# Students' Statistical Reasoning in Constructing Newspaper Articles

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This paper addresses the final year of a 3-year longitudinal international study, which addressed the development of 9th and 10th grade students' statistical knowledge and reasoning processes. The study engaged students in the construction of data-based projects, which involved the processes of designing, analyzing, interpreting, representing, communicating, and thinking critically and reflectively. This paper addresses students' reasoning on one of the final activities of the program, namely, students' construction of newspaper articles. The findings highlight the importance of placing special emphasis on students' abilities to think critically *about* data and *beyond* data.

Statistical education is well recognised as fundamental to students' development as mathematically literate citizens (Watson, 1998). Meaningful statistical experiences can help students cope with the increasing use of data and data-based arguments in society, and can help them develop an appreciation of mathematics as a way of interpreting their world (Australian Association of Mathematics Teachers, 1996; Cobb, 1999; Gal & Garfield, 1997; Greer, 2000; Hancock, Kaput, & Goldsmith, 1992; National Council of Teachers of Mathematics, 1998).

There has been an increasing focus on student-driven classroom projects, where students are given opportunities to engage fully in the practices and processes of meaningful statistics (Derry, Levin, Osana, & Jones, 1998; Hancock et al., 1992; Lajoie, Lavigne, Munsie, & Wilkie, 1998; Lehrer & Romberg, 1996; Moore, 1998). However, as Gal (1998) noted, curricula still place a strong emphasis on procedural skills in statistical tasks, while allocating little time to developing students' abilities to "make sense of and communicate about the meaning of data" (p. 275). In particular, little attention has been given to students' own statistical constructions such as argued cases, investigative problems, newspaper articles, and various data-gathering instruments. Yet statistical construction is a natural component of authentic data-based projects, especially when students and teachers work within a collaborative learning environment that values and encourages a diverse range of reasoning processes (Lehrer & Romberg, 1996; Scardamalia & Bereiter, 1992). Unfortunately, we know little about the reasoning processes entailed in these types of constructions (Hancock et al., 1992; Jacobs, & Lajoie, 1994; Lehrer & Romberg, 1996), and even less about effective ways of assessing students' statistical processes (Lajoie et al., 1998).

The present study attempted to address these limitations by designing instructional programs that had a strong focus on students' active engagement in data construction, analysis, interpretation, and representation, together with the communication of their findings in novel and statistically convincing ways.Students' critical assessment of their own constructions and that of their peers was also an important feature of the programs. More specifically, the following reasoning processes were emphasised in the programs (Gal & Garfield, 1997; Derry et al., 1998; Scheaffer, Watkins, & Landwehr, 1998; Watson, 1998).

*Understanding and reasoning about the processes of statistical inquiry*. Understanding and appreciating the phases of a statistical inquiry (e.g., formulating questions, planning a study, collecting, organizing, and analyzing data).

*Reasoning about data.* Knowing that raw data need to be reduced to facilitate interpretation, and being able to describe, compare, and explain sets of data.

*Reasoning about statistical measures.* Understanding what measures of central tendency tell about data sets, knowing which measure is best to use under different conditions, and knowing how to utilize measures of centre and spread for comparing data sets.

*Reasoning about representations of data.* Understanding how data are summarized and presented (Lajoie et al., 1998), together with determining the appropriateness of the tables, charts and/or graphs constructed to represent data. To reason effectively about data representations, students must be able to reason about data and understand how to read, construct, and interpret a graph/table/chart; they must also know how to modify these representations to better represent a given data set.

*Reasoning and communicating in a critical and philosophical manner*. Included here are: (a) being aware of possible biases or limitations in the generalizations that can be drawn from data; (b) being able to use statistical terminology appropriately, convey results in a convincing manner, and develop reasonable arguments based on data or observations; (c) being able to challenge the validity of the data interpretations and representations of others; and (d) being able to critically evaluate statistical information, to skilfully defend or reject particular statistical arguments, to effectively critique statistical problems posed by others, and to think flexibly and creatively in extending and modifying statistical problems.

Components of the above reasoning processes are addressed here within the context of 10th grade students' construction of a newspaper article. The article served as one of several ways in which we assessed the students' statistical development from their participation in the programs.

## Methodology

### *Participants*

The students addressed here were from a 10th grade class (N=22) in a co-educational Lutheran school. The students had already completed the first program in their 9th grade. The focus here is on the second program.

### *Program*

Both the 9th and 10th grade programs followed Lajoie et al.'s (1998) approach of employing multiple contexts within which students could develop their statistical understandings and reasoning processes. We worked collaboratively with the classroom teacher in implementing the program, ensuring that a community of learners was fostered (Cobb & Bowers, 1999). Students worked collaboratively on most of the activities and were encouraged to express their ideas and sentiments in an open and constructive manner.

The students were provided with the appropriate technological tools and a website that housed the students' constructions and also contained forums for student-student interactions and teacher-researcher discussions. The 10th grade program comprised 16 sessions (approx. 70 mins. each), which covered the following key aspects.

*Reasoning about data inquiry, data analysis, and data representation*. The basis for most of the activities in this program was an international survey, which the students and their overseas counterparts had constructed in the previous grade (English, Charles, & Cudmore, 2000). Sample questions from the survey appear in Figure 1.

The first half of the program was devoted to exploring the survey data, discussing issues of sampling, addressing approaches to organizing and reducing data, and revising measures of central tendency. As the students worked with the data, they identified patterns and trends, made conjectures, drew inferences, and engaged in philosophical discussions on some of the more contentious survey issues (e.g., "Should students have a say in the design of their school uniform?" "Do you believe that natives are entitled to their tribal lands?")

- Do you think that students should wear school uniforms? (strongly agree, agree, disagree, strongly disagree)
- Do you think that students should be involved in the design of school uniforms? (yes, no)
- Do you think your social life takes preference over your schoolwork? (Yes, no)
- Which of the following types of books do you enjoy reading? (selection of book types given)
- How many bathrooms are in your home (selection of 1 through to 5 or more)

*Figure 1*. Examples of survey questions.

Considerable time was spent exploring ways in which trends in the survey data could be represented visually. Excel was used for this. An emphasis was placed on selecting and constructing appropriate representations for displaying the survey findings. Students communicated their constructions both informally as shared class activities and more formally as a part of their documentation on the website.

*Reasoning and communicating in a critical and philosophical manner*. In the second half of the program, the students applied their understandings to the construction and critical analysis of (a) investigative problems for their class and overseas peers to solve and (b) a newspaper article. These constructions were based on data of their choice from the survey. After generating their problems, the students critically analyzed one another's creations, made modifications to their problems based on this feedback, and then posted their final problems on the website for their overseas peers to try (English et al., 2000). For the newspaper article, which the students completed individually, the instructions shown in Figure 2 were given. The students prepared their articles on disc, and supplied printouts for the class.

Write a newspaper article based on what you have found in your exploration of the data from the three countries. Your article should include appropriate graphs / tables. What you write must be based on what you have found in the comparison of your data. It should be presented with an appropriate heading. It should also include the source of your data.

*Figure 2.* Instructions for construction of newspaper article.

The students completed a critical reflection sheet on the day following their construction of the newspaper article. This sheet asked them to consider the issues shown in Figure 3.

- When you were given the task of constructing a newspaper article using the data from the survey, what issues did you consider?
- What questions did you ask yourself when you were trying to clarify what you were doing?
- What obstacles did you encounter during the construction of your newspaper article?
- How did you overcome these obstacles?
- Does your newspaper article present a convincing argument? Why/why not?

*Figure 3*. Critical reflection sheet completed after the newspaper article.

As the final part of the newspaper activity, each student gave a class presentation (using Powerpoint). As the student was doing so, his/her peers completed a critique form assessing various aspects of the article (points for consideration included "What was the main argument of the article? Did you find the argument convincing? Why/why not?")

### *Data Collection*

Data collection included field notes, video and audiotapes of the students' discussions and class presentations, informal student and teacher interviews, and students' records of their work (on the website, on their computer discs, and their handwritten reponses).

## Analysis of Students' Newspaper Articles

Drawing upon the work of Derry et al. (1998), Garfield and Chance (2000), Lajoie et al (1998), and Watson (e.g., 1997, 1998), the students' newspaper articles were analysed in terms of the following components.

- *Communicating the statistical issues*. Whether the student (a) clearly identified the issue/s being addressed; (b) indicated the data source.
- *Reasoning with the data and their visual representations.* Whether the student (a) referred to sample size; (b) used appropriate statistical measures (e.g., frequencies, means); (c) considered more than one data set; (d) used appropriate and correctly constructed representations (e.g., bar graph); (e) used more than one form of representation.
- *Thinking about the data and beyond the data*. Whether the student (a) was able to interpret the data, in contrast to simply reporting them; (b) acknowledged possible biases or limitations; (c) presented acceptable arguments or reasoned judgements (Kuhn, 1991) based on the data; (d) included philosophical comments (e.g., ethical considerations).

Instances of inappropriate generalisations or associations in the students' articles were also noted.

## Overview of Students' Reasoning on the Newspaper Articles

### *Communicating the Statistical Issues*

The majority of students (77%, N=22) were able to both clearly identify the issues being addressed in their article and indicate the data source (e.g., see Figure 4).

### *Reasoning with the Data and their Visual Representation/s*

In contrast, few students (23%) referred to the size of the student samples from the countries that had completed the survey (Australia, Canada, Zambia). The sample sizes were uneven, and furthermore, the Canadian sample comprised females only.

Nevertheless, all students were able to use appropriate statistical measures in reporting their findings. However, despite the time devoted to the basic measures of central tendency during the program, the majority of students (73%) simply reported frequencies (mostly expressed as percentages). Forty percent of the students cited averages, which was the only measure of central tendency addressed by the students. Some students, such as Jeff (Fig.4) reported both frequencies and averages.

More students (55%) chose to address just one data set in their article (e.g., minutes spent talking on the telephone in a typical day) rather than two sets (e.g., minutes spent talking on the telephone in a typical day and number of hours of sleep the previous night). Of those in the latter category, only two students made inappropriate associations that were not supported statistically (e.g., "Do teenagers spend too much time on the phone and consequently suffer from not having enough sleep?")

The use of appropriate and correctly labelled visual representations was evident in all but two of the newspaper articles. Just over half the students included two forms of representation to illustrate their arguments, such as Jeff's use of bar graphs and frequency tables.

*Where Plumbers Go to Make Money* (Jeff P.)

According to recent data taken from the International Survey 1999 -- Part A for Australia (Fig.1), Canada (Fig.2), and Zambia (Fig.3), the most likely place to find a job installing a bathroom is Canada. The mean number of bathrooms registered by a student population in Australia, Canada, and Zambia would suggest that there are on average 1.5 more bathrooms in Canada than in Australia and 0.6 than in Zambia. If the average bathroom costs approximately $7000, then a plumber in Canada is making an additional $10,500 than his Aussie mate and about $4000 over the local Zambia plumber.

***Mean Values*.** Surprisingly, Australia is ranked as having on average the least number of bathrooms. Australia = 2.4, Canada = 3.9, Zambia = 3.3.

***Frequency***. It would appear that just having 5 bathrooms in Australia is considered excessive. The majority of Australian homes have 2 - 3 bathrooms (Fig.4). Zambia, on the other hand (Fig.5) has two extremes -- either 2 or 5 bathrooms. The most opulent it would appear are the Canadians who predominantly (Fig.6) have no fewer than 2 bathrooms with the largest sample of students having no less than 5. It would seem that to be a Canadian and to be clean you need more than just 1 bathroom. The poor old plumber in Australia is being left behind in the bathroom trade.

(*Figs 1-3 were bar graphs of student population by no. of bathrooms for each of the countries, while Figs 4-6 were frequency tables of the numbers of bathrooms in each country*).

*Figure 4.* Jeff's newspaper article (excluding his figures).

### *Thinking About the Data and Beyond the Data*

Students' ability to think critically about their data and reflect on their issues was of particular interest, given that the development of statistical literacy requires a knowledge of what is involved in interpreting the findings from a statistical investigation (Garfield & Chance, 2000). A good proportion of the students (68%) went beyond simply reporting their results to interpreting them for the newspaper reader. In doing so, some students brought in additional data for comparison purposes, such as the recommended number of hours of sleep for students of their age, or, as in Jeff's case (Fig. 4), a comparison of the estimated amounts of money that could be earned from bathroom installation in the three countries.

It was pleasing to see that the majority of students (86%) could give acceptable arguments or reasoned judgements based on the data they were addressing. For example, in his article on mobile phone use, Jamie presented an argument as to why the Australian and Canadian students had more mobile phones than their counterparts in Zambia; he supported his argument by referring to further data from the survey:

> According to the results from the three countries, mobile phones are more popular and common in the well developed countries such as Australia and Canada but not in the developing country such as Zambia. This may happen because of the income they have and the amount of money they have left. The people in Zambia usually have more people in their family compared to the other countries. Another reason can be they can't afford that much money to own or have a mobile phone. Refer back to the pocket money the students have each month, the Australian and Canadian always have much more than the students in Zambia. Zambians usually got less than US$10, but the Australian and Canada students, they usually got more than US$30. Some of them may even have more than that. So, maybe, shortly in the future, there will be more people who have mobile phones in Zambia because the wagga will become higher during that time.

In Erico's newspaper article ("Kids Need Pets"), a rational argument was presented as to why students from smaller families believe in the importance of pet ownership over students from larger families:

> The results of the survey represented in these graphs show that students in Australia and Zambia who don't have many people in their family have a stronger belief that pets are important in their home than students who have more people in their family. For example, the Australian results show that more than 70% of students think pets are important for them whereas less than 45% of students whose family has more than 4 people, think pets are important. This may be because the students who don't have many people in their family have stronger beliefs that the pets are important in their homes to them than the students who have many people in their family. Children whose families are small may feel lonely in their homes, so they feel more strongly that pets are important in their house.

Six students also included some philosophical discussion in their articles, such as the comments that appeared in Lauren's article, which addressed the issue of students' social life taking preference over their school work:

> After observing these results, I have noticed that this is quite a substantial problem for Canada and Australia that must be addressed immediately. Aren't parents as strict as they used to be? Do kids not consider it as important to achieve highly and succeed at school or is it that schools simply do not place enough pressure on children to succeed or the punishments aren't influential enough or as dreadful enough as they used to be?"

It was hoped that the students would comment on sampling issues, but only six students did so. For example, in her article Lauren noted:

> These results, however may not be entirely accurate, as they were completed by only a very small

percentage of students from only three specific countries. Therefore the results are not very widespread, and accurate or definite results or conclusions cannot be drawn.

Students' critical reflection on the construction of their newspaper article also revealed little attention to sampling issues. In their response to the question, "Does your newspaper article present a convincing argument? Why/why not?" 10 students replied "yes" because "It's based on the data" while only four students stated that their arguments were not entirely convincing because of the nature of their data (e.g., "No, because not an equal amount of information was supplied."). Non-statistical reasons were also offered by six of the students, some quite inappropriate such as "Yes, my article presents a convincing argument because every male knows that females spend a lot more time on the phone than the males and this article proves it."

## Concluding Comments

Students' construction of a newspaper article using data from their international survey provided one effective means of determining whether students could apply, within a novel context, the reasoning processes they experienced in the programs. On the whole, the students demonstrated an ability to reason with the basic data types, to use simple statistical measures to identify patterns and trends, and to communicate their findings in both text and visual formats. However, the students' application of measures of central tendency was limited to the mean, suggesting that the programs needed to broaden students' experiences in dealing with a range of statistical situations. Nevertheless, the students were able to present acceptable statistical arguments and reasoned judgements, with several students extending their discussion to incorporate philosophical or ethical comments on the issues they reported.

It is evident, though, that greater attention needed to be placed on developing the students' concepts of sampling (Watson & Moritz, 2000), as well as their abilities to reason *about* data, rather than just *with* data. This includes critical and insightful thought about evidence presented, together with an ability to reason beyond the given data to consider possible explanations, implications, and issues for future research. It is imperative that statistical programs include a strong focus on the range of reasoning processes addressed here. In particular, an increased focus is needed on effective statistical reasoning within social contexts such as those that the media presents students on a daily basis (Watson, 1998).

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