INVESTIGATING THE 'DATA SENSE' OF PRESERVICE TEACHERS ®

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Teacher educators have a concern about the level of mathematical (including statistical) content knowledge of students who enter teacher education programs. Many students have knowledge of certain statistical procedures but lack a real understanding of those procedures such as why and when some should be used in preference to others. This paper reports on a study into the statistical knowledge of primary (elementary) teacher education students. An open-ended task (using a small multi-variate data set) was given to the students and required them to examine and report any interesting features in the data. Aspects of the students' level of 'data sense' was evaluated through an investigation of the statistical procedures that they used in relation to the report which they produced on what the data showed.

INTRODUCTION

A concern for pre-service teacher educators is the level of mathematical content knowledge of their students. In particular, just how well prepared students are for teaching, with respect to their statistical knowledge when they enter their teacher education programme is unclear. In New Zealand, the place of statistics in the school curriculum is undisputed. The current national curriculum statement, *Mathematics in the New Zealand Curriculum* (MiNZC) (Ministry of Education, 1992), following the trend of previous curricula, recognizes Statistics as one of six strands (the others being Number, Algebra, Measurement, Geometry and Mathematical Processes). Consequently, Statistics is part of the mathematics programme in classrooms from Year 1 onwards. Teacher education students could be expected to have had a minimum of 11 years of compulsory schooling during which time statistics would have been part of their own mathematical learning, and many students would have had 13 years of mathematics learning at school.

Students may well have competency with certain statistical skills (such as calculating a mean when given a set of numbers) but the students' levels of understanding may not match their skill levels. Consequently, students should be given opportunities to develop "data sense" (Friel, Bright, Frierson, & Kader, 1997). Data sense, which includes being able to generate information on which graphs and statistics are constructed, is considered to be an important part of becoming statistically literate. The opportunity to develop data sense should occur especially as part of a problem-solving process (Garfield, 1993) such as through investigations. Friel et al (1997) describe the carrying out of a statistical investigation as a process consisting of the following: posing a question, collecting data, analyzing data, interpreting results, and communicating results. All these components of a statistical investigation encourage students into a variety of statistical thinking, some of which is considered unique to the realm of statistics (Wild & Pfannkuch, 1999). Wild and Pfannkuch described the different components of statistical thinking such as recognition of the need for data (rather than reliance on anecdotal evidence); transnumeration, which they defined as a dynamic process of changing data representations in order to arrive at a better understanding of the statistical system; the recognition of variation, which is necessary for learning and decision-making under uncertainty; being able to reason using statistical models; and being able to integrate context knowledge with statistical knowledge to help the development of meaning.

When considering how well students manage an investigation through all its stages , Wild and Pfannkuch's model of statistical thinking provides both a way of examining the level at which the students are involved in the investigation and an indicator of the extent to which the investigation is completed. The components of statistical thinking can be identified in the variety of aspects that students are involved in while carrying out an investigation and they potentially show how the students have engaged with the data to make sense of it.

This study investigated the extent to which a group of students took an open-ended task (having no specific instructions on statistical procedures to be used) and completed a thorough statistical investigation of the data. The major goal for the students was for each student to produce a written report on what they found in the data set, providing evidence for any statements made.

METHOD

A group of 30 preservice teacher education students were given an open-ended task to investigate a small multivariate data set in order to produce a written report on anything that they found interesting in the data. Evidence to back up their claims had to be supplied. The students (in the first year of their three-year teacher education programme) were at the beginning of a statistics module in an elective course in mathematics. Of the 30 students, 21 had studied mathematics through to year 13 of high school and as such, would have been exposed to more sophisticated statistical procedures than would have been necessary to deal adequately with this investigative task.

The task used the 'data cards protocol' as developed by Watson, Collis, Callingham, and Moritz (1995). Specifically, the students were each given a set of 16 cards, with each card containing some data about one child. (See Appendix for an example of one data card.) Other similar studies, such as Chick (2000), have involved the participants being given the data in the form of a table; it was decided that for this study, utilizing the 16 separate data cards would allow the students to tabulate the data if they decided that this would be helpful. The seemingly simple task of tabulating data is one way of the students manipulating the data to make sense of it. The in-class task, as an investigation by each individual student, had to be completed within one hour.

Aspects of the types and appropriateness of procedures used by the students in the investigation have been reported elsewhere (Burgess, 2001). This study examines the written reports that were the outcome of the students' investigations and aims to find how these are linked to the extent of transnumerative-type thinking exhibited in their reports. Was the report indicative of both the degree of completeness of the investigation and the statistical level at which the students had engaged with the task? Are there particular types or amounts of transnumerations that would relate to or give an indication of the level of sophistication of the written report produced?

RESULTS AND DISCUSSION

The written statements in the reports were classified into two major types: summary statements and generalizations. The statements that were merely a verbal description of facts shown from tables, graphs, or statistical summaries were classified as summary statements. Two examples of summary statements are:

- "*The four people who eat seven or more fast food meals each week are males.*"
- *"It appears that watching TV is the most popular pastime."*

In comparison, some statements were classified as generalizations about the data. These statements went beyond the data at an individual level and dealt with group trends, even though the statement would not have applied to each individual in the group. It was clear that this type of statement showed that the student was thinking at a higher statistical level through being able to deal with group trends instead of focusing on the individual. An example of such a generalization is:

- "*I found that that the average fast food meals consumed by the children whose favourite activity was watching TV was considerably higher than the children whose favourite activities were more mind and body stimulating."*

The writing of generalizations based on the data indicates a higher level of data sense than the writing of statements which are verbal forms of information shown in other forms. The students responsible for the generalizations are showing that they are able to interpret their transnumeration of the data, and integrate this with some contextual or statistical knowledge. In comparison, the summary statements show that the students are not connecting the transnumeration with other statistical knowledge. Although the instructions for the task specifically asked for a written report about anything interesting in the data, it is significant that nine of the 30 students wrote nothing about the data. The investigation carried out with these nine students appeared to involve them in no more than performing some isolated statistical procedures, such as:

- tabulation (eight students each created at least one table);
- calculation of statistical summaries (three students) such as the measures for a box and whisker plot, even though the plot was not completed, and means (two students); and
- graphs (six students produced 11 graphs), a number of which were incomplete or inappropriate for what was being represented.

These nine students appeared to lose the major purpose of the task. They performed some statistical procedures but for no apparent purpose other than performing a statistical procedure. There was no interpretation of what they had done. Although the task had a time limit of one hour, it is not believed that this had a major influence on the completion of the task since the data set was relatively small and consequently any calculations performed were not particularly time-consuming. These students appeared to not view the task as a complete process to be worked through. Since the students did not transnumerate the data to any significant effect in order to ‘get inside it’, nor provide any evidence that they had integrated a contextual knowledge of the data with statistical knowledge demonstrated through some procedures, it would be reasonable to conclude that they have a low level of data sense as it applies to the investigative process.

To investigate the writing of generalizations, a number of factors were examined to see whether there was any relationship between these factors and the type of statements that made up the written report. The students’ reports were grouped, one for those students who included generalizations in their reports, and the other for those who did not write any such statements (see summary in Table 1). Was the number of instances of transnumerations significant in relation to the written reports? Were the types of transnumerations signficant in relation to the written reports? Examples of transnumerations used included:

- tabulation of the data or subsets of the data with tallies and/or frequencies being recorded;
- recording of fractions, percentages, or ratios for particular variables of interest (e.g. 6/18 play sport, of which 50:50 male:female);
- listing of data for one variable (in some cases, numerical data was left unordered)
- statistical summaries, such as mean, range, median, or quartiles;
- subgrouping of the data, such as identification of gender which had not been explicitly provided; favourite activities grouped such as ‘active’ or ‘passive’ or other similar groupings; and weights or ages grouped into at least two intervals;
- graphs, such as bar, pie, box and whisker, and line. Note: Graphs that were considered to be inappropriately drawn from a statistical point of view, yet could be interpreted in some way, were included in the count.

Since a number of the tables that the students formed included more than one variable, the number of variables in each table was determined.

Table 1
Summary of Use of Transnumerations for the Students Who Wrote Generalized Statements Compared With Those Who Did Not Write Any Generalized Statements

Type or feature of transnumeration used	Average number per student for	
	group who wrote generalized statements (n= 14)	group who did not write generalized statements (n = 16)
number of transnumerations	6.2	6.3
tables created	2.0	2.0
variables per table	1.9	1.3
graphs capable of being interpreted	0.2	0.8
data subgrouped	1.5	0.75
summary statements written	1.6	1.5
summary statements involving more than one variable	0.7	0.1

Altogether, 14 of the 30 students wrote 17 generalizations. Only three of the generalizations involved only one variable; the rest involved from 2 variables, such as type of favourite activity and the number of fast food meals consumed, up to 4 variables – age, gender, favourite activity, and number of fast food meals consumed. The 14 students who wrote these generalizations also wrote a total of 23 summary statements, while the other 16 students wrote 24 summary statements. This would indicate that the writing of summary statements about the data did not necessarily encourage the students to go to generalize about what they had found and thereby conclude the investigation process to a higher level.

Since most generalizations (14 out of 17) dealt with more than two variables, the students responsible for the generalizations had identified trends across groups within the data and had made connections between variables. The generalizations could be considered to indicate a higher level of thinking about the data, as the students have considered within-group trends as well as across-group trends, rather than focus only on particular features of the data. They have also related their statistical procedures to the context of the data, thus exhibiting a wider range of statistical thinking in the investigation. The majority of summary statements (35 out of 47) only dealt with one variable. For example:

- *“They average 4 take out meals a week”.*
- *“It appears that watching TV is the most popular past-time.”*

Interestingly, 10 of the 12 summary statements that involved more than one variable were written by students who went on to make generalizations. Again, a higher level of thinking could be indicated when the student is able to look at features across two variables simultaneously. Thus it appears that if a student is inclined to look at trends involving more than one variable, then it is very likely that they would go on to write generalizations as the conclusion of their investigation rather than merely ‘reporting’ some feature in a summary statement.

Table 1 also indicates some other interesting features between the two groups of students. There was no significant difference between the two groups with regard to: the total number of transnumerations of data; number of tables created; or the number of summary statements written. However, there was a noticeable difference in the number of variables considered in their data tables: the group responsible for the generalizations were more likely to create tables involving more than one variable. This would also link with the number of summary statements involving more than one variable which has already been discussed above. The ability to tabulate data in such a way as to be able to examine more than one variable at a time illustrates statistical thinking which leads to more sophisticated written summaries of the data.

Another factor which seems to be significant is whether the students have a tendency to subgroup the data. Subgrouping was obviously not specifically mentioned in the task instructions, but to some students it was an obvious way to transnumerate the data in order to make more sense of it. The two most commonly used subgroupings were of gender (as determined by the name of each child in the data-set) and favourite activity into the groups of active activity (such as swimming, netball, or football) as opposed to passive activity (such as reading or watching TV). Table 1 indicates the difference in average number of subgroupings formed by each of the two groups. If a student is able to recognize subgroups of data that could provide interesting leads in making sense of the data, it would suggest that they are exhibiting a higher level of statistical thinking.

It is possibly surprising that there were a greater number of graphs drawn by the ‘non-generalizing’ group than the ‘generalizing’ group. The generalizing group were able to delve further into the data without the need of graphs. Maybe for the other group of students, the graphs assumed an importance on their own in the investigative process that obstructed the progress towards written generalizations based on the data. There were only two students who acknowledged the small sample size as creating a difficulty for drawing a conclusion. They wrote:

- *“Overall there is not enough data for a conclusion. A bigger sample size would show a clearer picture.”*
- *“To make this survey more conclusive, a larger population would need to be surveyed”*

These two students have drawn on other statistical knowledge when considering how to make sense of the data. It could be considered surprising that so few of the students recognized this and made comment on it, given that the majority (70%) of students had completed 13 years of mathematics study at school and would have covered sampling in the senior school. It is possible however that the instructions for the task could have diverted the students away from considering sample size, as they had been instructed to report on any interesting aspects in the data. To go beyond the data in considering the data as samples might have been considered as falling outside the instructions for the task.

CONCLUSIONS AND IMPLICATIONS

There are a number of factors within the various types of transnumerations that appear to be significant indicators of whether a student will carry an investigation through to the stage of writing generalized statements based on the data. If the student has the tendency to identify subgroupings of data, then it is more likely they will go on to generalize. Similarly, if in tabulating the data they focus on more than one variable, then again they are more likely to generalize at the conclusion of the investigation. The number of graphs drawn could be a 'contra-indicator' of subsequent generalizations, in that the student may feel that the investigation is complete with the production of graphs. The writing of summary statements also does not give an indication as to whether the student will generalize about the data.

The above conclusions need to be viewed in the light of a number of limitations:

- the data set was small (only 16 observations in each of 6 variables);
- the students did not have an opportunity to discuss or explain their thinking or aspects of their reports, either with their peers or in follow-up interviews with the researcher. This would have given greater insight into their statistical thinking in relation to their investigation of the data.
- the time limit for the investigation may have prevented some students from completing aspects of their report that they would have otherwise done; their level of statistical thinking could have been greater than that indicated.
- For some students, because of the length of time since they had been involved in school statistics, they would have been out of the way of thinking statistically in a 'formal' way.

The small size of the data set meant that it may have been possible for the students to develop a reasonable data sense without performing extensive transnumerations of the data. For instance, some students who formed an unordered listing of one variable were able to use this listing to be able to make a worthwhile statement about the data. If the data set had been much larger, more transnumeration would probably have been necessary to get a 'feel' for what the data was showing. The larger the data set however, the more time that calculations and other transnumerations would take before getting to the more interpretative part of the process. Research with a similar investigation but with a much larger data set would give interesting comparisons with this study.

There appear to be two factors that are important in determining whether a student will be able to generalize as a result of an investigation into a data set. Firstly, being able to focus on more than one variable at a time may be important for students to be able to arrive at generalizations from a data set. Secondly, whether the student looks for and identifies possible subgroupings of data also appears relevant. Whether these two aspects are more developmentally related or more teaching related is unknown. If teachers specifically encourage more focus on these two aspects as part of the investigative process (such as through making greater use of multivariate data sets than what they may be currently doing) would students develop greater data sense, or are there developmental considerations as to when is the most appropriate time for students to be able to handle these aspects of statistical thinking? Further research is needed in this area.

There are a number of implications that arise from this study, with regard to the teaching and learning of statistics, and in particular, the development of data sense and a broad range of types of statistical thinking. It would appear that students may be accustomed to the development and use of isolated statistical skills, rather than seeing these as a useful part of a complete investigation. Through investigations, students can be encouraged to see the purpose of particular types of transnumeration and especially the need to integrate their statistical thinking with their contextual knowledge. Teachers may need to put more emphasis on investigations within their statistics teaching, so that students develop a greater understanding of the process of investigations and how the parts of the process are interdependent. Students would, through being involved in investigations, see a purpose to developing particular statistical skills and thus the development of all the facets of statistical thinking would improve.

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APPENDIX: EXAMPLE OF ONE DATA CARD

Name:	Janelle MacDonald
Age:	18
Favourite activity:	Reading
Eyes:	Blue
	66 kg

How many fast food meals do you eat every week? 4