THE UNIVERSITY OF WAIKATO
Te Whare Wānanga o Waikato

Faculty of Education

Te Kura Toi Tangata

Waikato Journal of Education

Te Hautaka Mātauranga o Waikato

Volume 15, Issue 3: 2010

Special Edition: Being a Researcher and Doing Research

WAIKATO JOURNAL OF EDUCATION
TE HAUTAKA MĀTAURANGA O WAIKATO

Waikato Journal of Education is a refereed journal, published annually, based in the Faculty of Education, The University of Waikato, Hamilton, New Zealand. It publishes articles in the broad field of education. For further information visit the WJE website http://edlinked.soe.waikato.ac.nz/research/journal/index.php?id=8

Correspondence and articles for review should be addressed to: Research Manager, Wilf Malcolm Institute of Educational Research, Faculty of Education, The University of Waikato, Private Bag 3105, Hamilton, 3240, New Zealand. Email: wmier@waikato.ac.nz

Business correspondence: Orders, subscription payments and other enquiries should be sent to the Administrator, *Waikato Journal of Education,* Wilf Malcolm Institute of Educational Research, School of Education, The University of Waikato, Private Bag 3105, Hamilton, 3240, New Zealand, Email: wmier@waikato.ac.nz

Subscriptions: Within NZ $40; Overseas NZ $50

Publisher: Faculty of Education, The University of Waikato
Cover design: Donn Ratana
Printed by: Waikato Print

Call for papers

The Waikato Journal of Education provides an avenue of publication for quality articles on education. This peer-reviewed journal welcomes a range of topics including interdisciplinary, philosophical and applied research approaches.

Submissions are now invited for consideration for publication in the November 2011 issue. Please submit an electronic copy and a separate page with author/s contact details by **30 April 2011** to WMIER Research Manager, Carolyn Jones (cjjones@waikato.ac.nz), Faculty of Education, University of Waikato, Private Bag 3105, Hamilton 3240, New Zealand.

ISSN 1173-6135

WAIKATO JOURNAL OF EDUCATION

TE HAUTAKA MĀTAURANGA O WAIKATO

VOLUME 15, Issue 3: 2010

Minding the Aesthetic: The Place of the Literary in education and research
TERRY LOCKE 3

Lecturer–student Views on Successful Online Learning Environments
ELAINE KHOO, MICHAEL FORRET AND BRONWEN COWIE 17

Teaching Te Reo Māori as a Second Language in Primary Schools: Two Case Studies
RICHARD HILL 35

Reading at Risk: Why Effective Literacy Practice is not Effective
SHEILPA PATEL 51

Developing Decision-Making in Rugby
DARRYL PARRANT AND ANDREW J MARTIN 69

Professional Discipline: Analysis of New Zealand Teachers Disciplinary Tribunal Decisions
KATE DIESFELD 87

Restorative Practice and Behaviour Management in Schools: Discipline Meets Care
WENDY DREWERY AND MARIA KECSKEMETI 101

Towards Understanding Models for Statistical Literacy: A Literature Review
SASHI SHARMA, PHIL DOYLE, VINEY SHANDIL AND SEMISI TALAKIA'ATU 115

Conceptions, Language, Culture and Mathematics and the New Zealand Curriculum
JUDY BAILEY AND MERILYN TAYLOR 131

Reasons for Joining the Teaching Profession: Primary Student Teachers
GOVINDA ISHWAR LINGAM 141

The Others and/in Me
JOAN VALENZUELA 157

Waikato Journal of Education 15, Issue 3: 2010

TOWARDS UNDERSTANDING MODELS FOR STATISTICAL LITERACY: A LITERATURE REVIEW

SASHI SHARMA
The University of Waikato

PHIL DOYLE
The University of Auckland

VINEY SHANDIL AND SEMISI TALAKIA'ATU
Marcellin College

ABSTRACT *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 this literacy. The growing importance of statistics in today's information world and conceptions and components of statistical literacy are outlined. Frameworks for developing statistical literacy from research literature are considered next. Strengths and weaknesses of the models are considered. Examples of tasks used in statistics education research are provided to explain the levels of thinking. The paper concludes with some implications for teaching and research.*

KEY WORDS

Statistics education, statistical literacy, levels of thinking, curriculum, assessment

INTRODUCTION

It is common to see statistics used in newspapers and magazines, such as "opinion poll shows that 46% of New Zealanders support the anti-smacking bill" and a car manufacturer who claims, "90% of the cars we have made are still on the road." What do readers make of these statements?

Statistics is a relatively new learning area in the national curriculum and has gained increased attention in today's information society (Makar & Rubin, 2009; Shaughnessy, 2007; Shaughnessy & Pfannkuch, 2004). Many daily activities often require an understanding of statistics to make intelligent decisions. Decisions concerning business, industry, employment, sports, health, law and opinion polling are made using an understanding of statistical information and techniques (Gal, 2004; Rumsey, 2002; Wallman, 1993; Watson, 2006). Rumsey (2002) points out that statistical literacy is an extremely important prerequisite for both everyday life and for effective participation in the workplace. News reporters often cite the results of opinion polls such as the anti-smacking claim. However, the quality of such polls may vary considerably and some understanding of sampling techniques, sources of bias and sample size may be necessary in order to raise concerns about what is being communicated in media reports. In the anti-smacking example, the sample may be biased, unrepresentative or too small to draw meaningful inferences. Hooke (1983) states that although the use of statistics has made great progress, this progress has been accompanied by a corresponding increase in the misuse of statistics. The public, whether it gets its information from television or newspapers, is not well prepared to defend itself against those who use statistical arguments to bolster their claims. Rumsey (2002) claims that due to the "overwhelming amount of unregulated, unrestricted information being thrust upon a public that is generally ill equipped to consume the information" (p. 33), many problems arise. There is a crucial need to increase public awareness regarding the quality of the information they are being asked to consume.

According to Best (2004), people have four different perspectives towards data and statistical information. There are the *awestruck*, who see statistics as incomprehensible and treat them as mysterious objects that have magical powers. Then, there are the *naïve*, who know little about statistics and believe that statistics are always accurate and hence do not question numerical information. Next, there are the *cynics*, who believe that one can prove anything with data and hence tend to ignore statistical information, especially those that challenge their own beliefs and experiences. Finally, there are the *critics*, who postpone judgment and ask questions about how the data were collected and interpreted and then decide if the statistics are still useful despite their flaws. Professional organisations such as the National Council of Teachers of Mathematics (2000) (NCTM) and national curriculum policy like *The New Zealand Curriculum* (Ministry of Education, 2007) certainly promote a critical perspective towards statistics. For instance, NCTM warns that "statistics are often misused to sway public opinion on issues or to misrepresent the quality and effectiveness of commercial products" (p. 48). NCTM further recommends that students need to question the assumptions behind the data and "have some degree of uncertainty" about any conclusions that are drawn (p. 48). Hooke (1983) writes that the car manufacturer's claim at the beginning of this paper may be true, but its meaning is questionable until other facts come to light, such as how long the company has been making cars. It may have been in business for only the last five years.

The importance of statistics in everyday life has led to calls for an increased attention to statistics and statistical literacy in the school mathematics curriculum (Gal, 1995; Ministry of Education, 2007; Rumsey, 2002; Watson, 2006). 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). It appears that the increased focus on learning statistics in schools has been a welcome move. Watson (2000) states that the cross-curricular need for statistical literacy skills is recognised in many curriculum documents around the world. Callingham (2007) writes that students need to think critically about social situations in which data are used, sometimes referred to as applying 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. According to Doyle (2008), the most striking change in *The New Zealand Curriculum* (Ministry of Education, 2007) is the name change for the mathematics learning area to Mathematics and Statistics. The document acknowledges that statistics "involves interpreting statistical information, evaluating data-based arguments and dealing with uncertainty" (p. 26). 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). Students should be able to evaluate critically claims like those at the beginning of this section, ask "worry questions" and make judgments about the validity of the claims made.

WHAT IS STATISTICAL LITERACY?

Although the importance of statistical investigations and literacy is shared by many teachers, education researchers and curriculum documents both here in New Zealand and internationally, conceptions of statistical literacy vary as much as data (Batanero, 2002; Gal, 2004; Shaughnessy, 2007). Ben-Zvi and Garfield (2004) have issued a timely reminder that given the importance of statistical literacy, thinking and reasoning, it is crucial that people working in this area use the same language and definitions when discussing these terms. Batanero (2002) writes, "we have not reached a general consensus about what are the basic building blocks that constitute statistical literacy or about how we can help citizens construct and acquire the abilities" (p. 37).

According to (Wallman, 1993), statistical literacy "is the ability to understand and critically evaluate statistical results that permeate our daily lives—coupled with the ability to appreciate the contributions that statistical thinking can make in public and private, professional and personal decisions" (p. 1). We see in Wallman's (1993) definition both a personal and a societal need for our students to develop statistical literacy skills. Callingham (2007) reminds us that such a definition requires that students must develop not only the mathematical skills required to understand statistical information, but also an appreciation of the social context in which the data is set. Chick, Pfannkuch and Watson (2005) describe statistical literacy as "transnumerative thinking" where students will be able to make sense of and use different representations of data to make sense of the world around them. Ben-Zvi and Garfield (2004) state that statistical literacy includes basic and important skills that may be used in understanding statistical information or research results. These skills may involve organising data, constructing tables and working with different representations of data. They add that statistical literacy may also include an understanding of concepts, vocabulary and symbols and an understanding of probability as a measure of uncertainty. Garfield and Gal (1999) identify statistical literacy as a common goal for statistics instruction across all educational levels and contexts. They see 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 because "most students are more likely to be consumers of data than researchers" (p. 4).

In line with the expanding conception of statistical literacy, Gal (2004) defines statistical literacy as a basic principle for participation in society and the "key ability expected of citizens in information-laden societies" (p. 1) where decision-making is based on critical skills from statistical literacy. Gal reasons that statistical literacy involves both cognitive and dispositional components and that some of these components are held in common with literacy and numeracy whereas others are unique to statistical literacy. Gal claims that statistically literate people can critically evaluate and, where appropriate, express their opinions regarding statistical information or data-related arguments. Schield (2004) indicated that statistical literacy is "critical thinking about arguments that use statistics as evidence and that it *focuses* primarily on inductive reasoning and strength of argument for a disputable claim" (p. 16). Likewise, Watson (2006) sees statistical literacy as 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 (p. 11). For Watson, questioning claims in social contexts such as media reports is fundamental to statistical literacy.

Clearly, the type of statistical literacy that Gal (2004), Garfield and Gal (1999) and Watson (2006) identify is different from just being able to read and evaluate data and graphs. There are many levels and contexts in Gal's framework. The emhasis on contextual understanding, dispositions and critical thinking presents a challenge for assessment. From the definitions of statistical literacy provided by Gal, a number of aspects entwine to create a complex construct. A framework has to be identifued to provide information about the development of cognitive skills inclding critical thinking and dispositions.

STATISTICAL LITERACY FRAMEWORKS

Despite the challenges of the terminology, it is generally accepted that statistical literacy is an important component of statistics education (Doyle, 2008). This section considers three frameworks or models that attempt to represent the features of statistical literacy. The first framework is from Gal's (2004) research into the understanding of statistics by adults. The second model is the Statistical Literacy Construct from Watson and Callingham (2003). The third emergent model, called the framework for statistical thinking in empirical enquiry, is built upon statistics education literature as well as interviews with statisticians and undergraduate students (Wild & Pfannkuch, 1999).

A model of statistical literacy

Gal (2004) proposes a statistical literacy model that involves both a knowledge and certain attitude or dispositional components that operate together. According to Gal there are five interrelated cognitive elements that must be used to exhibit the knowledge component of statistical literacy: mathematical knowledge, statistical knowledge, knowledge of the context, literacy skills, and critical questions.

Furthermore, Gal states that critical evaluation of statistical information (after it has been understood and interpreted) depends on the ability to access critical questions and activate a critical stance. He adds that some of these elements are held in common with literacy and numeracy whereas others are unique to statistical literacy. Gal writes that the components and elements in the model should not be viewed as fixed and separate entities but as a context-dependent, dynamic set of knowledge and dispositions that together produce statistically literate behaviour.

According to Gal (2004), statistical literacy focuses on aspects necessary to establish an awareness of data and critical thinking that must take place in order to consume data. It also focuses on the dispositional aspects of statistical literacy, a form of enquiry and action that an individual engages in as a result of processing the information. He also examines how these knowledge bases can interact with a person's dispositions, beliefs and attitudes towards data and statistics in general. For Gal, the dispositions or associated attitudes and beliefs motivate citizens to be critical thinkers with statistics. The dispositional elements of statistical literacy skills recognise that students should adopt a critical attitude to information at all times and become *professional noticers*. He questions the tacit assumption that students who learn to process data can transfer these skills to interpreting and critically evaluating statistical information. Gal points out that when a true level of statistical literacy has been reached, it allows the individual to take the knowledge bases and critical-thinking skills that have been accumulated and apply them on their own to the statistical information they encounter in everyday life and workplace.

Moreover, Gal (2004) adds that anyone who lacks these skills is functionally illiterate as a productive worker, an informed consumer or a responsible citizen. Shaughnessy (2007) writes that although there are some overlaps between Gal's model of statistical literacy and Wild and Pfannkuch's (1999) model of statistical thinking, they are focused on different constructs—what adults need to be able to do in reading contexts versus statistical activity. According to Gal (2004), reading contexts emerge when people are at home and watching television or reading newspapers or shopping or participating in community activities. Batanero (2002) suggests that while Gal's model can be useful at a macro-level of analysis for understanding what statistical literacy involves and to help policy makers to take decisions about the big ideas that should be taught at different curriculum levels, we need specific micro-level models that can be used to analyse statistical concepts.

Statistical Literacy Construct

The Statistical Literacy Construct from Watson and Callingham (2003) builds on previous work by Watson (1997, 2000) where she uses the Structure of Observed Learning Outcomes (SOLO) taxonomy of Biggs and Collis (1982) from developmental psychology to categorise statistical thinking into a three-tier hierarchy. In the first tier of Watson's model students develop an understanding of the basic statistical and probability terms. In the second tier students develop an understanding of statistical terms and concepts in context. At the most sophisticated level (tier 3) students develop a questioning attitude and use critical thinking. Watson (2000) writes that the hierarchy of skills can be viewed as a progression of levels of statistical understanding and each tier in the hierarchy builds on the one before it.

Watson (1997) used the following newspaper extract based on an Australian newspaper to illustrate the levels of students' statistical understanding as they grappled with an applied context:

Q1. If you were given a sample, what would you have?

> About six in 10 United States high school students say they could get a handgun if they wanted one, a third of them within an hour, a survey shows. The poll of 2508 junior and senior high school students in Chicago also found 15 percent had actually carried a handgun within the past 30 days, with four percent taking one to school.

Q2 Would you make any criticisms of the claims in this article?

Q3 If you were a high school teacher, would this report make you refuse a job offer somewhere else in the United States, say Colorado or Arizona? Why or why not? (p. 72)

The article makes a claim for the population of the United States based on a sample taken in Chicago. The questions were used in a survey context with students from grades 6 to 11. Question 1 was used at the start of the survey to address tier 1 and questions 2 and 3 were used near the end. According to Watson (1997), the words "sample" and "population" are purposely not used in questions 2 and 3 to explore if students recognise these concepts in the article. The order of questions 2 and 3 means that tier 3 of critical statistical literacy is addressed first. According to Watson (1997), responses such as "They could be lying" illustrate some acknowledgement of one issue of sampling in this context. However, the optimal response requires students to recognise the unusual and inappropriate claims made for the United States as a whole on the basis of the sample from Chicago. Watson (1997) claims that if students miss this critical engagement aspect, they may be assisted by question 2, which specifically draws attention to other parts of the United States.

The rubric assessing responses to the above questions is shown in Table 1. The levels of responses for the description of sample (Q1) reflect those identified in tier 1 of the hierarchy. The levels assessed from a combination of responses to questions 2 and 3 identify the characteristics in appreciating context (tier 2) and thinking critically (tier 3). Levels 1 and 2 are reflective of the students' increasing understanding of sampling construct in the context of the article (tier 2 thinking). Watson (1997) reasons that Level 3 responses are in transition to authentic critical thinking whereas level 4 responses attain the tier 3 critical thinking without assistance.

Table 1. Criteria and examples for responses to sampling task

Level	Rubric	Example
0	No appreciation	Something on a letter.
1	Single idea	A test. A bit.
2	Two ideas	A little to test. A part of a whole
3	Related ideas	A little bit of something to test what it is like.
0	No engagement with sampling	Nothing unusual. They should not have guns.
1	Single ideas	They could be lying.
2	Sampling issues	They should ask everyone in the United States.
3	Issues only with hint	Q3. Maybe it would be different in Arizona than in Chicago.
4	Issue without a hint	Q2. Which school in Chicago? Were the people asked representative of the entire high school population in the United States?

(Adapted from Watson, 1997 and 2006)

Gal (2004) asks some worry questions about statistical messages that are relevant for the third step of questioning claims. Typical of these questions are the following: Where did the data (on which the statements are based) come from? Was a sample used? How were they sampled? Is the sample representative of the population? Overall, could this sample reasonably lead to valid inferences about this population?

Watson and Callingham (2003) have developed the three-tiered view into their Statistical Literacy Construct. Their model is a six-level hierarchy that represents increasingly sophisticated thinking starting from idiosyncratic through to critical mathematical:

1. **Idiosyncratic**
   Idiosyncratic engagement with context, tautological use of terminology, and basic mathematical skills associated with one-to-one counting and reading cell value sin tables.
2. **Informal**
   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 table, graph and chance calculations.

3. **Inconsistent**
   Selective engagement with context, often in supportive formats, appropriate recognition of conclusions but without justification, and qualitative rather than quantitative use of statistical ideas.
4. **Consistent Non-critical**
   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.
5. **Critical**
   Critical, questioning engagement in familiar and unfamiliar contexts that do not involve proportional reasoning, but which do involve appropriate use of terminology, qualitative interpretation of chance, and appreciation of variation.
6. **Critical Mathematical**
   Critical, questioning engagement with context, using proportional reasoning particularly in media or chance contexts, showing appreciation of the need for uncertainty in making predictions, and interpreting subtle aspects of language.

(Watson & Callingham, 2003, p. 117)

At the Idiosyncratic (level 1) and Informal (level 2) levels students are only merely interacting with the language and meanings of statistical terms. For the Inconsistent (level 3) and Consistent Non-critical (level 4) levels of the construct, students are beginning to engage with the context and uncover the statistics embedded in the context. In the last two levels of the progression, Critical (level 5) and Critical Mathematical (level 6), students are able to be critical and challenge claims made in statistical reports and data. Watson and Callingham (2003) believe that traditional textbook questions could fulfill the requirements of levels 1 and 2 but that the same types of questions were unlikely to fulfill the need to challenge students' critical thinking and that teachers would have to seek out contexts such as media reports to motivate and engage students.

There is a close relationship of the characteristics associated with levels of statistical literacy and Watson's (1997) three-tired framework of statistical literacy. The mathematical and statistical skills required at the different levels of the construct reflect the terminology of statistical ideas and its usage, which are suggested as essential at tier 1 of the framework. The engagement with the context of statistical inquiry reflects tiers 2 and 3 of the statistical hierarchy and thinking critically to question inappropriate claims and methods (the goal of tier 3) appears from level 5 onwards. Callingham (2007) suggests that the boundaries between levels are not rigid edges but rather provide a set of levels that give a convenient way of describing changes as students progress to higher levels of thinking. She adds that teachers can use this as a tool to assess students' statistical literacy.

A real strength of the Watson and Callingham (2003) model is that the researchers have validated their statistical literacy scale with responses from a large number of Australian students. This has enabled them to attempt to determine how and when instruction for statistical literacy could take place and how instruction can be scaffolded to help students' progress. Watson (2003) state that "Level 6 [of the statistical literacy construct] is the goal by the time students leave school but without an appreciation of the preceding levels of likely progression, it is not possible to plan experiences that will assist students to the higher levels of understanding" (p. 3). Watson (2003) does not attempt to align year levels with the levels of development observed; however they does observe, "by the end of compulsory schooling many students are not performing at the highest levels described above" (p. 3). Watson (2006) uses the term "stage" in association with the six hierarchical clusters (to describe performance on individual tasks) rather than the term level. Perhaps this is to avoid confusion with curriculum and year levels.

The following surveying school task illustrates the levels of students' statistical understanding as they engaged with the task:

> A class wanted to raise money for their school trip to the Movieworld on the Gold Coast. They could raise money by selling raffle tickets for a Nintendo Game system. But before they decided to have a raffle they wanted to estimate how many students in their whole school would buy a ticket. So they decided to do a survey to find out first. The school has 600 students in years 1 to 6 with 100 students in each grade.
>
> How many students would you survey and how would you choose them? Why?
>
> Five students in the school conducted surveys.
>
> 1. Shannon got the names of all 600 students in the school and put them in a hat and then pulled out 60 of them. What do you think of Shannon's survey?
> 2. Jake asked 10 children at an after-school meeting of the computer games club. What do you think of Jake's survey?
> 3. Adam asked all the 100 children in Grade 1. What do you think of Adam's survey?
> 4 Raffi surveyed 60 of his friends. What do you think of Raffi's survey?
> 5. Claire set up a booth outside of the tuck shop. Anyone who wanted to stop and fill out a survey could. She stopped collecting surveys when she got 60 kids to complete them. What do you think of Claire's survey?
>
> (Watson, 2006, p. 37)

According to Watson (2006) the lack of engagement with the task associated with surveying a school before selling raffle tickets is likely to indicate reading difficulties as the introductory comments explaining the task are quite lengthy and structurally complex. The response, *choose them all because the more raffle tickets they sell the more money they get* indicates that misinterpretation of the task may be related to the belief that the aim is to sell tickets rather than survey students about selling tickets. The response also indicates a link to literacy skills for some students and the possible issues of reading a narrative. At stage 2, responses indicate literacy skills are sufficient for the scenario to be understood but explanations focus on single features of sampling such as *ask 400, ask everyone or ask the people I meet*, without considering the need to represent the population.

Watson (2006) states that at stage 3, students are not likely to detect the crucial features for fairness or bias. For instance, Raffi surveyed 60 of his friends, is either judged good because *it is easy* or bad because *they all like him*. It must be noted that the comments focus on inappropriate features of the methods in making decisions on whether they are good or bad. At stage 4, students tend to appreciate many contexts although they cannot go further to question claims. In terms of a survey task, students present representative but not random ideas for example, *I would choose 10 from each class*.

At the top two stages of the statistical literacy construct, students demonstrate skills similar to critical-thinking skills associated with the third tier of the Statistical Literacy Hierarchy. At stage 5 students are likely to be successful without sophisticated use of mathematical skills. For the surveying task students are likely to suggest random methods or random methods combined with representation such as *10 from each grade, 5 boys and 5 girls picked at random*. As mentioned previously, sophisticated statistical and mathematical skills are associated with success at stage 6, especially in media contexts. In relation to the surveying school task, students are likely to detect two flaws in the method proposed by Jake to survey a school. For instance, there are not enough people and they are selectively chosen. As stated earlier, they are likely to pick up the non-representative nature of the sample from Chicago in the media extract.

The Statistical Literacy Construct had been proposed because the researchers felt that while statistical literacy was a part of the school curriculum, "very little research has been carried out to document the progress made by students as they progress through … their schooling in developing both statistical techniques and critical evaluation skills" (Watson & Callingham, 2003, p. 116). There was an attempt to understand how development in statistical literacy was related to the development of statistical concepts in students. There are some obvious differences between Gal's (2004) approach and that taken by Watson and Callingham (2003). Gal presents a full definition of statistical literacy along with the necessary components that are needed. However, Watson and Callingham differentiate between hierarchical levels of statistical literacy. The different approaches can be explained by the contexts of their studies into adults and students respectively. The essence of both Gal's and Watson and Callingham's descriptions are very similar. Both emphasise a need for statistical knowledge and skills, the ability to communicate ideas, the centrality of context, and the need to be critical. In both descriptions of statistical literacy there are clear references to "being critical". Critical thinking and critical literacies are embedded across the statements for key competencies, values and descriptions of learning areas in the new curriculum (Ministry of Education, 2007).

A framework for statistical thinking in empirical enquiry

As mentioned earlier, Wild and Pfannkuch (1999) have developed a model for statistical thinking which builds upon statistics education literature as well as interviews with statisticians and undergraduate students. The researchers have identified four dimensions: an investigative cycle, types of thinking, an interrogative cycle, and dispositions. The investigative cycle or PPDAC cycle (problem, plan, data, analysis and conclusion) describes the process of statistical investigation.

Wild and Pfannkuch's second dimension states that there are five fundamental types of statistical thinking: recognition of the need for data transnumeration (or using different representations of data to give better understanding), understanding variation, using statistical models and integrating the statistical with the contextual. The interrogative cycles (generate, seek, interpret, criticise and judge) describe the thinking process that statisticians use when dealing with the problem and the data. Finally, Wild and Pfannkuch describe the dispositions that statisticians require for statistical problem solving. Their dimensions are non-hierarchical and non-linear; however, the investigative cycle and the interrogative cycle are sequential.

Wild and Pfannkuch's (1999) dispositions components are scepticism, imagination, curiosity, awareness, openness, propensity to seek deeper meaning, being logical, being engaged and persevering. Under scepticism Wild and Pfannkuch see the need to "adopt a critical eye". Although some of the statisticians that Wild and Pfannkuch researched believed that the dispositions could not be taught, they describe how the investigative cycle and the interrogative cycle for example can be used as thinking tools to prompt students to address certain issues. Both Gal (2004), with his attitudes and beliefs, and Watson and Callingham (2003) describe a need for similar dispositions in their models. While the latter framework comes out of the work of statistics educators working in classrooms with students, the Wild and Pfannkuch (1999) framework comes from the researchers researching from the statistician's viewpoint and looking at what statisticians believe they do. Wild and Pfannkuch do not attempt to describe the progression or development in statistical literacy or the development of statistical concepts in students but rather outline what statisticians actually do. The focus is on describing a much wider framework for statistical thinking. They do not appear to see statistical thinking or statistical literacy as separate entities but rather that there is "holistic thinking informed by statistical elements" (Wild & Pfannkuch, 1999, p. 244).

Usefulness of models

Shaughnessy (2007) argues that models of statistical literacy focus on critical survival skills for consumers of statistical information. These have a prescriptive nature, "indicating what learners throughout their lives need to do in order to be well informed, or to make good decisions or to take advantage of the data that is available to them" (p. 96). Shaughnessy (2007) claims that statistical thinking models help both teachers and researchers to attend to the important concepts and processes in the teaching and learning of statistics. Moreover, the models reflect what we want learners, consumers and producers of statistics to know. He states that models of statistical thinking are primarily normative models of what statisticians feel are the important concepts and processes of their discipline.

The three frameworks described above are by no means the only ones available for describing statistical thinking or statistical literacy. Reading (2002) suggests "profile for statistical understanding" based on the SOLO taxonomy across five areas of statistics: data collection; data tabulation and representation; data reduction; probability; and interpretation and inference. Jones et al. (2000) developed a framework for characterising children's statistical thinking that provides a coherent picture of young children's thinking and their cognitive knowledge. The framework has four levels of thinking across four key constructs. Both frameworks do not specifically mention statistical literacy and are similar to the hierarchical framework of Watson and Callingham (2003).

FUTURE DIRECTIONS AND CHALLENGES

The knowledge and the dispositional elements of Gal's (2004) statistical literacy model and Watson's (2006) statistical literacy framework have implications for statistics education. We draw implications for the statistical literacy strand in the New Zealand curriculum with respect to both directions for teaching and research.

The notion of critical questions or the need for people to become familiar with flaws and biases in statistical information is a key aspect of Gal's (2004) model and Watson's (2006) statistical literacy framework. As mentioned in the literature review, Watson has undertaken valuable research that invited students to challenge claims in media reports. Watson concluded that at the highest level of the statistical literacy framework students possessed the confidence to challenge what they read in the media so long as teachers made them aware of the expectations that they must constantly question conclusions. Watson argues that appropriate critical questions can be extracted from media articles. Moreover, she recommends that these questions should be introduced in the primary curriculum, as there is a need for children to begin to question statistical reports at an early age.

The literature indicates that statistical literacy is a complex construct. It encompasses all key components of the statistical thinking and probability. However, beyond these characteristics is the realisation of the importance of engagement with context in defining the underlying construct of statistical literacy. Hence, it is not just knowing curriculum-based formulas and definitions but integrating these with an understanding of the increasingly sophisticated and often unfamiliar settings within which questions arise. It would seem that the use of media articles as a medium for teaching and learning could enhance the development of students' statistical literacy.

Context plays a particularly key role in the development of statistical literacy. Watson (2006) argued that students at higher levels of the statistical literacy hierarchy are more able to interact critically with the contexts in which tasks are situated. Students' motivation towards statistical literacy could be influenced by the context in which the tasks are embedded. Teachers need to choose contexts that suit specific needs of their students.

Best (2004) argues that most people are not accustomed to questioning statistics. If Best is correct in identifying this as common among adults, then what are the implications for schoolteachers? Perhaps teachers need to promote a critical orientation towards statistics from early year levels. Whitin and Whitin (2003) claim that even kindergarten children can be encouraged to question numerical information.

The ability to interpret and critically evaluate reports that contain statistical elements is paramount in our information-laden society. The literature review supports a view that evaluation of statistical information in reports may be in the category of higher order thinking. Higher order thinking skills may not be easy to teach since traditional teaching and assessing focus on the lower order thinking skills which are methods and procedures of statistics. Garfield and Ben-Zvi (2008) suggest that teachers need to promote classroom discourse that include statistical arguments and sustain exchanges that focus on significant statistical ideas. Moreover, they add that this can be done by encouraging students to express their views and asking other students to comment on these views.

While researchers have investigated students' cognitive development in statistical literacy (Watson, 2006; Watson & Callingham, 2003), few have explicitly investigated the associated dispositional component (motivation beliefs and attitudes) that affect or support statistically literate behaviour. Panksepp (2003) argues that many higher order cognitive abilities co-evolve with corresponding affective processes. Gal (2004) explains that development of research methods in this area is crucial for understanding the forces that shape statistically literate behaviour in diverse contexts. According to Gal, changes in dispositions can be measured as part of evaluating the impact of educational interventions aimed at improving statistical literacy of all walks of life.

What are the student attitudes and motivation towards statistical literacy and the way we can teach it? How can we modify our teaching methods to improve student attitudes?

The models of development in statistical literacy documented in this paper can enable teachers to trace students' individual and collective development in statistical literacy during instruction. The models offer a coherent picture of students' statistical literacy and they can provide a knowledge base for designing and implementing instruction. The models provide useful information regarding the type of statistical literacy that can be expected at different levels.

Existing classroom schemes of work tend to focus more on generating data rather than interpreting or evaluating other studies or reports. The focus is on students going through the statistical inquiry cycle. School textbooks may also play a central role in statistics classroom to help students develop statistical skills and techniques. Students are expected to be able to work through the exercises by themselves with the teacher available to help them. In light of changed curriculum expectations and extended social expectations for statistical literacy, teachers across the different learning areas will have increased expectations placed on them in terms of appreciating statistical literacy and how to develop it. It is likely that professional development for teachers will be needed if they are to assist their students to achieve the highest levels of statistical literacy before they leave formal schooling.

ACKNOWLEDGEMENT

This research project is funded by the Teaching and Learning Research Initiative and called *Developing Secondary School Students' Understanding of Statistical Literacy in a Data Analysis Environment.*

REFERENCES

Batanero, C. (2002). Discussion: The role of models in understanding and improving statistical literacy. *International Statistical Review, 70,* 37–40.

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

Ben-Zvi, D., & Garfield, J. B. (2004). Statistical literacy, reasoning and thinking: Goals, definitions, and challenges. In D. Ben-Zvi & J. B Garfield (Eds.), *The challenge of developing statistical literacy, reasoning, and thinking* (pp. 3–16). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Best, J. (2004). *More damned lies and statistics: How numbers confuse public issues.* California, CA: University of California Press.

Biggs, J., & Collis, K. (1982). *Evaluating the quality of learning: The SOLO taxonomy.* New York, NY: Academic Press.

Callingham R. (2007). *Assessing statistical literacy: A question of interpretation.* Retrieved from www.stat.auckland.ac.nz/~iase/publications/17/6D1_CALL.pdf

Chick, H., Pfannkuch, M., & Watson, J. (2005). Transnumerative thinking: Finding and telling stories within data. *Curriculum matters, 1,* 86–107.

Doyle, P. (2008). *Developing statistical literacy with students and teachers in the secondary mathematics classroom.* (Unpublished master's thesis). University of Waikato, Hamilton, New Zealand

Gal, I. (1995). Statistical tools and statistical literacy: The case of the average. *Teaching Statistics, 17,* 97–99.

Gal, I. (2004). Statistical literacy: Meanings, components, responsibilities. In D. Ben-Zvi & J. B. Garfield (Eds.), *The challenge of developing statistical literacy, reasoning and thinking* (pp. 47–78). Dordrecht, The Netherlands: Kluwer Academic Publishers.

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

Garfield, J. B., & Gal, I. (1999). Teaching and assessing statistical reasoning. In I. V. Stiff and F. R. Curcio (Eds.), *Developing mathematical reasoning in grades k-12* (pp 207–219). Reston, VA: National Council of Teachers of Mathematics.

Hooke, R. (1983). *How to tell the liars from the statisticians*. New York, NY: Marcel, Dekker.

Jones, G. A., Thornton, C., Langrall, C. W., Mooney, E. S., Perry, B., & Pratt, I. (2000). A framework for characterizing children's statistical thinking. *Mathematical Thinking and Learning*, *2*(4), 11–50.

Makar, K., & Rubin, A. (2009). A framework for thinking about informal statistical inference. *Statistics Education Research Journal, 8*(1), 82–105.

Ministry of Education. (2007). *Literacy progressions: Meeting the reading and writing demands of the curriculum.* Wellington, New Zealand: Learning Media.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics.* Reston, VA: Author.

Panksepp, J. (2003). At the interface of the affective behavioural and cognitive neurosciences: Decoding the emotional feelings of the brain. *Brain and Cognition, 52*(1), 4–14.

Reading, C. (2002). *Profile for statistical understanding*. Proceedings of the Sixth International Conference on Teaching Statistics, Cape Town, South Africa.

Rumsey, D. J. (2002). Discussion: Statistical literacy: Implications for teaching, research and practice. *International Statistical Review, 70,* 32–36.

Schield, M. (2004). Statistical literacy and liberal education at Augsburg College. *Peer Review, 6*(4), 16–18.

Shaughnessy, J. M. (2007). Research on statistics learning and reasoning. In F. K. Lester (Ed.), *Second handbook of research on mathematics teaching and learning* (pp 957–1009). Reston, VA: The National Council of Teachers of Mathematics.

Shaughnessy, J. M., & Pfannkuch, M. (2004). How faithful is old faithful? Statistical thinking: A story of variation and prediction. *Mathematics Teacher, 95*(4), 252–259.

Wallman, K. K. (1993). Enhancing statistical literacy: Enriching our society. *Journal of the American Statistical Association, 88*(421), 1.

Watson, J. M. (1997). Assessing statistical literacy using the media. In I. Gal & J. B. Garfield (Eds.), *The assessment challenge in statistics education* (pp 107–121) Amsterdam, The Netherlands: IOS Press & The International Statistical Institute.

Watson, J. M. (2000). Statistics in context. *The Mathematics Teacher, 93*(1), 54–58.

Watson, J. (2003). Statistical Literacy at the school level: What should student know and do? *Proceeding of the 54th International Statistical Institute Session.* Berlin, Germany.

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

Watson, J. M., & Callingham R. (2003). Statistical literacy: A complex hierarchical construct. *Statistics Education Research Journal, 2*(2), 3–46.

Whitin, D., & Whitin, P. (2003). Talk counts: Discussing graphs with young children. *Teaching Children Mathematics, 10*(1), 142–149.

Wild, C. J. & Pfannkuch, M. (1999). Statistical thinking in empirical enquiry (with discussion). *International Statistical Review*, *67*(3), 223–265.