HELPING TEACHERS TO MAKE EFFECTIVE USE OF REAL-WORLD EXAMPLES IN STATISTICS

Helen Chick and Robyn Pierce
University of Melbourne, Australia
h.chick@unimelb.edu.au

Real-world data can be used in the classroom to stimulate the learning of important statistical principles. A recent study with pre-service primary/elementary teachers highlighted that even when teachers were supplied with a suitable statistically rich example, some did not identify its affordances, and struggled to bring out the significant ideas in their planned lesson. This paper examines some of the issues associated with example use, and investigates whether a simple intervention might help teachers make more effective use of such examples. The results suggest that a simple framework of focus and planning questions may help teachers to identify significant statistical ideas for teaching and bring them out in their lessons. This is not to say that addressing content and pedagogical content knowledge issues more explicitly with teachers will not also be helpful, especially since some shortcomings in both areas were still evident in the lesson plans.

INTRODUCTION

This paper brings together research and discussion associated with the use of real-world examples in the teaching of statistics. It had its genesis in work of the first author (Chick, 2007) on example use in mathematics teaching generally. This led to a study on how a group of pre-service primary teachers planned to use supplied real-world data in their teaching (Chick & Pierce, 2008a; 2009). The study revealed that in many cases teachers could not "see" all the teaching opportunities offered by the real-world data. This prompted consideration of issues associated with (i) choosing suitable real-world data sets that allow the illustration of important statistical principles and (ii) planning to capitalise on such opportunities in the classroom (Chick & Pierce, 2008b). The results of research in this area, including a follow-up study on helping teachers better identify how examples might be used for teaching statistical principles (Chick & Pierce, 2009), highlight the importance of teaching this skill and not assuming that determining and using an example's affordances will be obvious to a novice The purpose of the current paper is to synthesize the work done to date and present some new data that illustrate issues believed to be important for teaching.

BACKGROUND

There are many reasons for using real-world examples for teaching statistics. They provide a motivating context for learning and can demonstrate the utility of statistical concepts. The goals of statistical literacy include being able to interpret and critically evaluate real-world data, and hence it makes sense actually to develop these skills with such data (Watson, 2006). The teacher's task of choosing and using real-world examples, however, is complex. Building on the ideas of Gibson (1977), who introduced the term "affordances" to describe the perceived ways an object or example can be utilised, Chick (2007) explored what affordances teachers found in examples they employed in teaching several elementary mathematics topics. It seemed apparent that successful implementation of examples in a lesson depended on both content knowledge (in these cases, knowledge of mathematics) and pedagogical content knowledge (e.g., knowledge of students' likely misconceptions and how best to help students to construct understanding).

At the time this project began, the authors were alerted to the regularly updated website of the local water company (Melbourne Water, 2007). The website contained a wide range of data in graphs and tables depicting information about past and present capacities and volumes of the water reservoirs that supply the city of Melbourne (copies are reproduced in Chick & Pierce, 2008a, 2009). A drought was affecting the region at this time, and concern about water storage levels was very topical. When the authors saw the website they could see its potential for use in teaching: the data could be used to focus on any of a number of key statistical principles at the upper primary and secondary levels. These principles included graph and table reading and interpretation; identifying and explaining variation; making predictions; relating tabular data to graphical data and vice versa; relating data to their real-world context; determining appropriate averages; identifying

In C. Reading (Ed.), *Data and context in statistics education: Towards an evidence-based society. Proceedings of the Eighth International Conference on Teaching Statistics (ICOTS8, July, 2010), Ljubljana, Slovenia*. Voorburg, The Netherlands: International Statistical Institute. www.stat.auckland.ac.nz/~iase/publications.php

causes of changes; discussing social implications; evaluating methods of data representation; reinforcing mathematical concepts; identifying the key "messages" within the data; and learning the general process of interpreting and querying real world data. It was decided to use these data for research into the complexity of example use.

In thinking about the process of transforming a potentially useful example into a learning experience in the classroom the authors posited three key stages (Chick & Pierce, 2008b). They were interested in the role of content knowledge (CK) and pedagogical content knowledge (PCK) in recognizing affordances and turning the example into a "didactic object", that is, something that can be used for teaching (Thompson, 2002).

- Stage 1: Choosing or constructing the example, which involves CK to recognize affordances, and PCK to determine if the example is likely to be suitable for the class.
- Stage 2: Planning to use the example, which involves PCK in order to ensure that the affordances are realized and the example is made into an effective didactic object, and CK to ensure that the statistical concepts are addressed appropriately.
- Stage 3: Implementing the plan in the classroom, which requires both CK and PCK so that the lesson achieves its goals and that issues that arise are addressed appropriately.

In 2007, the authors used the water storage data example with 27 pre-service primary (elementary) teachers (PSTs), in order to explore Stages 1 and 2 of the example-use process (Chick & Pierce, 2008a). Since the example had been chosen for the PSTs the research could not examine what examples a teacher might choose independently for a lesson, but it did allow for an examination of the affordances seen by different teachers in one example. The PSTs were asked to identify what topics they thought could be taught using the water storage data, and to list questions students could be asked about the data. This allowed an examination of the range of affordances perceived by the PSTs, for this particular example. The PSTs, in pairs, then produced a plan for a lesson, with the objective of "teaching some aspects of statistics". The resulting 13 lesson plans were then examined to identify the extent to which the affordances of the data set had been utilized.

A striking finding from the 2007 PST's responses to this task (Chick & Pierce, 2008a) was the shallow and vague nature of the lesson plans. The researchers acknowledged that a written lesson plan may not show all the detail of intended focus and coverage that the PSTs had in mind for their class. Nevertheless, their written plans did not articulate key concepts that they intended to convey, and in nearly half the cases the main activity planned for the lesson did not make connections between the activity and the original water storage data. Indeed, it was rare for the lesson to capitalize in a substantial way on even one of the affordances of the graphs and tables on the website. Part of the difficulty seemed to arise from the PSTs' attention to the general methods of teaching rather than its content. The planned activities involved group work, predominantly, with extensive class discussion and hands-on tasks. This emphasis on pedagogical approaches—which, it must be said, were generally appropriate—was not balanced by a similar concern for the detail of the principles to be taught and how to bring this out in the planned activities. Although this might be attributed to the PSTs' relative inexperience, being in only the second year of their four-year course, the authors had seen cases in other contexts where examples were underutilized by practicing teachers. It was of interest to examine how to help teachers increase their capacity to identify and capitalize on affordances in examples. The remainder of this report describes an activity that was conducted with PSTs to help them learn more about this process, and contrasts some lesson plans to highlight some of the issues that have been discussed (a more extensive quantitative report of the outcomes of these studies may be found in Chick and Pierce, 2009).

FOCUSING ON AFFORDANCES AND MAINTAINING ATTENTION ON CONTENT

In 2008 a new cohort of 27 PSTs completed the water storage data lesson planning task. This time, however, the previous week's workshop incorporated a learning task focused on identifying affordances in resources. The workshop occurred during the 2008 Olympic games and the PSTs were given a newspaper page with the latest results and medal tallies. The workshop leader (the first author) suggested that this resource could be utilized for a mathematics lesson on a current topical event. The researchers deliberately chose to focus on mathematics more generally, rather than statistics, although there were certainly statistics-oriented affordances in the Olympics material. In the first phase of the workshop PSTs had to identify three mathematical teaching opportunities that could utilize the resource. To assist, they were supplied with a grid having a row for each teaching idea, and three columns headed “What aspect of the resource am I using?”, “What content area/s is/are present?”, and “What might I do with this in a classroom?”. Additional questions were provided to increase the 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 with the resource?

A class discussion was conducted, allowing PSTs to exchange ideas and the workshop leader to introduce the idea of affordances. There was explicit discussion of what aspects of the examples themselves allowed certain mathematical topics to be addressed. The PSTs, in groups, then chose one idea to develop further into an activity that could play a central role in a lesson for students at the upper primary level. The authors’ intention was that this workshop activity would provide the PSTs both experience with, and additional language for, the process of identifying and implementing learning opportunities, especially from within materials that are of general interest but have not (yet) been adapted or reinterpreted to meet teaching and learning needs.

In the workshop of the following week, the PSTs were given the water storage data task in the same format as the previous year’s cohort. No reference was made to the Olympic games affordances activity that they had experienced. The analysis of the results (Chick & Pierce, 2009) utilised a hierarchy for evaluating the lessons according to the levels of statistical literacy that might be developed in students being taught according to the lesson plans. This analysis revealed that the 14 lessons from the 2008 cohort, in contrast to their 2007 counterparts, generally contained more appropriate and better-developed statistical content, paid greater attention to context and implications, and made better use of the affordances of the water storage data. To highlight some of the qualitative differences, two pairs of contrasting lessons will be presented and discussed.

TWO PAIRS OF CONTRASTING CASES

The chosen pairs of lessons are exemplifying cases (Bryman, 2004), to demonstrate some of the contrasts evident in the more quantitative data of Chick and Pierce (2009). Each pair of lessons addresses a particular statistical theme: average for the lessons in Table 1, and graph interpretation in Table 2. The low-level lessons came from among the ten low-level lessons of 13 produced by the 2007 cohort and the high-level lessons were from the eight high-level lessons of the 14 produced by the 2008 cohort. The lesson descriptions given in Tables 1 and 2 are verbatim or slightly condensed summaries of the lesson plans that were produced by the pairs of PSTs.

One topic addressed by each of the lessons in Table 1 was “average”. In the low-level lesson, the averages were to be based on data that the students collected themselves from rain gauges around the school. There was virtually no use made of the website data, apart from some ad hoc questions in the introduction. It was not clear if and how the meaning of average might be addressed; the vague statement in the introduction that says “Introduce the concept of averaging rainfall over one month” did not give any indication about whether this was intended to be a first experience of “average” or how it might be introduced in context and with what data. Given the low rainfall experienced at the time, the graphs and average were likely to be interesting only because of their low or zero values. As well as this lack of specificity about average, it was unclear what graphs might be produced and what issues might be addressed in the concluding discussion.

In contrast, the activities in the high-level lesson made extensive use of the water storage data, and required reading data as well as regraphing the data using an assigned and appropriate representation. Although the meaning of average was not discussed, it was put to a suitable statistical purpose in comparing the data for different months. There was a lack of clarity regarding the choice of six apparently arbitrary years from the ten years of data available, but there was a suitable organizational structure for looking at change over several years (for a given month), and then looking at seasonal changes within a year by looking at the average monthly values.

Low-Level Lesson Introduction: Introduce the concept of averaging rainfall over one month. View the website and explore the data using teacher questions (e.g., Which month had the highest rainfall in 2001? Why has there been a drop in water storage over the last five years?). Discuss concepts and clarify ideas. Introduce the experiment: students measure rainfall on a daily basis for 20 school days. Main part of lesson (after data have been collected): Students then choose how to represent this data (they can average the data or do a daily representation). Teacher will offer suggestions to the groups. Based on the data, students also create a predicted rainfall graph for another month. Conclusion: Students present graphs to class, explaining their choice of representation. Discussion of graph appropriateness, plus other key content (such as averaging, measurement units). Predictions are discussed, together with variables and influences. Students check their predictions by further data gathering.
High-Level Lesson Introduction: Introduce the website to students, and make comparison of the water storage percentages for 2 or 3 years, discussing difference in patterns throughout year (gradual and sharp changes). Compare January and December. Main part of lesson: Students divided into 4 groups, each group creates multiple copies of a bar graph for one of four months over six given years of the ten year period [it is not clear why 1997, 1998, 2003, 2004, 2007, 2008 were chosen by the PSTs]. When done, students combine with those who did different months, taking one of the copies of their original group's graph. In these new groups, students are to (a) identify which month has the higher average rainfall [sic: storage levels, perhaps?] in the 6 years; (b) identify trends that can be seen over the years; and (c) plot, on their graph, where they predict storage level will be for their month in 2010. Conclusion: Students share predictions, with the teacher creating a table of the water storage predictions for the months in 2010. The reasons for similarities and differences between individual answers will be discussed.

Table 1. Two lessons that use the water storage data to address average

The second pair of lessons, shown in Table 2, addressed the reading and interpretation of data, together with aspects of graph production. Again, the low-level lesson made little use of the affordances in the actual water storage data; they were used only briefly and by just a few of the students in the lesson. Instead, the "water" situation was used as a motivation for having students collect and graph their own rainfall data. The teacher then assigned each group to produce a different type of graph. Although the issue of what graphs are suitable for certain purposes is an important one, it is questionable if there is value in actually requiring students to *construct* an inappropriate graph, especially since that was the only graph that they produced. The description of the lesson's conclusion was very vague, as it was not clear what "similarities and differences" and "implications" were going to be discussed and with what purpose.

The high-level lesson made greater use of the website data, and had a much more focused approach to the goals of developing skills in reading graphs. The PSTs who prepared this lesson listed example questions that highlighted how they might help students orient themselves to given data. The activity in the main part of the lesson required students to practise the skill of reading data values, and then use suitable technology to produce a graph that could be used to examine trends appropriately.

The low-level lessons in these two pairs of cases were characterized by minimal use of the affordances in the resource, activities with vague descriptions that obscured their intended purpose, and, in some cases, dubious use of statistical tools. The high-level lessons, on the other hand, had the water storage data as the focus of the activities, not just a motivator for using something else. Many of the affordances offered by the resource were utilized: such as graph reading, prediction, graph production, and use of appropriate averages. Moreover, questions for student consideration were specified, there was a clearer description of how the activities would be conducted, and their purpose was more evident. Although not noticeable in these examples, another characteristic of the 2008 lessons was the attention given to the context and therefore the implications of the data.

Low-Level Lesson Introduction: Students are to have collected data from rain gauges around the school for the preceding 20 days. Students put the data into a table in their books, and the teacher explains that the data will be put into a graph. Main part of lesson: Students assigned a particular graph to produce in a group of 4 or 5 (scatter plot, bar graph, line graph, box-and-whisker plot), using the rainfall data. Groups present graphs to class. Class discussion on which graph is more suitable for what kinds of data. One group looks up the water storage website to research rainfall in other parts of Melbourne. Conclusion: Students compare their own data with the research found on the website. Class discusses findings, compare similarities and differences and discuss implications.
High-Level Lesson Introduction: Introductory discussion about the drought and how students see its effects. Students look at the table and graph from the water storage data and teacher “gives students an idea of how to read” them, via some specific questions (simple comparison questions, compare two different reservoirs, highlight the characteristics of the line graph and focus on a particular date). Main part of lesson: Students then to focus on three months of each year, read the data for that, enter this data into Excel, and then produce a bar graph. Students to complete the graph to the end of 2008 by estimation, based on previous years' characteristics. Students to write a written report justifying their choice. Conclusion: Class discussion at end about falling water rates. Students share methods used to work out their prediction for the end of 2008. Class then to make a prediction about 2010 and why.

Table 2. Two lessons that use the water storage data to address graph interpretation

DISCUSSION AND CONCLUSIONS

Although the small scale of this research means that only limited conclusions can be drawn, the results do highlight the complexity associated with recognizing the affordances in a real-world data set (Stage 1 of the teaching-with-examples process) and then planning how to make critical concepts from the example evident in the classroom (Stage 2). The third stage, implementing, has not been examined here, although Chick and Pierce (2008b) report on some of the issues related to that stage, and Eichler (2008) has done work looking at statistics teachers' classroom practices. The difficulty that some of the PSTs had in capitalizing on the affordances of the water storage data were similar to those reported by Sullivan, Clarke, and Clarke (2009), in their study of teachers translating a complex fraction comparison task into a lesson for middle school students. Just as in the Sullivan et al. study, the lessons produced in response to the water storage data task showed evidence of a lack of content knowledge (e.g., asking students to work out averages of percentages), a vagueness about the focus of classroom activities, and coverage that was often shallow.

The preliminary workshop, with its focus on identifying what teaching content can be found and used from the resource, seemed to make a difference for most of the PSTs, again noting that this is not a conclusive result. It is conjectured that although PSTs are genuinely concerned about students' learning, and want to make this learning “enjoyable” in some sense, their attempts to make learning “enjoyable” sometimes neglects attention to content and how to make that content accessible to students. Furthermore, lack of content knowledge implies that teachers simply cannot see what content needs to be addressed. In addition to a general improvement in the quality of the lesson plans, the second cohort's lessons appeared to have greater attention to encouraging students to examine data in order to understand the data's context and implications. Such lesson plans, if implemented, would move students along the path towards having the “critical statistical literacy required to become informed citizens” (Watson, 2006, p. 2).

Finally, the structure and focus of the preliminary workshop and the research task itself appear to have potential as professional development activities. Pfannkuch (2008, p. 5) wrote that “the challenge for teacher educators is to find ways of improving teachers' statistical content and pedagogical content knowledge”. The two activities—the preliminary workshop and the lesson-planning task—could be combined, so that focusing questions and explicit discussion about affordances are considered before actually designing a lesson plan based on some real-world data set. There would also be opportunity to discuss the statistical appropriateness of certain ideas (such as appropriate use of the mean), which could serve to develop teachers' statistical content knowledge. Discussion of what might happen during the implementation stage (Stage 3) might also be beneficial.

The results reported here have potential to make connections between research and teaching practice at the school level. It would be useful to extend the research and teaching practice connection by examining Stage 3 of the process as well. Finding ways to enhance statistical content and pedagogical content knowledge is particularly critical for teachers—especially including primary teachers—who have limited experience in mathematics and statistics. Increasing teachers' awareness of what teaching and learning opportunities there are in real-world data sets, helping them to design lessons that capitalize on these affordances, and then enhancing their capacity to implement these objectives in the classroom should serve to improve the statistical education of students.

REFERENCES

Bryman, A. (2004). *Social research methods* (2nd ed.). Oxford: Oxford University Press.

Chick, H. L. (2007). Teaching and learning by example. In J. Watson & K. Beswick (Eds.), *Mathematics: Essential research, essential practice, Proceedings of the 30th annual conference of the Mathematics Education Research Group of Australasia,* (pp. 3-21). Sydney: MERGA.

Chick, H. L., & Pierce, R. (2008a). Teaching statistics at the primary school level: Beliefs, affordances, and pedagogical content knowledge. In C. Batanero, G. Burrill, C. Reading & A. Rossman (Eds.) *Joint ICMI/IASE study: Teaching statistics in School mathematics. Challenges for teaching and teacher education. Proceedings of the ICMI Study 18 and 2008 IASE round table conference.* Mexico: ICMI/IASE.

Chick, H. L., & Pierce, R. (2008b). Issues associated with using examples in teaching statistics. In O. Figueras, J. L. Cortina, S. Alatorre, T. Rojano, A. Sepulveda (Eds.), *Proceedings of the Joint Meeting of PME 32 and PME-NA 30* (Vol. 2, 321-328). Mexico: Cinvestav-UMSNH.

Chick, H. L., & Pierce, R (2009). *Using data from the media for teaching statistical thinking.* Manuscript submitted for publication.

Eichler, A. (2008). Teachers' classroom practice and students' learning. In C. Batanero, G. Burrill, C. Reading, & A. Rossman (Eds.) *Joint ICMI/IASE study: Teaching statistics in school mathematics. Challenges for teaching and teacher education. Proceedings of the ICMI Study 18 and 2008 IASE round table conference.* Monterrey: ICMI and IASE. Online: www.stat.auckland.ac.nz/~iase/publications.

Gibson, J. J. (1977). The theory of affordances. In R. Shaw & J. Bransford, (Eds.), *Perceiving, acting and knowing: Toward an ecological psychology* (pp. 67-82). Hillsdale, NJ: Lawrence Erlbaum.

Melbourne Water. (2007). *Water storages.* Website accessed on 23 August 2007. http://www.melbournewater.com.au/content/water/water_storages/water_storages.asp. This website, with up-to-date data, was still accessible on 26 August 2009.

Pfannkuch, M. (2008). Training teachers to develop statistical thinking. In C. Batanero, G. Burrill, C. Reading, & A. Rossman (eds.) *Joint ICMI/IASE study: Teaching statistics in school mathematics. Challenges for teaching and teacher education. Proceedings of the ICMI Study 18 and 2008 IASE round table conference.* Monterrey: ICMI and IASE. Online: www.stat.auckland.ac.nz/~iase/publications.

Sullivan, P., Clarke, D., & Clarke, B. (2009). Converting mathematics tasks to learning opportunities: An important aspect of knowledge for mathematics teaching. *Mathematics Education Research Journal, 21,* 85-105.

Thompson, P. W. (2002). Didactic objects and didactic models in radical constructivism. In K. Gravemeijer, R. Lehrer, B. van Oers, & L. Verschaffel (Eds.), *Symbolizing, modeling, and tool use in mathematics education* (pp. 191-212). Dordrecht, The Netherlands: Kluwer.

Watson, J. M. (2006). *Statistical literacy at school: Growth and goals*. Mahwah, NJ: Lawrence Erlbaum.