Developing statistical literacy with Year 9 students: A collaborative research project

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Despite statistical literacy being relatively new in statistics education research, it needs special attention as attempts are being made to enhance the teaching, learning and assessing of this strand. It is important that teachers are aware of the challenges of teaching and assessing of this literacy. In this collaborative research study, two cycles of teaching experiments were carried out in two year 9 classes. The data set consisted of audio and video-recordings of classroom sessions, copies of students' written work, audio recorded interviews conducted with students, and field notes of the classroom sessions. The results shed light on tools and techniques which the research team used to help students develop critical statistical literacy skills. The findings have implications for teaching and further research.

Key words: statistical literacy, high school students, collaborative research, teaching experiments, relevant contexts, data based arguments

Introduction

Every day, people all over the world are bombarded with a complex array of numbers and statistics (Budgett and Pfannkuch 2010; Gal 2004;Paulos, 2001; Schield, 2010). For example, statistics of opinion polling, business, employment and health regularly appear in the news media and research reports. According to a number of educators (e.g. Best 2001; Gal 2004; Paulos 2001), people without statistical literacy may be misled or have difficulty in interpreting and critically evaluating such messages. Best (2001) writes that consumers need to understand that statistics is a social construct and that people debating social problems may chose statistics selectively and present them to support their point of view. For example, gun-control advocates may be more likely to report the number of children killed by guns, whereas opponents of gun-control may prefer to count citizens who use guns to defend themselves from attack. However, people often choose to rely on an author's interpretation and seem not to engage adequately with such information.

The importance of statistics in everyday life and workplace have led to calls for an increased attention to statistical literacy in the mathematics curriculum (Ministry of Education 2007; Schield 2010; Shaughnessy 2007; Watson 2006). Schield (2010) argues that one of the most important goals for teaching statistics in schools is to prepare students to deal with the statistical information that increasingly impacts on their lives. More specifically, critical stance (Gal 2004) - the ability to take and evaluative stance with respect to statistical flaws and biases contained in media, marketing and financial reports - is of vital importance in the quest for statistical literacy. In New Zealand, Begg et al. (2004) have called for a greater emphasis to be placed on statistical literacy in the curriculum so that students can become active and critical citizens. The use of the term statistical literacy is much more explicit in the

new curriculum document with the addition of statistical literacy achievement objectives (Ministry of Education 2007).

Additionally, schools are being asked to prepare students to be flexible thinkers, lifelong learners, and to manage complexities of an uncertain world (Ministry of Education 2007). They need to think for themselves when faced with contradictory information from diverse sources and contexts (Gal 2004; Paul 2011). Watson (2003) stated that in this century decision making for all citizens is likely to be made based on the critical thinking skills derived from the statistical literacy strand.

Gal (2004) sees statistical literacy as the need for students to be able to interpret results from studies and reports and to be able to pose critical and reflective questions about those reports. Gal would like students to come away from a statistical literacy class with an ability to evaluate statements from reports and ask a set of questions such as: Where did the data come from? What kind of study is it? According to Watson , statistical literacy is the " meeting point of the chance and data curriculum and the everyday world, where encounters involve unrehearsed contexts and spontaneous decision-making based on the ability to apply statistical tools, general contextual knowledge, and critical literacy skills" (2006, 11). Clearly, the type of statistical literacy that Gal (2004) and Watson (2006) propose is different from just being able to read and evaluate data and graphs. Aspects of Gal's notion of statistical literacy have been incorporated in the New Zealand Curriculum.

It is interesting to see terms like statistical thinking and statistical literacy in the revised curriculum document as well as notions of critical thinking in the key competencies and descriptions of effective pedagogy (Ministry of Education 2007). However, many of the theories and developments of statistics education are still very new. It is not clear how many teachers are aware of the theories and developments in statistics education and how many teachers understand teaching as inquiry and the implications of research in their classrooms. For instance, there may be a match/mismatch between the stance taken by the current curriculum towards statistical literacy and what teachers understand of statistical literacy (Doyle 2008).

Research in New Zealand and overseas (Garfield and Ben-Zvi 2008; Hill, Rowan and Ball 2005; Hunter 2010) has consistently acknowledged the importance of the teacher in student learning. A key theme of *Effective Pedagogy in Mathematics/Pāngarau Best Evidence Synthesis Iteration [BES]* is that "quality teaching is not simply a matter of 'knowing your subject' or 'being born a teacher" (Anthony and Walshaw 2007, 4). There is a need for quality professional development in secondary schools to make sure that good practice occurs in as many classrooms as possible. Teachers need to become fully conversant with the theory to participate in the research process. A design research approach allows researchers and teachers to work together within a research process in which researchers and teachers work together to explore student learning.

The research approach

According to Bakker (2004), statistical ideas need to be developed slowly and systematically using carefully designed sequences of activities in appropriate learning environments, which challenge students to explore, conjecture and evaluate their reasoning. One way to develop these sequences of activities is through a research-and-development process called design research (Cobb 2000). Design research is cyclic with action and critical reflection taking place in turn. There are benefits for

teachers and researchers undertaking such research. In this type of collaborative research the teacher is involved in the whole process and takes part in posing questions, collecting data, drawing conclusions and writing reports.

Research design and data collection methods

The following inter-related research questions guided our study:

- How can we support students to develop statistical literacy within a data evaluation environment?
- How can we develop a classroom culture where students learn to make and support statistical arguments based on data in response to a question of interest to them?
- What learning activities and tools can be used in the classroom to develop students' statistical critical thinking skills?

Preparation for the teaching experiment

This phase consisted of literature review (statistical literacy, teaching experiment) and the first attempt at reformulating a teaching sequence. Then, the research team proposed a sequence of ideas, skills, knowledge and attitudes that they hoped students would construct as they participate in activities. The team planned activities to help move students along a path towards the desired learning goals. As part of the activities, students evaluated statistical investigations or activities undertaken by others including data collection methods, choice of measures and validity of findings (Ministry of Education 2007). The team envisioned how dialogue and statistical activity would unfold as a result of planned classroom activities.

The teaching took place in regular classrooms and as part of mathematics teaching. The teaching activities were spread over up to two weeks to suit the school schedule. The research team was involved in designing, teaching, observing and evaluating sequences of activities. There were two cycles of teaching experiments. The goal was to improve the design by checking and revising conjectures about the trajectory of learning for both the classroom community and the individual students. Students' thinking and understanding was given a central place in the design and implementation of teaching eight lesson in each cycle. The research team performed a retrospective analysis after each lesson to reflect on and redirect the learning. In addition the team performed analysis of the unit after an entire teaching experiment has been completed. The continually changing knowledge of the research team created continual change in the learning sequence.

Data Collection

The data set consisted of video-recordings of classroom sessions conducted during the design experiment, copies of all the students' written work, audio recorded mini-interviews conducted with students, and field notes of the classroom sessions. Semi-structured interviews were also conducted while the design experiment was in progress, with six groups of three students. These interviews were scheduled after class sessions and focused on students' interpretation of classroom events with a particular emphasis on the identities they were developing as consumers of statistics. . Each teacher-researcher kept a logbook of specific events that took place during the data collection period. The team was engaged in conscious reflection and evaluation of situations as they unfolded.

Data Analysis

The research team read the transcripts, watched the videotapes, and formulated conjectures on students' learning on the basis of episodes identified in the transcripts and video. The generated conjectures were tested against other episodes and the rest of the collected data.

Results

Statistical literacy is more than the ability to do calculations and read tables and graphs. Our findings show that students are actually quite good at this. Students were able to interpret and critically evaluate statistical information and data related arguments. Additionally, they were able to discuss and communicate their understanding and opinions to others. Students can be exposed to critical questions in statistics as reflected in the following student quote:

> The simplest question I want to ask is how they got the information. Now that we have talked about statistic … and now that we probably understand a bit about statistics, I would want to ask how they got the information

We noticed that literacy skills are critical in the development of statistical literacy. Students were required to communicate their opinions clearly orally and in writing. Students in the class were of different language abilities and needed to interact in order to improve the group's statistical communication. This presented various demands on students' literacy skills as indicated in the following student quote:

> Because usually, like in normal maths, we don't use literacy … like we use addition, subtraction but we actually have some kind of literacy for the things we do in statistics.

The classroom discourse was important for statistical literacy. Most of our classroom activities included group and whole class discussion of the data. This typically involved a small group activity in which the students worked on problems together and then reported back to the whole class. The two teachers took time to remind the students how to work in groups (e.g. how to agree and disagree and how to present to the class). Our results show that students can be taught how to question and challenge in respectful ways as part of classroom discourse. Students found group work useful:

> When you are working alone you just get one point of view and when you are working in a group you get different perspectives of other ideas … how other people are thinking, learning in class

Context is an important component of statistical literacy. Our findings show that students need exposure to both familiar and unfamiliar contexts. Engagement with context helps students develop higher order thinking skills. However, our results show that some contextual knowledge may be a barrier for some students. This is revealed in the journal entry below:

> My students found the language used in the Hans Rosling video difficult to understand. I had to show the clip a couple of times. Some students even questioned why I was using this clip..

Teachers were able to address this in two ways. The first was to start from familiar contexts before moving to unfamiliar contexts. The other was to use contexts

of interest to the students. This involved handing over some of the control and planning of lessons to students.

Teachers had an important role in the construction of a purposeful classroom environment. Teachers needed to guide the pedagogical setting so statistically relevant aspects were discussed

Limitations and implications for teaching and research

The limitations of design research can relate to technical and human aspects. On the technical side, the recording devices used in the study may not have captured everything that was said by the students and the teachers. On the human side, interview data may be subjective, hence has limitations associated with reliability. Students' views, during interviews in particular, may have been influenced by our unequal relationship. Their teachers assessed their work, so during the interviews, students may have said things they thought we wanted to hear. Another human limitation relates to researcher prejudices and biases. Since we were both the practitioners and the researchers, data collection and analysis could have been affected by our predispositions and partiality. Major implications for practice and research that can be drawn from this study are discussed below.

We envision statistical literacy going beyond calculations. It is more than the ability to do calculations and read tables and graphs. Students should be able to interpret and critically evaluate statistical information and data related arguments. Additionally, they should be able to discuss and communicate their understanding and opinions to others. This has potential consequences in how the teaching of statistical literacy might be altered for greater effectiveness. For example, ample class time should be spent on discussion and reflection rather than presentation of information.

As well as statistical knowledge, literacy knowledge and skills are important for statistical literacy. Since all statistical messages are conveyed through written or oral text the understanding of statistical messages requires the activation of various literacy skills. Additionally, students are required to communicate their opinions clearly orally or in writing so others can judge the validity of their arguments. These present various demands on students' literacy skills. Teachers need to help students access information.

We believe that the nature of the learning environment and classroom culture are major contributors to success for students, and teachers need to put a high priority on building a classroom climate that positively engages all students. Students need to understand the importance of sharing their opinions in order to advance their statistical ideas. It would be valuable for teachers to help students reflect on the purposes of explaining and justifying their thinking to others

The ability to interpret and critically evaluate reports that contain statistical elements is paramount in our information laden society. Teachers need to give students some basic foundations for critiquing and evaluating statistically based information that they encounter in daily life. We assume that students can be taught these reasoning skills through using media articles as a springboard into learning about how to evaluate these reports. Consequently they will become familiar with a list of worry questions and apply them to real life examples without prompting, consistent with Gal (2004).

Groth (2007) argues that the relationship between educational research and teaching practice has often been stormy because researchers are often interested in theoretical aspects and general questions whereas teachers are usually interested in

solving problems related to situations that arise in the classroom on daily basis. We believe that a partnership between schools and universities can help strengthen cyclic flow of information.

References

Anthony, A, and M. Walshaw. 2007. *Effective pedagogy in mathematics/Pangarau best evidence synthesis iteration [BES]* Wellington: Ministry of Education

Bakker, A. 2004. Reasoning about shape as a pattern in variability. *Statistics Education Research Journal,* 3, no. 2: 64-83.

Budgett, S. and M. Pfannkuch. 2010. Using media reports to promote statistical Literacy for non-quantitative major. In *Proceedings of the 8th International Conference on the Teaching of Statistics,* ed. C. Reading, Ljubljana, Solvenia: International Statistical Institute and International. Association for Statistical Education. Available www.stat.auckland.ac.nz/~iase/publications.php [© 2010 ISI/IASE]

Begg, A. M. Pfannkuch. M. Camden. P. Hughes. A. Noble. and C. Wild. 2004. *The school statistics curriculum: statistics and probability education literature review.* Auckland: Auckland Uniservices Ltd, University of Auckland.

Cobb, P. 2000. Conducting teaching experiments in collaboration with teachers, In *Handbook of research design in mathematics and science,* ed. A. Kelly and R. Lesh, 307-333. Mahwah, NJ: Lawrence Erlbaum.

Doyle, P. 2008. *Developing statistical literacy with students and teachers in the secondary mathematics classroom*, Unpublished masters thesis. Waikato University, Hamilton, New Zealand.

Gal, I. 2004. Statistical literacy: Meanings, components, responsibilities. In *The challenge of developing statistical literacy, reasoning and thinking,* ed. J. B. Garfield and D. Ben-Zvi, *47-78.* Dordrecht, The Netherlands: Kluwer.

Groth, R. E. 2007. Reflections on a research-inspired lesson about the fairness of dice. *Mathematics Teaching in the Middle school* 13: 237-243.

Garfield, J. B. and D. Ben-Zvi. 2008. Preparing school teachers to develop students' statistical reasoning. In *Proceedings of the ICMI Study 18 and 2008 IASE Roundtable Conference,* ed. C. Batanero, G. Burrill C. Reading and A. Rossman. *Joint ICMI/IASE Study: Teaching Statistics in School Mathematics, Challenges for Teaching and Teacher Education.*

Hill, H., B. Rowan. and D. Ball. 2005) Effects of teachers' mathematical knowledge for teaching on student achievement. *American Educational Research Journal* 42: 371-406.

Hunter, R. 2010. Changing roles and identities in the construction of a mathematical community of inquiry. *Journal of Mathematics Teacher Education 13*, 397-409.

Ministry of Education. 2007. *The New Zealand curriculum*. Wellington: Learning Media.

Paul. R. 2011. *Critical thinking: How to prepare students for a rapidly changing world.* The Critical Thinking Foundation: USA.

Paulos, J. A. 2001. *Innumeracy: Mathematical illiteracy and its consequences*. New York: Hill and Wang.

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