scores". These scores, scaled in theory from 1 to 1000, are produced by the Australian Curriculum, Assessment and Reporting Authority (ACARA), which then divides these scores into "bands" and sets national minimum benchmarks for each year level tested. It is a complex process but it is part of teachers' "professional" statistical literacy to at least be familiar with the parts of the scale that apply to their students (see quote 25). Several teachers commented on the confusion between "bands" and the more familiar numbered levels associated with the Victorian Essential Learning Standards (VELS) (e.g., quotes 26 and 27). Some teachers were not familiar with the acronyms ATSI (Aboriginal or Torres Straight Islander) and LBOTE (Language Background Other Than English) (quote 28), despite the fact that these are now standard acronyms used in schools.

25. Scaled scores or bands - these numbers mean nothing to me.
26. I don't believe anyone understands national benchmarks or its comparison to VELS.

27. Suggest a graphic indicating comparison to VELS levels would be more useful.
28. [Points to the acronym ATSI] What does this mean?

Local context requires knowledge of details of the school and student cohort referred to in the report. This was impossible since the report summarises data from a fictitious school, so teachers made little attempt to explain the findings but suggested generic responses that would be appropriate (quotes 29–32).

29. [Circled sections on school boxplots below the median] What can be done to improve the results; targeted intervention. [Referring to numeracy plot] As a year 7 teacher you would plan to go back to the primary curriculum to give students a greater understanding.
30. [Grammar & Punctuation plot] Why are the scores so high at the top compared with state/national top?
31. [School writing plot] Why such a spread? [Top whisker of Grammar & Punctuation plot] Why so well? [Numeracy plot] Why so low?
32. School appears to be focusing on Reading and Writing but little focus on maths/numeracy. – Hard to judge without previous years' figures to see changes.

Reactions

It was clear that some teachers were overwhelmed by what they perceived as the complexity of the report (e.g., quotes 33-39). Some teachers expressed the view that they did not intend to engage with such reports for a variety of reasons (e.g., quotes 40–42), including sheer cynicism regarding statistics (quote 43).

33. I found this whole sheet confusing.
34. This would be useful if I knew what it referred to.
35. … not keen on tabled data—prefer visual. I would prefer one system:VELS. I don't believe everyone understands national benchmarks or its comparison to VELS.
36. Too many figures and comparisons.
37. Top half of the report: figures don't make sense to me.
38. I need some PD on how to interpret box-and-whisker.
39. This only works for colour photocopiers.
40. I would not use this report to inform my teaching.
41. As the LOTE teacher in the school, I don't feel that this data does a great deal for me.
42. As an English teacher I don't respond well to numbers and tend to dismiss them.
43. ... Still one can make stats say anything, can't one.

Implications and conclusions

The results provide an important snapshot of the way that teachers might respond to the school assessment data that they receive. Their reactions range from those verging on the statistics-phobic (e.g., responses 33 and 42), through to deep engagement with the issues. The contrasts in the reactions of teachers to different types of representations of data (tables versus graphs) was interesting, and has important consequences for those who prepare data for schools. Although there was a marked preference for graphical representations, these were still problematic for some, and others appreciated the detail provided within the tables. Many teachers reacted strongly about the overwhelming complexity of the data, with quotes 33–37 being but a sample of the 50 or so teachers who expressed uncertainty or confusion over some or all aspects of the data.

Although this part of the research project did not target specific skill-based competence within statistical literacy, the teachers' responses to prompts A, B, and C still revealed

specific areas of difficulty, particularly with general boxplot reading skills. The non-standard presentation of the boxplot data may contribute to this, especially since other reports (not shown here) are different again.

The results point to a strong need for professional development in the area of professional statistical literacy, and also has implication for pre-service courses. They also alert us to important issues related to teaching statistics at the secondary level, such as preferences for graphical or tabular presentations of data, and difficulties with reading, comparing or interpreting data. Although boxplot representations provide a concise summary of data, many teachers appear to be in need of more experience with interpreting data in this form. The extent of teachers' difficulties and ways of developing their fluency in interpreting such data is an issue for future research.

Acknowledgements

This research is funded by the Australian Research Council (LP100100388), the Victorian Curriculum Assessment Authority and the Victorian Department of Education and Early Childhood Development. We acknowledge the contributions of other members of the research team: Ian Gordon, Sue Helme, Roger Wander (University of Melbourne); Jane Watson (University of Tasmania); Magdalena Les (VCAA); and Sue Buckley (DEECD). We also thank all participating schools and teachers.

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