HELEN L. CHICK and ROBYN PIERCE

TEACHING FOR STATISTICAL LITERACY: UTILISING AFFORDANCES IN REAL-WORLD DATA

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ABSTRACT. It is widely held that context is important in teaching mathematics and statistics. Consideration of context is central to statistical thinking, and any teaching of statistics must incorporate this aspect. Indeed, it has been advocated that real-world data sets can motivate the learning of statistical principles. It is not, however, a straightforward task to take a real-world example and incorporate it into a lesson that will teach important statistical principles. This paper considers issues involved in using real data to exemplify statistical ideas and examines pre-service teachers' attempts to design teaching activities using such data. Pre-service teachers were supplied with a topical data set and asked to plan lessons that would teach some key statistical idea to year 6 students. The lessons were analysed using a hierarchy for teaching statistical literacy, and great variation was found in the level of statistical thinking demanded in the planned lessons. Teachers who had completed a preliminary activity helping them to think carefully about what might be taught from real data in general produced lessons with stronger statistical content. A key requirement for having lessons with deep consideration of statistical ideas is to identify the actual affordances for teaching contained within a data set; the planning process then benefits from explicit attention to making that content evident in the teaching activities.

KEY WORDS: affordances, lesson planning, pedagogical content knowledge, statistical thinking

Introduction

In many countries over the last 20 years, statistics has gained a greater presence in the school mathematics curriculum, even in the primary (elementary) grades (e.g. National Council of Teachers of Mathematics, 2000; Victorian Curriculum & Assessment Authority, 2008). The need to increase students' statistical literacy skills has been widely argued, given the importance of these skills within society at large (e.g. Pfannkuch, 2008; Watson, 2006; Wild & Pfannkuch, 1999). This real-world relevance has also been emphasised as one of the ways of approaching the teaching of statistics, including through the use of examples from the media (e.g. Watson, 1997, 2006). Given the push for using real-world examples, this paper examines the complexities for teachers of taking real-world situations and using them to facilitate the learning of statistical literacy.

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Background

The importance of “statistical literacy” (Wallman, 1993) in the education of students has received increasing attention in the last two decades. To be statistically literate requires having knowledge and understanding of numeracy, statistics, general literacy and data presentation, sufficient for making effective use of quantitative data and summary reports in a personal or professional setting (Ben-Zvi & Garfield, 2004; Gal, 2002; Watson, 2006). It includes the ability to question data sampling techniques, to evaluate explanations and consequences of the data and to identify limitations in the data and the conclusions. Statistical literacy is fundamental for students to be able to make sense of, and make sensible decisions about, the vast amount of data that they encounter in their daily lives. Franklin, Kader, Mewborn, Moreno, Peck, Perry & Schaeffer (2005, p. 1) highlighted how critical statistical literacy is: “Every morning the newspaper and other media confront us with statistical information on topics ranging from the economy to education, from movies to sports, from food to medicine, and from public opinion to social behaviour”. In Australia, a government report highlighted that “The ability to make sound judgments and deal analytically and critically with information presented in varied forms and often involving complex data, is important for informed citizenship” (Department of Education, Training & Youth Affairs, 2000, p. 13). This importance is emphasised in learning benchmarks that highlight the capacity to interpret data, even in the primary grades (Curriculum Corporation, 2000).

This emphasis raises the question of how to teach statistical literacy effectively. Many educators have advocated the use of real-world examples as a motivator for learning. Lajoie, Jacobs & Lavigne (1995) suggest that:

> Alternative teaching methods that utilize a problem-solving approach to teaching statistics at the elementary and secondary schools can reinforce the active nature of learning … Doing statistics involves opportunities to inquire, investigate, analyze, and interpret rather than to compute and memorize. Such active involvement makes statistical terms more meaningful, facilitates understanding, and demonstrates the use of statistics in analyzing real-world problems. (p. 411)

Miller (2004) suggests that getting real-world ideas into mathematics lessons is as simple as reading the morning paper, but there are, in fact, complexities. Real-world examples are not intrinsically good: They may not be useful for teaching or even be valid statistically. Furthermore, even well-chosen examples may be difficult to use effectively in the classroom.

Nevertheless, Watson (2006) highlights the importance of teachers providing students with productive experiences with real-world examples. The citizens of the future require a sound foundation for statistically literate engagement with media reports and other data.

There are necessary prerequisites for the successful teaching of statistical principles using real-world data; among them, the following three stages are relevant to the current study (see Chick & Pierce, 2008a). First is the requirement that teachers have sufficient statistical literacy to be able to interpret and question the data. Second, teachers need the capacity to identify the statistical principles that can actually be taught through the data. Finally, teachers must be able to design lessons, with sound pedagogy, that bring to the fore the statistical principles to be learned by the students. We will look at these three stages in turn.

Understanding Content: the Statistical Literacy Hierarchy

The first requirement—adequate statistical literacy on the part of the teacher—is the content knowledge necessary for successful teaching. It is also a goal of successful teaching, to be achieved by the teacher's students. In the *Guidelines for Assessment and Instruction in Statistics Education* report, Franklin et al. (2005) provided a framework for statistical problem solving involving four steps: formulate questions, collect data, analyse data and interpret data. Within each step, there are three hierarchal levels, with progression characterised by a greater engagement with context and deeper understanding of statistical tools, techniques and principles. To work with the already partly processed statistical information presented in the media, it is the "interpret data" step that is particularly critical. Nevertheless, this step itself requires some understanding of how the data have been collected and analysed and for what purpose, so the other steps also require attention. Even when interpreting "processed data", the teacher needs to be able to guide students through the task of considering all of the steps. The case of graphical representation of data is particularly significant, since many media articles present data in graph form. Monteiro & Ainley (2007) refer to *transparency* in reporting their work on student teachers' interpretation of media graphs. This idea encompasses the notion of looking not only "at the graph" but also "through the graph" to incorporate consideration of context; it is affected by both the design of the graph and the ability and knowledge of the reader. The capacity to look through and beyond the graph—making sense of context, trends and implications—rather than merely reading data points is central to statistical literacy. Aoyama & Stephens (2003) draw attention to the work of the respected Japanese educator, Kimura, who has suggested that the "key task of statistical literacy is to extract qualitative information from quantitative information and/or create new information from quantitative and qualitative data" (p. 207). This requires attention to context and the ability to reorganise and analyse information. However, learning to interpret data and to develop critical thinking with data—and teaching students how to do this—is not a trivial task.

A more fine-grained framework for considering individuals' levels of statistical literacy is provided by the statistical literacy hierarchy of Watson & Callingham (2003). Their framework derives from a Rasch analysis of students' responses to a wide variety of statistical literacy tasks and reflects increasing critical engagement with the data, variation and context. There are six levels in the framework: *idiosyncratic*, *informal*, *inconsistent*, *consistent non-critical*, *critical* and *critical mathematical*. At the lowest, idiosyncratic, level, the user engages with the data in unconventional or unfocussed ways, with simplistic or even incorrect application of statistical principles; the user may correctly read single data points but for no clear purpose. Progressing through the middle levels of the hierarchy, there is growing facility with appropriate terminology and methods and an increasing capacity to attend to context, inherent variation and implications of the data. At the highest level, critical mathematical, there is a critical, questioning engagement with the context, use of proportional reasoning, appreciation of the need for uncertainty in making predictions and capacity to interpret subtle aspects of language (p. 14). This framework will be presented in more detail later in the paper because if we interpret the critical mathematical level as a *goal* of schooling, then it is of interest to examine the statistical literacy levels aimed for by teachers in their lessons.

Identifying Potential for Teaching: Affordances

The second requirement for the successful teaching of statistical literacy through the use of real-world data is the capacity to identify exactly what principles can be addressed through the example or data. A teacher needs to be able to determine if, for example, a data set is suitable for illustrating the idea of mean. The concept of affordances, originating with Gibson (1977) and adapted by Chick (2007), is useful here. Chick defined the term *potential affordances* as the opportunities that are inherent in a task, lesson or example. Teachers may or may not recognise all the affordances that an example has; this depends on (a) their content knowledge or, in other words, their own level of statistical literacy, together with (b) the vision to see that the example could be utilised in the classroom. This latter requirement is loosely posited as an aspect of pedagogical content knowledge (Shulman, 1986). If a teacher develops lessons around a real-world data set or situation, then these lessons can only reflect the affordances the teacher has identified, and not necessarily all the potential affordances that are present.

Planning for Teaching: a Proposed Hierarchy for Statistical Literacy Lessons

Finally, there is a third requirement: The teacher then has to turn the data set—and the affordances it offers—into a didactic object in the classroom (Thompson, 2002, p. 198), so that it demonstrates the desired statistical principles or concepts to students. That the task of turning an important example into a pedagogically productive lesson is complex has been highlighted in the study of Sullivan, Clarke & Clarke (2009). They reported on the challenges experienced by a group of teachers in turning a powerful problem into a suitable lesson that would convey the mathematical ideas. They observed that many of the lessons proposed by teachers addressed the critical concepts only vaguely.

It is this step, when a real-world example is turned into a didactic object, which determines whether or not desired principles are likely to be learned in the classroom. In particular, if statistical literacy is to be developed through classroom activities with real-world data, then teachers' lessons must develop the statistical skills and dispositions at the upper levels of the statistical literacy hierarchy of Watson & Callingham (2003). Although this hierarchy originally referred to *students' responses* to statistical tasks, discussion with Watson (personal communication) validated our conjecture that a simple reinterpretation of it might provide a hierarchy for the *teaching* of statistical literacy. This is presented in Table 1, illustrated with examples based on the lesson planning task used in this study. As before, the higher levels of the hierarchy are characterised by lessons and activities that encourage students to address context, conduct deep and critical analysis and bring to bear more sophisticated statistical tools. There seems to be potential to evaluate lessons according to this modified hierarchy, on the assumption that such an evaluation is indicative of what levels of statistical literacy the lessons might allow students to attain.

Teachers Teaching for Statistical Literacy

The current study investigates two of the three stages identified as being prerequisite for successfully teaching statistical literacy, namely the

TABLE 1

A Teaching for Statistical Literacy Hierarchy (adapted from the statistical literacy hierarchy, Table 3, Watson & Callingham, 2003)

Level	*Lesson characteristics for participating students*	*Examples with the Melbourne Water Data*
6. Critical mathematical	Lessons at this level demand critical, questioning engagement with context, using sophisticated mathematical reasoning particularly in media or chance contexts, showing appreciation of the need for uncertainty in making predictions and interpreting subtle aspects of language.	Lesson requires students to interpret the variation and trends in water levels throughout a year and over several years (e.g. seasonal changes or compare same months in different years), with differences discussed in percentage terms (not absolute terms); students make predictions while also discussing what may influence the actual outcomes.
5. Critical	Lessons at this level require critical, questioning engagement in familiar and unfamiliar contexts that do not involve sophisticated mathematical reasoning, but which do involve appropriate use of terminology, qualitative interpretation of chance and appreciation of variation.	Lesson requires students to interpret the variation and trends in water levels throughout a year and over several years (e.g. seasonal changes or compare same months in different years), with differences discussed in absolute terms; has students make predictions while also discussing what may influence the actual outcomes.
4. Consistent non-critical	Lessons at this level require appropriate but non-critical engagement with context, multiple aspects of terminology usage, appreciation of variation in chance settings only and statistical skills associated with the mean, simple probabilities and graph characteristics.	Lesson requires students to describe simple characteristics of the graph, but without discussing the variation or seasonal effects. Some comparisons might be made, but without questioning or encouraging explanation.
3. Inconsistent	Lessons at this level expect selective but inconsistent engagement with context, appropriate recognition of conclusions but without justification and qualitative rather than quantitative use of statistical ideas. Some statistical ideas evident, but not connected to each other or related to the context in any depth.	Lesson requires students to produce a table of data from the graph, e.g. from 1 year only, and may observe trends but without discussing reasons. Students also required to read graph data, but without being related to the broader context of the drought.
2. Informal	Lessons at this level require only colloquial or informal engagement with context often reflecting intuitive non-statistical beliefs, single elements of complex terminology and settings and basic one-step straightforward tables, graphs and chance calculations.	Lesson requires students to read off the highest and the lowest water storage levels and calculate the difference; discussion may be about water evaporating.
1. Idiosyncratic	Lessons at this level suggest idiosyncratic engagement with context, tautological use of terminology and basic mathematical skills associated with one-to-one counting and reading cell values in tables.	Lesson fails to address any statistical concepts; or asks students to “read values” without attending to context or meaning; or incorporates activities that are not related to the given data (e.g. collect rainfall data from around the school)

identification of affordances and then planning an appropriate lesson. The issue of teachers' personal statistical literacy (or content knowledge) is not examined explicitly; we note that the participants all had similar backgrounds in basic high school statistics and the material covered in their education course (described below). In order to examine the complexities of teaching through the use of real-world data, the following research questions are addressed:

1. What affordances for teaching do teachers identify in a supplied real-world data set?
2. What, of these affordances, do they actually choose to plan to implement in their lessons?
3. What levels of the statistical literacy hierarchy are evident in their lesson plans?
4. What impact does a simple guided introduction to mathematical affordances in real-world situations have on teachers' capacity to identify and plan teaching to incorporate affordances in new situations?

In addition, the usefulness of the modified hierarchy for analysing the potential of lessons for developing statistical literacy is examined.

Method

The Participants

The participants were consenting students enrolled in the "advanced" stream of a mathematics education subject for pre-service primary (elementary) school teachers in Australia. To be permitted to enrol in the advanced stream, the pre-service teachers (PSTs) had to be in the top 20% in the prerequisite mathematics education subject. The PSTs were in their fourth semester of a sequence of mathematics education subjects, which focussed on primary-level content and pedagogy. In their second semester of study, about 10 months prior to this research, they had completed a unit on "chance and data". This had considered types of graphs, aspects of graph reading (including Curcio's (2001) framework of "read", "read between" and "read beyond") and measures of central tendency. The participants were pre-service teachers rather than practising teachers, which ensured that (a) participants had similar known backgrounds, (b) the study used a reasonable sized sample, (c) time was available to complete the task and produce a well-defined data set and (d) a "treatment" aspect for the study was possible. The pre-service teachers had had 4 weeks of classroom practicum experience as part of their course. It is acknowledged that the experience and teaching expertise of practising teachers compared to the pre-service teachers may produce different results, but the authors have anecdotal evidence from their professional development work with practising secondary teachers that, in fact, the outcomes would be similar to those reported here.

Two cohorts of PSTs were involved in this study, one from the year 2007 (27 PSTs) and the other from the year 2008 (also 27 PSTs). The data for this study were generated from a lesson planning task given to both cohorts. The 2007 cohort completed this lesson planning task as a stand-alone activity in a workshop, conducted by the second author. The 2008 cohort had a preliminary workshop on identifying affordances in real-world situations 1 week prior to completing the lesson planning task. The preliminary workshop was conducted by the first author, with the second author observing and making field notes. The lesson planning task was then conducted by the first author in the following week's workshop using the same protocols as those established in 2007. All workshops were 110 minutes in duration.

The Lesson Planning Task

The lesson planning task required the PSTs to examine a website containing real-world graphical and tabular information and prepare a lesson to teach some statistical principles of their choice. As a teaching context, the PSTs were asked to imagine teaching a grade 6 class (typically 11- and 12-year-old students) that had been studying about "their environment". The real-world information given to PSTs was about local water storage levels, obtained from the Internet (Melbourne Water, 2007). Public awareness about water storage levels was heightened because of recent extended drought conditions and legislated restrictions on water use in the region. The topic had a high profile in the media and primary school students were aware of water conservation issues. The data on the website included a table that showed capacity, current actual volume, percentage full, overnight change in volume and 24-h rainfall information for nine local water storage reservoirs. In addition, an interactive line graph showed the "total volume" and "percentage full" information for the entire water system over the course of a year, for every year since 1997, and could display one or more years simultaneously. The PSTs were shown this interactive graph in class, but were also given a hard copy showing all the years' data as multiple lines on a single static graph as shown in Figure 1 (which shows the 2007 data).

After being shown the data and being informed of the grade 6 teaching scenario, the PSTs were told to imagine that they had discovered these data while browsing on the web and had realised it could be used in planning a lesson involving some cross-disciplinary "integrated curriculum" work. To gather data about their perceptions of the affordances in the resource and to help orient them to the lesson planning task, the PSTs were first asked to provide individual written responses to four preliminary questions, two of which are relevant for this report:

(a) What are some of the statistics/"data" topics you think you could address in class with this resource?

Melbourne's water storages are currently 38.4% full
Water storage data as at 23/8/2007
Melbourne's water consumption to 8am today (includes Western Water): 987ML

Reservoir	*Capacity*	*Current Volume (ML)*	*% Full*	*Change since yesterday (ML)*	*Rainfall (mm) to 8:00am*
Thomson	*1,068,000*	*262,225*	*24.6*	*+649*	*0.0*
UpperYarra	*200,000*	*146,262*	*73.1*	*+423*	*0.0*
O'Shannassy	*3,000*	*3,075*	*100.0*	*-51*	
Maroondah	*22,000*	*18,681*	*84.9*	*-54*	*0.0*
Sugarloaf	*96,000*	*53,827*	*56.1*	*+356*	
Yan Yean	*30,000*	*6,189*	*20.6*	*+39*	
Greenvale	*27,000*	*16,702*	*61.9*	*-14*	
Silvan	*40,000*	*34,755*	*86.9*	*-340*	*0.0*
Cardinia	*287,000*	*138,913*	*48.4*	*-87*	
Total	*1,773,000*	*680,629*	*38.4*	*+1095*	

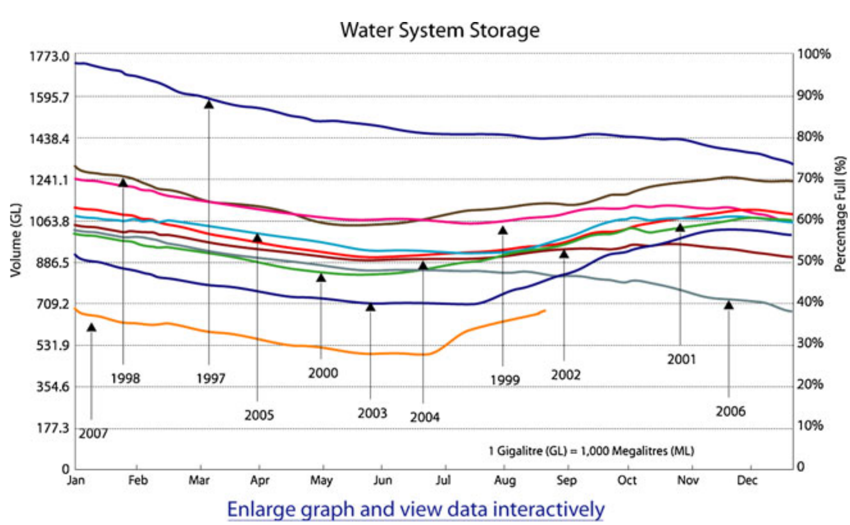

Figure 1. Melbourne water data used for the lesson planning task (Melbourne Water, 2007)

(b) What are some of the questions you might ask children to answer or consider, with this resource?

Next the PSTs were asked to work in pairs, using a supplied template, to plan a lesson to teach the hypothetical grade 6 students some aspects of statistics/"data" using the Melbourne water website page. The lesson plan template emphasised an "introduction, main content, conclusion" basic structure for the lesson and was annotated with reminders to think carefully about how to incorporate content, identify what questions to ask and explain what examples they would use. This generated a total of 27 lesson plans for analysis: 13 from the 2007 cohort and 14 from the 2008 cohort. The PSTs were informed that the lesson's duration could be as long as necessary to achieve their objectives. They were also asked to indicate how they would assess students' learning. Local curriculum documents were available for consultation. The data analysed for this study were from the lesson plans and PSTs' responses to questions (a) and (b) above. The lesson plans provided by the participants indicated their intended rather than enacted curriculum (Stein, Remillard & Smith, 2007), since actual taught lessons were not observed. This design allowed consistency (e.g. by removing the confounding factor of teachers having different classes to work with) and also made it easier to probe what affordances were identified.

Potential Affordances in the Water Storage Data

It is important to reflect on what opportunities for teaching are available using the data about this real-world situation. The authors collaborated on producing a list of possible affordances for the teaching of statistics arising from the water storage data, augmented by some of the PSTs' own suggestions. The data provide opportunities for graph and table reading (individual values; looking for maxima, minima, changes; using headings/labels/scales to determine what the graph/table is about; determining trends over time; querying unusual values), identifying and explaining variation in water storage for given months and years, making predictions, relating tabular data to graphical data and vice versa, relating data to their real-world context (e.g. explaining seasonal trends), determining appropriate averages (e.g. average water storage volume at the beginning of July), identifying causes of changes, discussing social implications, evaluating methods of data representation, reinforcing mathematical concepts (e.g. percentage, units of volume), identifying the key "messages" within the data and learning the general process of interpreting and querying real-world data. It should be noted that the resource provides opportunities to learn about and understand the specific water situation, as well as to learn general statistical literacy principles.

The Preliminary Workshop

One week prior to completing the lesson planning task, the 2008 cohort had a workshop intended to explicitly help PSTs identify affordances in real-world data. This occurred during the time of the 2008 Olympic games. The PSTs were given a newspaper page with that day's Olympic games data on it—including competition results, medal tallies and ranking by country—and the workshop leader (the first author) suggested that this was an opportunity to plan a mathematics lesson on something that was of contemporary interest. PSTs were given 10 – 15 minutes to identify three mathematical teaching opportunities capitalising on the resource. To focus their attention on the real-world data and affordances, the PSTs were given a table with a row for each of their three ideas, with column headings to help them to identify the feature in the resource ("What aspect of the resource am I using?"), the mathematics topic involved ("What content area/s is/are present?") and the mathematics teaching opportunity ("What might I do with this in a classroom?"). The table was followed by some additional questions, intended to help PSTs focus on the mathematics within the resource itself.

- What mathematical topics are immediately obvious IN the resource?
- What other mathematical topics can be supported by appropriate use of the resource ITSELF?
- What other mathematical topics could be motivated by the resource but are not DIRECTLY connected to the resource?
- Are there other useful non-mathematical topics that might arise while capitalising on the mathematics?
- At what grade level do you think you could use the resource?

The class then shared some of their ideas, and the workshop leader discussed the idea of "affordances", the attributes of the example/ resource that allow mathematics content to be addressed and how to have a lesson with deep mathematical ideas that are still related to the resource. PSTs then picked one of their three examples (or an idea from someone else that had appealed to them) and developed this into a substantial activity that might form the core of an upper primary school lesson. No direct reference was made to this workshop activity when the lesson planning task was given to them the following week.

Data Analysis

The PSTs' written responses to the questions and their lesson plans for the lesson planning task were collected for analysis. The first research question, concerning the affordances that the PSTs observed in the water storage data resource, was addressed by looking at the PSTs' responses to questions (a) and (b) listed in "The Lesson Planning Task" section. Content analysis (Bryman, 2004) was employed to examine these data for common themes. For question (a), concerning the topics that could be addressed using the water storage resource, the first author recorded the suggestions of the PSTs in a spreadsheet and then conducted a preliminary clustering by common topics. A similar approach was taken for question (b), which asked what questions the PSTs might ask of their students. The categorisations were checked independently by the second author, and any discrepancies were resolved by discussion. Broader categorisations for question (b) were then obtained by further clustering the results, resulting in four general statistical principles (reading data, interpreting data, consideration of context and attention to implications) and the question (b) data were further classified by this scheme.

The lesson plans provided the data to answer the remaining three research questions. The lesson plans were summarised by the first author, to give a more succinct record of the activities, topics, sequence and approaches that the teachers proposed (see Figure 2). These summaries allowed a determination of the topics that the PSTs chose to address (research question 2), using a similar content analysis approach to that used for question (a).

The lessons were then categorised according to the hierarchy for teaching for statistical literacy in order to address the third research

Summary of lesson: "Interpreting measures of centre and spread". Review of mean, median and mode, using arbitrary examples. Discuss table and terms, then get students to order percentage data in pairs. Work out mean percentage full, then median, and ask class how to find mode (and since no "more common value", thus mode is not practical). Have students work out range. Discuss outliers and how extreme they are. Ask if this affects other measures of spread [*Which others?! May have meant "centre" not "spread" based on conclusion*]. Repeat finding mean, median, mode and range for the "change since yesterday" data [this is not explicitly stated, but inferred from the claim that the mode is -8]. Discussion about mode, and if this accurately reflects the centre. Concluding discussion about why use different measures of centre (mean is more affected by outliers, mode may not be in the middle). Discussion about proportion of reservoirs above/below half full. Implications for water conservation.

Topics: Measures of central tendency, data reading, percentages.

Level in the Teaching Statistical Literacy Hierarchy: 4/1 – Consistent non-critical AND Idiosyncratic. [*Intention of good discussion of different measures of centre, and connection to real data and its implications. However, measure of centre applied to wrong type of variable.*]

Figure 2. Example of a lesson summary and its classification

question (see Table 1). As mentioned earlier, the hierarchy for teaching for statistical literacy derives from the statistical literacy hierarchy of Watson & Callingham (2003), and the characterisations in the first column in Table 1 reflect their descriptors for statistical literacy, but adapted for the *teaching* of statistical literacy. The third column of Table 1 illustrates features of a typical lesson plan that uses the water data and has the characteristics of the given level. Higher level responses were characterised by consideration of variation, context and appropriate statistical techniques and terminology. Lower level responses were characterised by incorrect or inappropriate statistical approaches, or a failure to consider context or meaning of the data.

In the process of analysis, some lesson plans showed evidence of being at two distinct levels because they exhibited features of both levels. As an example, one lesson plan gave a careful consideration of different measures of central tendency and the effect of outliers on the mean, median and mode (level 4). However, the variable under consideration was the "percentage full" value for the reservoirs, which, because of the different capacities, was inappropriate for calculation of the mean (level 1). To resolve this, every lesson was assigned a pair of codes (4,1 in the case above), reflecting the two levels evident or, in the case of lessons having a single consistent level, the pair of codes had the same value (e.g. a lesson consistently at level 3 was assigned a 3,3 code).

The initial categorisations were made by the first author in the process of making the summaries; these were then confirmed or queried by the second author who checked the summaries and referred to the original lesson plans in this process. There was agreement on all of the first author's classifications; the only adjustments were the addition of a second classification to five of the 27 lessons. Comparisons across the two cohorts, particularly on the levels of their lesson plans within the hierarchy, were used to investigate whether or not the preliminary Olympic Games workshop may have had an impact (research question 4).

Figure 2 shows this lesson plan analysis using one of the lesson plans produced by the 2008 cohort. The summary section of Figure 2 gives the PSTs' lesson title and then summarises what was written by the (usually two) PSTs in their lesson plan. Italicised comments within square brackets are the authors'; material in parentheses was written by the PSTs. The authors identified the "Topics" evident in the lesson plans, and the final section of Figure 2 justifies the lesson's levels in the teaching statistical literacy hierarchy, with this particular lesson adjudged to have evidence of two levels.

Results

Perceived Affordances (Research Questions 1 and 4)

In their written responses to question (a), the PSTs identified a wide variety of statistics or “data” topics they perceived could be addressed in class using the water storage data. In analysing their responses, all topics were recorded and then grouped according to the categories listed in Table 2. It is noted that PSTs may have listed a number of different topics that fell into the same larger category; these contributed more than one to the count for that category (e.g. some PSTs listed “mean” without listing other measures of central tendency and thus PSTs who listed “mean, median and mode” contributed three to the “Measures of Central Tendency/Spread” category). Table 2 shows little difference between the suggestions of the two cohorts and a predominance of the expected topics such as graph reading and interpretation, graph production, measures of central tendency and percentages (this last topic is perhaps more mathematical than statistical). These were suitable topics for use in grade 6.

Question (b) required PSTs to list questions that children could be asked to answer or consider using the water storage data and further probed their identification of affordances in the resource. Responses varied from specific questions (e.g. “Which reservoirs are at less than 50% capacity?”) to broad queries (e.g. “How can we save water?”) and in some cases were vague or could not be answered by children using only

TABLE 2

Teaching topics identified by the PSTs (individual topic suggestions have been clustered into the thematic topics listed in the table)

Topic identified	*2007*	*2008*
Assumptions	1	0
Data collection	3	0
Graph/table interpretation	39	43
Graph production	26	22
Measures of central tendency/spread	45	43
Percentages	21	30
Predictions	9	9
Probability	8	5
Rates	3	8
Other statistical topic	1	10
Vague	8	5
Total	164	175

the supplied data set. The questions were clustered into four main categories: Reading Data (focussing only on a straightforward reading of data values but with no consideration of context or implications; e.g. "In what years did the volume drop below 50%?"), Interpretation (associated with reading the data, usually involving multiple steps and understanding what this means without going beyond the immediate data; e.g. "Is there a pattern of yearly water storage levels over a decade?"), Context (understanding the physical situation of the reservoirs, rainfall, consumption, drought or the units involved; e.g. "What does this [sic] data say about our water consumption?") and Implications (understanding what the data implies for the future and how it might affect us; e.g. "What could you use the data for to help you make decisions for your own life?"). Table 3 shows that the 2008 cohort produced nearly 40% more questions than the 2007 cohort, and the distributions of the questions were different. The 2007 cohort had more questions focussing on reading the data, whereas the 2008 cohort had more questions focussing on the bigger picture of context and implications. A chi-square test indicated that this difference was significant ($\chi^2 \approx 21.1$, $p \approx 0.0001$).

Affordances Implemented in the Lesson Plans (Research Questions 2 and 4)

The topics addressed by the lesson plans were identified and are presented in Table 4. All but one of the 27 lessons produced by both cohorts incorporated aspects of the technicalities and process of data reading, including "orienting" to the data by reading headings and axis labels. The remaining lesson required students to read data from the water storage table, but assumed that students knew how to do it, without placing an emphasis on the process of reading individual data points. Over two thirds of the lessons planned by the PSTs required students to produce graphs,

TABLE 3

Questions identified by the PSTs (individual question suggestions have been clustered according to the theme of the question)

Question type	*2007*	*2008*
Reading data	38	28
Interpretation	15	8
Context	19	56
Implications	15	28
Total	87	120

TABLE 4

Topics addressed by the lesson plans

	2007	*2008*
Measures of central tendency	5	5
Data reading	13	13
Percentage emphasis	2	3
Size of units	1	2
Graph making	11	8
Predictions/trends	2	5
Cause and effect ("What is really going on?")	4	5
Collect own data	6	1

often with some discussion of what constituted an appropriate representation. Nearly half of the lessons from the 2007 cohort asked students to collect their own data, in most cases without making connections to the original data and situation. The idea of having students obtain their own data appeared in only one lesson in 2008. It may be that the idea rippled through the groups in the 2007 cohort during the workshop, possibly causing some pairs to change their original plans for the lessons. Nevertheless, it was still the PSTs' choice to use the idea; this choice reflects their decisions about what they thought might be an appropriate teaching activity to conduct. The 2008 cohort planned more lessons on "big picture" concepts such as identifying why the data are the way they are, the trends shown and reasons for these, and what might happen in the future under what assumptions. Ten of the 27 lessons involved measures of central tendency, and in six of these, the variable chosen was not appropriate for the measure to be applied (e.g. see lesson in Figure 2; this provides some evidence about content knowledge, even though this was not a focus of the research). The PSTs' lessons rarely involved single topics, which is why the total numbers in Table 4 exceed the number of lesson plans.

Lesson Plans and the Teaching for Statistical Literacy Hierarchy (Research Questions 3 and 4)

The lessons were evaluated using the Teaching for Statistical Literacy Hierarchy (Table 1). Of the 27 lessons produced by the two cohorts, 17 had characteristics of two different levels, and for three of the lessons the difference between levels was wide: There was evidence of consistent non-critical or even critical levels of statistical literacy but accompanied by an idiosyncratic treatment of some aspect of the statistical ideas. In the most extreme case, one lesson began by making a well-considered attempt to address the causes of possible variation in the data, but then asked students to calculate such effects, using unspecified methods for which the supplied data seem insufficient. Ten of the lessons had some idiosyncratic aspects, with two being classified entirely at this level. There were seven lessons that were consistently at level 4 and/or level 5 (the consistent non-critical and critical levels); these tended to engage appropriately with the context and make appropriate use of the data to understand the big picture of trends and relationships. None of the lessons demonstrated level 6, the critical mathematical level of teaching for statistical literacy. The resulting data from this analysis using the statistical literacy hierarchy are graphed for the two cohorts in Figure 3 (note that there were 13 lessons produced in 2007 and 14 in 2008). The graph suggests that there were more lessons with idiosyncratic content from the 2007 cohort, in many cases reflecting the plans for the class to collect its own rainfall data but without attempting to connect this to the water storage data. The 2008 cohort produced a larger number of lessons achieving the critical level, arising from lessons that attempted to put the data in context and address variation.

Figure 4 was produced to investigate if there were any relationships between the themes of questions that the PSTs posed in response to preliminary question (b) and the level of the lesson plan that was produced. Data from both cohorts were combined for this analysis in

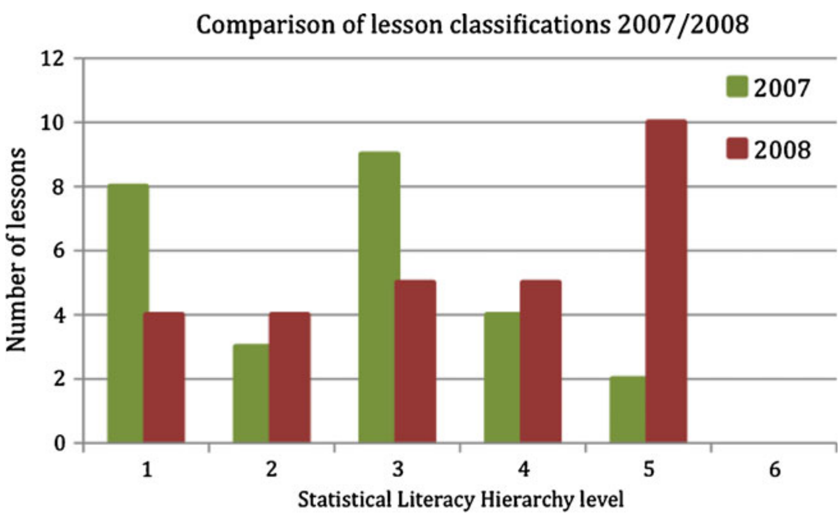

Figure 3. Teaching for Statistical Literacy Hierarchy levels in the PSTs' lessons (see methodology for an explanation of how each lesson was assigned two levels; both levels have been included in the graph)

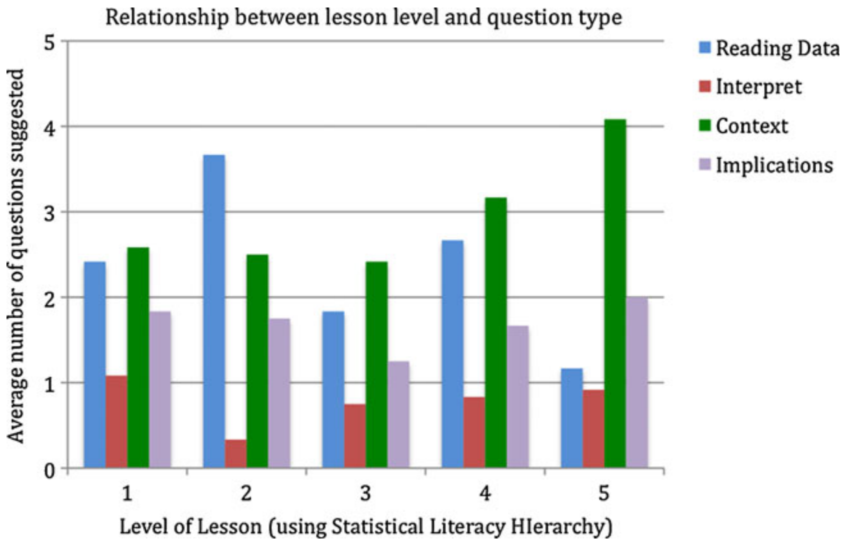

Figure 4. Average number of questions in different themes produced in response to question (b), against the level of the lesson in the Teaching for Statistical Literacy Hierarchy

order to show the full range of lesson levels and because of the smaller sample sizes of the individual cohorts. The number of questions produced for a lesson was the sum of the number of questions produced by each contributor to the lesson since (b) was responded to on an individual basis (in all but two cases two PSTs contributed to each lesson). Each lesson, in effect, appears twice in the data, since those that were assigned two levels contribute data to each level and those that were at a consistent level contribute data twice to that level. The number of questions on each theme was averaged for the lessons at each level. There are no obvious differences, although it might be noted that the higher-level lessons have a smaller number of questions focussing on data reading and a greater number of questions addressing context. This may well have had an impact on designing lessons that engaged with context and moved beyond merely dealing with the technicalities of graph reading.

Discussion

Returning to the research questions and summarising the results, it must be noted that in both years the cohorts identified a range of appropriate affordances from the water storage data, with the 2008 cohort proposing more questions for students that focussed on context and implications (research question 1). Many of these affordances made their way into the lesson plans (research question 2), with typical primary school level activities such as data reading and graph making predominating in the lessons. There was wide variation in the levels of statistical literacy likely to be fostered through the teaching of the planned lessons (research question 3). It was disappointing that no lesson appeared to reach the critical mathematical level of the Teaching for Statistical Literacy Hierarchy and that so many (over half) were at a low level (idiosyncratic, informal or inconsistent). This points to the difficulty of constructing lessons that address sophisticated or complex concepts.

The inclusion of questions (a) and (b) as tasks for the PSTs to complete before thinking about the lesson planning task served two purposes. The first was simply a research purpose: These questions were asked in order to examine what and how many affordances for teaching statistics the PSTs could find in the data. Secondly, the very asking of these questions may well have affected what the teachers planned to do in their lessons, by forcing them to think about what really was possible with the data. In this sense, they were possibly an aid to the task of lesson planning, although there is no definitive evidence of this without having a cohort of PSTs produce lesson plans without any preliminary questions.

In support of this hypothesis, however, there did appear to be an effect from the preliminary workshop conducted with the 2008 cohort (research question 4). Although there were no significant differences between the cohorts in terms of the affordances they initially identified in response to question (a), there were differences in what they planned to teach. All but four of the 14 lessons produced by the 2008 cohort had aspects of the lesson at the consistent non-critical level or higher, compared to only four lessons of the 13 in 2007 (and only two of these lessons were entirely at this level or higher, compared to five in the 2008 cohort). The emphases of the workshop, held the week before the lesson planning activity, were on identifying what a resource offered, especially with respect to mathematics topics and teaching opportunities. The idea of "affordances" had also been made explicit in the class discussion, together with the ideal of having a lesson with significant mathematical ideas that are connected to the content and topic of the resource material. Although the researchers had given no recapitulation of the importance of "affordances" and having mathematically focussed content in the actual water data lesson planning workshop, the PSTs in 2008 seem to have made use of these principles to produce lessons that, in general, had a greater attention to context together with relevant and significant statistical ideas. The concepts that the PSTs wanted to bring out were also much more clearly articulated in lessons from the 2008 cohort; furthermore, the 2008 cohort made noticeably greater use of the affordances in the resource.

The question of making concepts evident through teaching is a difficult one. It is difficult to evaluate the extent to which concepts will be made clear in teaching, based only on a lesson plan. Clearly, a complete evaluation can only be based on an examination of an actual lesson *and* assessment of student learning (Eichler 2008, has done some work in this area). Nevertheless, a lesson plan can provide some indications of the intended content and whether or not this is likely to be conveyed through the teaching activities. One of the striking features of the set of plans produced for this research and learning activity was the presence of sound pedagogical ideas, but often without clear evidence that these would attend to content as well. Nearly all of the lesson plans specified that students should work in groups on the tasks, without it being evident what specific learning outcomes might be enhanced by this. As a specific example of this tension between potentially productive pedagogy and making content explicit, consider the lesson summary in Figure 5. This appears to be a very strong attempt to set up an activity in which students are forced to make the data meaningful and attend to their context, impelled by the requirement to produce a "news report". What is not clear is whether any particular specific statistical concepts will be attended to, and which ones, and how. It is not evident from the lesson description whether or not there were specific statistical techniques that the PSTs planning the lesson wanted students to learn, and, if there were, the PSTs have not indicated how they would ensure such learning would take place.

It is important to note that this research did not explicitly examine the PSTs' statistical content knowledge, including whether or not they could make sense of the water data themselves. As mentioned earlier, their educational backgrounds should have provided sufficient background for the task and their lists of affordances suggest reasonable levels of statistical understanding, and, in fact, there is *some* evidence of their content knowledge from the actual data despite this not being a focus. Nevertheless, it is salutary to consider what is required of teachers: They

Summary of lesson: Introduce the graph to students and discuss what information they can see in it. Introduce students to the task of producing a television news report about the status of Melbourne's water. Students, in groups, to collect information from various websites as evidence for their reports. The reports are rehearsed for presentation. Students' reports to their class are videotaped. [*Note: A section of the lesson plan on assessing students' learning mentions* "interpreting the data" *and* "articulating understanding" *but does not articulate what aspects in any detail*.]

Figure 5. Television news report lesson summary

need to be able to comprehend the dynamics of rainfall and water storage, what each of the variables measure, how the data are collected, what statistical processes they have undergone, what story can actually be read in the data, what variation needs to be considered and what factors might affect the conclusions that can be drawn. These issues have been examined in the work of Monteiro & Ainley (2007). Without this understanding, PSTs—and, by extension, practising teachers—cannot design effective lessons in which students can learn these very principles for themselves. This is, of course, the first of the requirements for teaching statistical literacy with real-world data discussed at the beginning of the paper. Indeed, the hierarchy for the teaching of statistical literacy is very dependent on the PSTs' levels of understanding as measured by the original statistical literacy hierarchy of Watson & Callingham (2003).

Conclusion

The PSTs were certainly able to identify many of the expected affordances within the data, including the obvious graph reading and using data to make predictions. In the case of measures of central tendency, the PSTs occasionally found affordances that were not really present because some variables were not suitable for the chosen measures. This was indicative of a broader problem: The PSTs knew there were important statistical concepts to teach, but they were not always able to make appropriate choices about how to do so with the given data. This led to lessons in which there were mismatches between what the PSTs were intending to convey and what data they used to convey it, often due to the PSTs not using the data they had in the resource. Successful use of examples involves identifying not only what an example affords, but also what it does not. In addition, there was often a lack of specificity about how to convey the statistical ideas through the activities and discussion. This finding of vaguely articulated lesson plans reflects the results of Sullivan et al. (2009), in their study of teachers who also struggled to produce lesson plans with deep and substantive content.

The results from the two cohorts here suggest, however, that a simple intervention that provides guiding questions for teachers to help them identify exactly what can be afforded by a real-world data set may make a difference to the quality of the lessons produced using that resource. Consequently, programmes for pre-service teachers—and, similarly, practising teachers—may benefit from including explicit discussion of affordances, to help teachers identify what learning can be stimulated by such a real-world data set. In addition, the results point to the possible usefulness of helping teachers realise the importance of continually questioning whether or not a lesson plan is taking advantage of the affordances and bringing the desired content to the fore. The 2008 cohort appeared to make better use of the actual data they had in the resource and made better matches between the statistical principles and the data set itself. Further study should examine whether a more formalised approach to identifying affordances and making them explicit in teaching—extending the work done in the preliminary workshop with the 2008 cohort—can lead to more effective use of data sets for the learning of statistics.

In addition, the study found that the Teaching for Statistical Literacy Hierarchy proved suitable for analysing lessons. It would be useful to investigate whether teachers can benefit from knowing about the hierarchy and use it to plan lessons that develop statistical literacy at the critical and critical mathematical levels. Whereas teachers can recognise affordances, may have the necessary content knowledge and may have good pedagogical strategies, it appears that the challenge is to put all of these components together so that affordances are realised in the classroom. Awareness of a hierarchy may provide teachers with a focus for trying to lift the levels of statistical literacy being fostered in classrooms.

In this research, the PSTs were supplied with a data set that the researchers themselves believed offered many suitable affordances; what has not yet been investigated is how easy it is for teachers to choose data sets or media examples in the first place. Certainly, if real-world data sets are to be used as a context and impetus for learning statistics and to model the statistical literacy that should be brought to bear on *any* real-world data set, then it is vital that teachers have the capacity to identify such affordances and then design lesson activities that bring them out.

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Melbourne Graduate School of Education
University of Melbourne
Melbourne, VIC, 3010, Australia
E-mail: h.chick@unimelb.edu.au