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STUDENT ANALYSIS OF VARIABLES IN A MEDIA CONTEXT

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Abstract

Judging statistical claims from the media is fundamental to being statistically literate. In making a judgement it may be appropriate to graph, or at least visualise, the claim being made. Such is often the case when cause and effect assertions are made for two or more variables. The contexts in which claims are made can be quite varied and can overlap areas of the high school curriculum other than mathematics. It is important for mathematics teachers to be aware of the contexts which can motivate an understanding of the statistical principles and it is important for teachers of other subject areas such as science, social science, health, and technology to be aware of the mathematics necessary to make sense of statistical claims. A survey item based on a newspaper article which claimed an "almost perfect relationship between the increase in heart deaths and the increase in the use of motor vehicles" was administered to 1291 students to explore their ability to produce a graphical representation of the claimed relationship and their ability to question the claim itself. Implications of the hierarchy of understanding for high school teachers of mathematics and other subjects are discussed.

Introduction

There are many areas of the school curriculum which have recently recognised the need for statistical literacy, probabilistic understanding and data analysis skills. While many countries, e.g., the United States (National Council of Teachers of Mathematics, (NCTM) 1989), Australia (Australian Education Council (AEC), 1991), and New Zealand (Ministry of Education, 1992), have included probabilistic and statistical concepts in their curricula, they have not forgotten the importance of the applications of these concepts in social contexts outside of the mathematics classroom. In Australia these are found both in mathematics and in other areas of the curriculum.

The mathematics curriculum. In *A National Statement on Mathematics for Australian Schools* (AEC, 1991) a concern for wider application of concepts is shown under headings which require students to

- understand and explain social uses of chance (p.175); and
- understand the impact of statistics on daily life (p.178).

In the United States, the NCTM's *Curriculum and Evaluation Standards for School Mathematics* (1989) exhibit the same sentiments. There it is claimed that the curriculum should provide situations so students can develop an appreciation for

- statistical methods as powerful means for decision-making (p.105); and
- the pervasive use of probability in the real world (p.109).

Hence probability and statistics are suggested for inclusion in the mathematics curriculum not only because of their innate worth as intellectual topics but also because of their application in dealing with issues in wider society.

Of particular interest in this report are the graphing of relationships and the interpretation of associations found among variables. In Australia these topics are addressed with the following activities in the *National Statement*:

- Band B (for grades 5 to 7): represent data in tables and graphs and compare different representations of the same data, considering how well they communicate the information (p. 172);
- Band C (for grades 7 to 10): investigate and interpret relationships, distinguishing association from cause and effect (p. 178); and
- Band D (for grades 10 to 12): discuss relationships between variables and whether these imply cause and effect (p. 184).

Other curricula. Other areas of the school curriculum express similar objectives in relation to the interpretation of graphical representations and associations. In Australia four of these areas of the curriculum are Studies of Society and the Environment, Health and Physical Education, Science, and Technology. The importance of constructing and interpreting graphs, and understanding associations among variables is illustrated in the following extracts from the other subject area curriculum documents. From *A Statement on Studies of Society and Environment* (AEC, 1994c),

> As [students] progress, they learn to compare and classify information and to interpret sources such as surveys, maps, charts, and diagrams (p. 11-12).

Requirements of *Studies of Society and Environment: A Curriculum Profile for Australian Schools* (AEC, 1994d) expand through the years of schooling from "design graphs" (p. 21), to "interpret graphs ... and give real examples of the interpretation" (p. 37), to "select from line, bar or pie graphs or histograms to provide diagrammatic evidence of a viewpoint" (p. 185) and "refer to graphs, tables and statistical data to predict consequences of a plan..." (p. 99). More generally students use "the methodologies of the learning area to investigate different perspectives on an issue" (p. 9).

In the area of Health and Physical Education, although expressed in another context, the same requirements of statistical graphing and understanding of association arise. *Health and Physical Education: A Curriculum Profile for Australian Schools* (AEC, 1994a) requires that students use "qualitative and quantitative data to report on beliefs and theories of development" (p. 114) and examine "the factors that influence community decisions..." (p. 81). For example they "analyse the presentation of physical activity in the media and suggest reasons for the dominance of particular sports and the lack of coverage of women's sport" (p. 84). The necessity to consider variables and associations is evident when students critically analyse

- ... fitness programs and methods for evaluating fitness to design fitness programs for special needs (p. 8);
- ... the relationship between human growth and activity and food needs at different stages in the life cycle (p. 9);
- ... the influence of a range of social factors on the nutritional status of a population (p. 9);
- ... the policies and priorities of major health bodies in equitably meeting the health needs of specific groups (p. 10);
- ... the impact of medical and scientific advances on health services and products, considering cost, accessibility, effectiveness, client rights and ethics (p. 10).

Science would perhaps be expected to value graphing and skills of recognising data association, and indeed this is shown in the Working Scientifically strand of *Science: A Curriculum Profile for Australian Schools* (AEC, 1994b). Reference is made to the need for students to

- argue conclusions on the basis of collected information and personal experience (e.g., using graphs) (p. 48);
- select ways to present information that clarifies patterns and assists in making generalisations (e.g., organise data into tables and graphs to reveal trends and relationships) (p. 74);
- plan procedures to investigate hypotheses and predictions for situations involving few variables (p. 10);
- identify and consider factors that influence confidence in a conclusion (p. 11).

Technology: A Curriculum Profile for Australian Schools (AEC, 1994e) includes Design, Appraising, Investigating, Devising, and Evaluating in association with information, textiles, metal and wood work, food processing and systems. Again many of the specific experiences for students implicitly

include graphing and/or data association skills.
In Devising, students

- use a range of graphical representations, models and technical terms (p. 48).

In Information, students

- record and analyse the type of food advertising during children's peak television viewing time (p. 104).

In Systems, students

- analyse the advantages and disadvantages of a system of transport for small children (p. 140).

These experiences potentially require the analysis of associations among variables, their representation and interpretation.

Research. Research into the complex relationships among student understanding of association among variables, the ability to graph such associations, and the actual questioning of the associations is not found in the statistics education literature. Student ability to draw and interpret graphs of mathematical relationships has been studied (Curcio, 1987; Leinhardt, Zaslavsky & Stein, 1990), as has their ability to discover associations in tabular representations (Batanero, Estepa, Godino & Green, 1996). Difficulties related to representativeness and availability when making decisions about data were studied early in the work of Kahneman and Tversky (Kahneman & Tversky, 1972; Tversky & Kahneman, 1973). While warnings about the dangers of drawing cause-effect conclusions when inappropriate are widespread (e.g., Joiner, 1981; Moore, 1991; Tversky & Kahneman, 1980), student understandings related to the actual questioning of spurious correlations has not been the focus of research.

This report presents a hierarchical model for analysing statistical thinking in social and scientific contexts and then uses it to discuss responses to an item based on a newspaper article. The item, which provides an opportunity to question a claimed statistical relationship, illustrates the need to apply statistical understanding in social settings. Finally some of the implications of using cross-curricular topics to develop statistical understanding are discussed.

Target Skills and Levels of Achievement

Once accepting that statistical thinking in social and scientific contexts is an important part of statistical education, it is necessary to describe the associated skills and their levels of complexity. This will assist teachers in structuring learning experiences and planning related assessment. The skills required to be able to interpret stochastic information presented in society, often in the form of media reports, can be represented in a three-tiered hierarchy as outlined in Watson (in press):

- a basic understanding of probabilistic and statistical terminology,
- an understanding of probabilistic and statistical language and concepts when they are embedded in the context of wider social discussion, and
- a questioning attitude which can apply more sophisticated concepts to contradict claims made without proper statistical foundation.

These skills represent increasingly sophisticated thinking and are consistent with models of learning from developmental psychology (see for example, Biggs & Collis, 1982, 1991; Case, 1985; Watson & Collis, 1994). Each will be considered in turn.

Basic understanding of terminology. At the first stage of the hierarchy there are the skills related directly to specific topics in the curriculum; these are generally taught in a conventional fashion with students creating and analysing their own data sets. At various levels of the curriculum the topics include percentage, median, mean, specific probabilities, odds, graphing, measures of spread and exploratory data analysis. All can be taught without reference to social issues and are commonly covered in text books.

Embedding of language and concepts in a wider context. Once students with some rudimentary statistical concepts in hand are exposed to the media, a second need becomes important – to read and interpret written reports, rather than just perform computations. Some students who have excelled in the traditional symbolic aspects of the mathematics curriculum resist the requirement for reading, interpreting and writing when mathematics is presented in non-symbolic contexts. In all aspects of mathematical thinking, however, the need for application, interpretation and communication skills is being addressed (e.g., Schoenfeld, 1992). The necessity to tie statistical and literacy skills together is specifically acknowledged in the curriculum documents noted above and easily exemplified in media extracts such as the one used in this report.

At this second level of sophistication, more than just basic definitions are needed to be successful. It is necessary to recognise these in other contexts and be able to make sense of claims which are made. Since on most occasions, statistics are presented correctly, the requirement at this level is to understand and interpret statistics in order to draw conclusions and make decisions.

Questioning of claims. At the highest level of statistical thinking, students possess the confidence to challenge what they read in the media. It sometimes happens that claims are made without proper statistical foundation, either inadvertently or purposefully. Whether there is an intention to mislead or just insufficient information, students must be made aware that they need to constantly question conclusions. The specific questioning skills required at this level are exemplified by Gal (1994).

- Where did the data (on which this statement is based) come from? Was this a sample? How was it sampled?
- Is the sample large enough? Did the sample include people/ things which are representative of the population? Overall, could this sample reasonably lead to valid inferences about this population?
- What is the shape of the underlying distribution of raw data (on which this summary statistic is based)? Does it matter how it is shaped?
- Are the reported statistics appropriate for this kind of data (e.g., was an average used to summarise ordinal data)? Could outliers cause summary statistics to misrepresent the true picture?
- Is this graph drawn appropriately? Are the scales reasonable, or do they distort the true magnitude/trends of the data?
- Are the claims made in this article supported by the data or displays? Should additional information be made available to enable evaluation of these arguments?
- Is the causal relationship implied by this statement reasonable?
- How was this probabilistic statement calculated or reached? Are there enough credible data to justify this estimate of likelihood?

For classroom purposes it is important to appreciate the increasingly complex nature of the thinking involved as students move from developing a basic understanding of statistical terminology and concepts in a mathematical context, to understanding and applying them in a wider social context, to questioning their use by those who may wish to mislead members of society. Assessment of these skills goes hand-in-hand with their teaching and learning. There is no reason why the media cannot be used as a basis for assessment as well as for initial motivation or classroom discussion in conjunction with learning concepts.

Survey Item

The item which is the subject of this report was devised to assess student understanding in relation to the hierarchy described above. The first question assesses understanding of graphing in the second tier, that of embedding the concept in a social context. The second question assesses understanding of associations in the second and third tiers, particularly the ability to question claims. The item is shown in Figure 1.The implication in the headline is of a cause-effect relationship between cars and deaths. If the article had been about the road toll, the headline might not be surprising. The report, however, is about the relationship of the increase in heart deaths and the increase in automobile usage. The purpose of the question is to assess students' ability to describe graphically an "almost perfect relationship" and to give them the opportunity to query the cause-effect relationship implied in the headline.

Family car is killing us, says Tasmanian researcher

Twenty years of research has convinced Mr Robinson that motoring is a health hazard. Mr Robinson has graphs which show quite dramatically an almost perfect relationship between the increase in heart deaths and the increase in use of motor vehicles. Similar relationships are shown to exist between lung cancer, leukaemia, stroke and diabetes.

Draw and label a sketch of what one of Mr. Robinson's graphs might look like.
What questions would you ask about his research?

Figure 1. Item from media survey

The item was part of a media survey (Watson, 1994; Watson, Collis & Moritz, 1994) using newspaper extracts covering different topics in statistics. It was administered to 1291 students in Grades 6 to 11 in schools in Australia and England. While a detailed analysis of student development over the six grade levels will be presented elsewhere, the wealth of data makes available examples of different levels of response which occur during these years of schooling.

The analysis of the responses is in two parts. The first considers the types of graphs used by students to illustrate the relationship claimed in the article and the second considers the types of questions which were suggested for the researcher. The basic statistical understanding needed for these tasks relates to the recognition of the existence of a demonstrable association between two variables and the ability to draw a graph representing such an association. At the second tier the item requires the ability to embed these concepts in the context at hand. At the third tier there is the need to apply the statistical understanding, that the existence of an association does not prove that a change in one variable causes a change in the other, to question a cause-effect claim.

Responses to Part 1. For the first part of the question, asking for a graph, some students cannot get started or only make rudimentary attempts with no labelling. It is likely these students lack the prerequisite graphing skills to apply to a question of association. The graphs which represent the relationship adequately fall roughly into three categories. The first type of graph relates a car usage variable on one axis with a heart deaths variable on the other. Usually, but not always, the car variable is on the horizontal axis in the fashion to be expected of an explanatory variable. Arranging the variables in the opposite way is not considered a significant difference for the students if they have not had any instruction on the statistical conventions involved. Figure 2 illustrates a very basic graph with few details but a positive

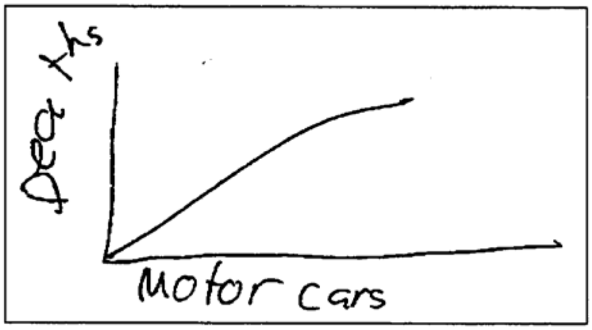

Figure 2. Basic graph of positive association

relationship of the type described. Many graphs add scales and hypothetical numbers on the axes.

The second type of representation includes two graphs, one for each of the two variables, car usage and heart deaths, plotted against time, usually with time on the horizontal axis. While statisticians would place the variables on a single axis with time as the common unit, it is felt that if students have had limited exposure to instruction and use their graphing skills in a fashion which demonstrates the required relationship, then this should be considered an adequate response. Figure 3 shows this type of graph with slightly more detail than shown in Figure 2.

The third type of graph follows the idea of the second using time as the "x-variable" (usually) but includes the other variables under consideration on the same graph. In Figure 4, the student has used a histogram to display the information for the two variables on one graph. Similarly in Figure 5, the student has produced a line graph to convey the same message. Again for students with little experience, these are good responses.

There are many attempts not considered adequate to describe the relationship. It is important to consider the features of these attempts in

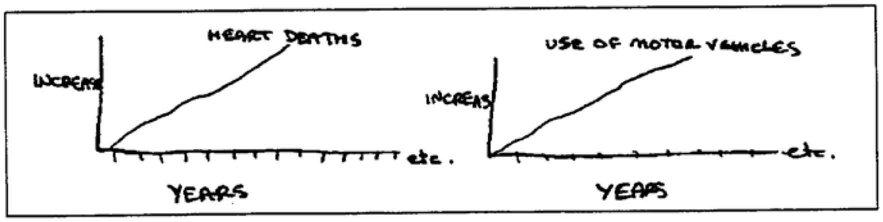

Figure 3. Student response of two graphs of positive association including time

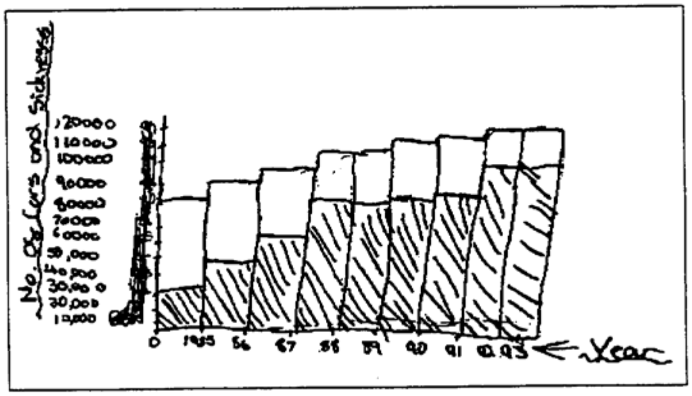

Figure 4. Student graph with the two variables on one graph

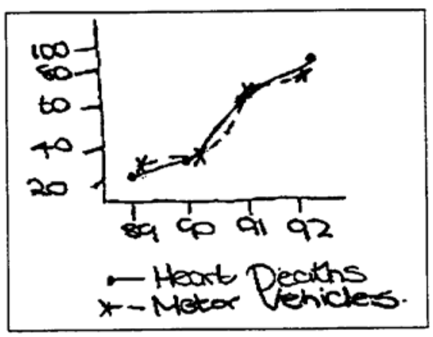

Figure 5. Student graph with the two variables on one graph

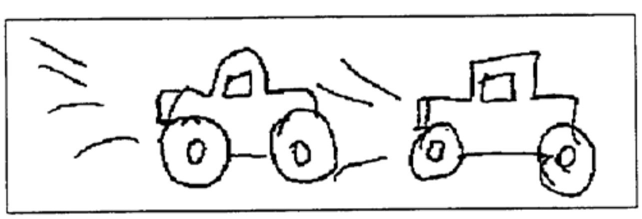

Figure 6. Student response which does not engage the graphic task

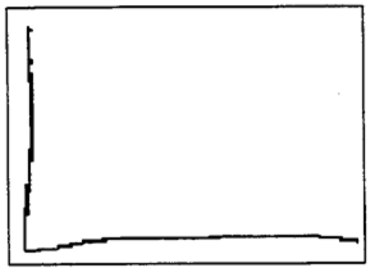

Figure 7. Student response which shows a single idea of axes

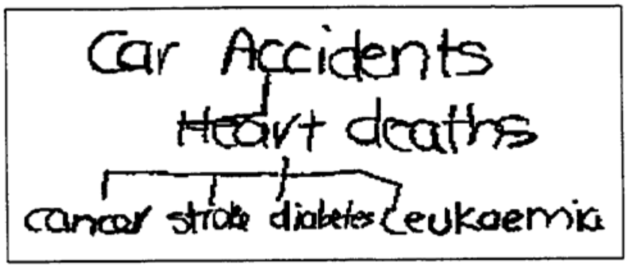

Figure 8. Student tree diagram of variables

order to assist students to higher levels of performance. Some students who respond but cannot engage the question, either draw pictures like in Figure 6 or say something like "I can't draw" or "we haven't studied graphs this year."

Some students can draw only the most rudimentary axes (e.g., Figure 7) or express the information in another form such as a tree diagram, which is inappropriate for the question (e.g., Figure 8). These kinds of response can probably be attributed to lack of ability to interpret the type of relationship and which variables should be included on the graph.

Quite a few students use no labelling to indicate which variables are changing in relation to each other (e.g., Figures 9 and 10), while others

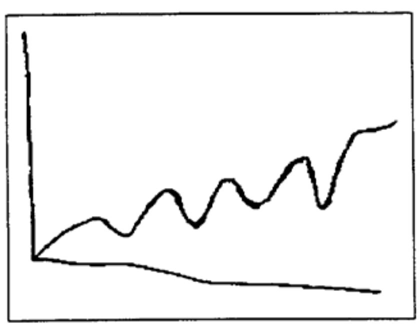

Figure 9. Student graph showing no labelling

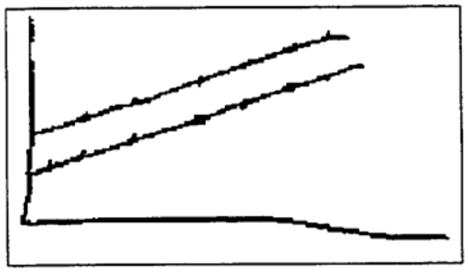

Figure 10. Student response unable to label variables to show relationship

include too many variables (e.g., Figure 11). A number of students attempt to show the information about variables with a histogram or pie chart but cannot show the association involved, as in Figure 12. Some responses show the idea of graphing of a single variable and do that relatively well in the context set but do not acknowledge the importance of another variable (e.g., Figure 13). Each of these responses appear to be able to display a single aspect of the task at hand: a potentially sensible graph but no labels to

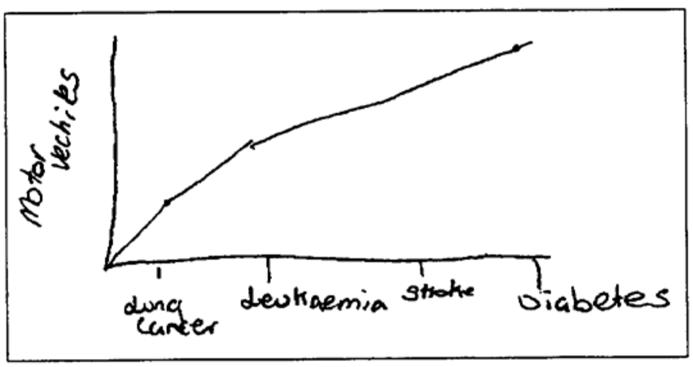

Figure 11. Student graph showing too many variables

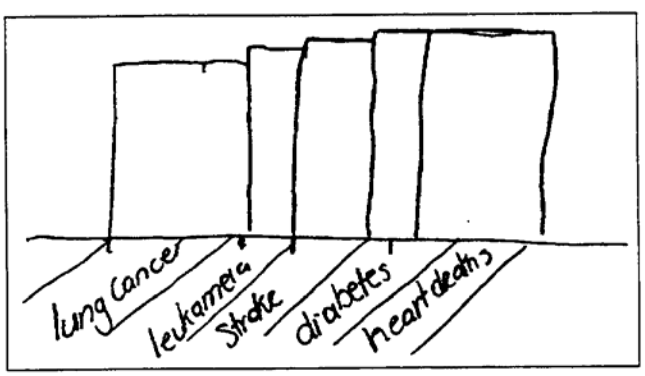

Figure 12. Student graph with no association shown

create meaning for variables, an appreciation of variables but no relationship, or an adequate relationship for a single variable with time.

Several students with fewer prerequisite graphing skills, nevertheless attempt to tell the story of the article visually. In Figure 14 a pictograph is used in an attempt to portray the association, while in Figure 15, arrows are

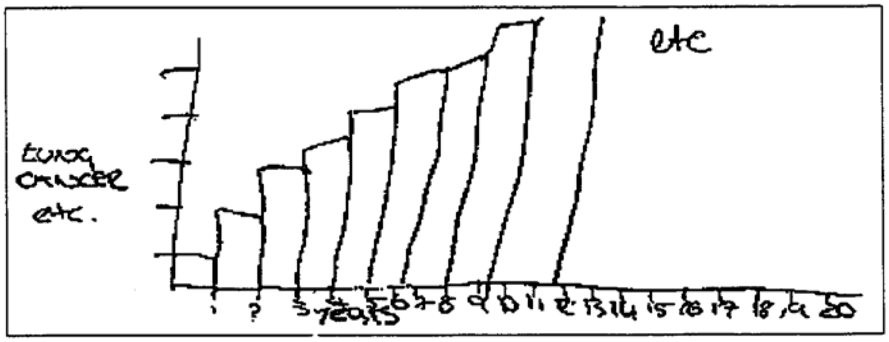

Figure 13. Student response displaying only one significant variable

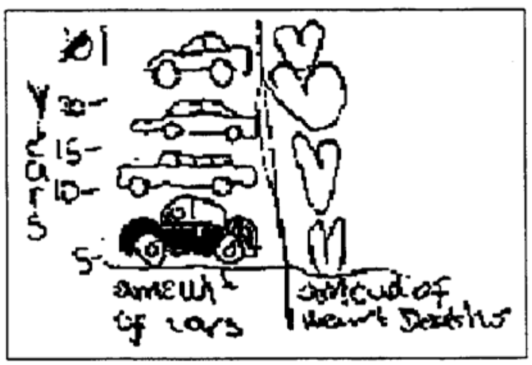

Figure 14. Grade 6 student response in context with a pictograph

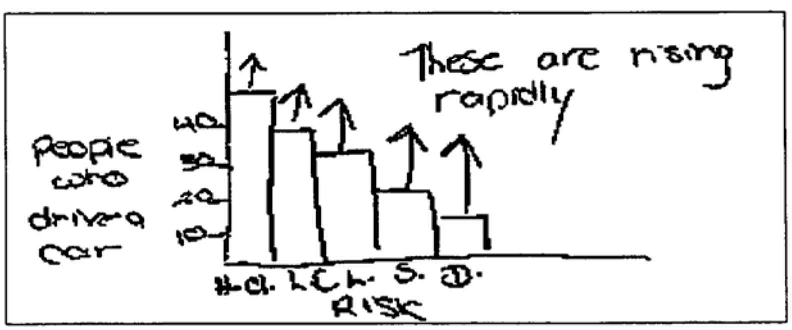

Figure 15. Grade 6 student response in context with an 'action' histogram

used to indicate the change. One suspects that with more experience in graphing these students would complete the task adequately.

Analysis of Part 1. Five general categories of response appear relevant to assist teachers in planning activities and assessment for students.

(1) No engagement with task:
"I can't draw."

Figure 6.

Draw tree diagram.

(2) Appreciation of a single aspect of the task:

Display an association with no labels, e.g., Figures 9 and 10.

Pick out some variables to graph but no logical relationship, e.g., Figures 11 and 12.

Graph only one variable with time, e.g., Figure 13.

(3) Appreciation of task but lack of graphing skills:

Figures 14 and 15.

(4) Appreciation of the task to display basic relationship:

Figure 2.

(5) Ability to perform task and add extra features:

Figures 3, 4 and 5.

Most statistics educators would be satisfied that responses in the final two categories have reached the second tier of statistical understanding, being able to apply the conventional concept of graph in the context set. Depending on the required outcome and assumed prerequisites, some would also accept the middle category of response as adequate for the task set. Whether these responses are genuine second tier responses is debatable and perhaps they should be deemed as 'in transition' into the second tier. They certainly appear to appreciate the context of the task.

For teachers interested in developing graphing skills in applied contexts, most concern would be focused on the first three categories. It appears that many prerequisite graphing skills are required, as well as an appreciation of how to apply them in a realistic context.

Responses to Part 2. The responses to the second part of the item inviting questions for the researcher, can be classified in four categories. At the lowest level are responses which indicate "None" or are not related to the statistical interpretation of the claims. Most of these believe the results or raise other questions:

> "No, it would probably be true."
>
> "Which state in Australia is the hazard worse?"
>
> "What kinds of accidents?"
>
> "Is there a chance of technology so we don't have to use fuel."

Some of these responses do not appear to have fully appreciated the task at hand.

The next level of response focuses on statistical questions but not those involving the relationship between the variables:

> "How many cases did you use?"
>
> "How and where he researched it."
>
> "Was it a fair sample?"
>
> "Did he test different cities?"
>
> "Have you got hard evidence?"

These questions are valid questions to ask of people reporting research but in the context of this item they do not get at the heart of the issue to be questioned. The responses reflect the second tier of statistical understanding.

The highest levels of response question the relationship between the increase in car usage and the increase in heart (or other) deaths. Many students ask the appropriate question but do not follow through to indicate that there may be some other factor influencing heart deaths:

> "How would people be dying because of the car?"
>
> "What part of the car causes most problems?"
>
> "How do you know for sure it is the motor car?"

Some students ask more specifically if there could be something else involved, without making their own suggestions:

> "Is there anything else that is likely to cause a heart attack anyway?"
>
> "How can you be sure that it is not caused by something else other than cars?"
>
> "Whether the number of deaths from heart attacks, lung cancer etc. would have increased anyway or what other sources would have contributed to this increase."

> "How was it obtained? Could there by any other contributing factors? Just because there is a correlation, doesn't mean that there is a direct link."

Other students actually suggest different variables could be involved in the explanation of heart deaths:

> "Has he considered other causes, eg smoking, pollution etc."
>
> "It is not only motor vehicles causing more illness. What about other factors causing the break down of our world's environment?"
>
> "Whether it's the motor vehicles or whether it's the more pollution of factories."
>
> "Surely something else could have contributed to this information. More junk food? More stress?"
>
> "Who he researched ie smokers, poor, people that live near growing industry? The age of the people? Their eating habits?"
>
> "Who was his sample space? What were the peoples' diet? Did they exercise?'
>
> "Did you take other things into account, such as diet changes and life styles over the years."
>
> "How old were the sampled people; what pressures did they have on them eg loans, house, car, any other debts?"

Sophisticated statistical language often will not used by the students. For those in this study it is not surprising given the mathematics curriculum of the students surveyed, who had met the idea of a cause-effect relationship only informally in science or social studies classes.

Analysis of Part 2. As with the previous items it is possible to suggest levels of response related to the complexity of statistical thinking. For Part 2 these lead to acceptable responses at the third tier, that of questioning claims.

(1) No engagement with statistical concepts:

> "None, it speaks for itself."
>
> "What should we do about it?"

(2) One peripheral statistical concept:

> "How many cases?"
>
> "Was it a fair sample?"

(3) Recognition of the difficulty but no development:

"How do you know for sure it is the motor car?"

(4) Recognition of cause-effect difficulty:

"Any other factors...?"

(5) Recognition of cause-effect difficulty with specific suggestion of other factors:

"What about pollution...?"

Responses in the final two categories have reached the third tier of statistical understanding, while those in the third category may be 'in transition' to this tier.

Summary. The two parts of this item seem to represent complementary skills of statistical thinking, rather than building on each other. It should be noted however that a higher level of functioning is required for an adequate response to the second part of the item, which was devised to assess the third tier skill of questioning claims. The first part of the item was devised to assess the second tier skill, that of applying the understanding of a concept (graphing a relationship) in the context of the article.

The structure reflects a sequencing which might be used in the instructional process. It is a structure which checks for the presence of understanding in the context of the task and then elicits the higher level questioning of claims made. Again it should be stressed that the ability to recognise intermediate level responses and value them (in discussion or with partial credit) is a step toward eliciting responses at a higher level.

Cross-curricular Implications

If one came across the item about Mr. Robinson in the daily paper, to which part of the curriculum would one turn for the background necessary to adequately interpret and question the claims made? Perhaps Health and Physical Education, because of the interest in population health which is part of that curriculum. Perhaps Technology, because of the implications arising from the use of the motor car. Perhaps Studies of Society and Environment, because of the community issues associated with heart disease and the impact of the automobile on the environment. Perhaps Science, because of the potential use of the scientific method of investigation. Or perhaps Mathematics where the tools of analysis for inference are found.

The point is that the Mr. Robinson article is relevant to many parts of the curriculum and it would provide an excellent cross-curricular activity. Often at the high school level, however, these five different subjects are taught at five different times by five different teachers. Whose responsibility is it to ensure students have the statistical understanding to interpret and question Mr. Robinson's claims? One worries that there may be a tendency for teachers in each area to avoid the responsibility and claim that another is responsible to ensure students have the necessary skills for contributing to social decision-making when they leave school. The Mathematics teacher may claim that the article is too applied or has no numbers to plot. The Health and Physical Education teacher may claim that there is too much mathematics involved. The Technology teacher may say there is too much health in the article; and so it continues.

What would be the potential on the other hand if teachers from all of these areas got together to plan a coordinated consideration of an example such as the Mr. Robinson article? Each could emphasise and research particular aspects associated with the context set, some going into more detail than others depending on the particular setting. Imagine the enthusiasm of a student who walked from a Health lesson to a Mathematics lesson to find the same issues addressed from a complementary perspective. It might provide more motivation to some students who wonder why they are in school and where it is all heading.

How much pressure does this put on teachers? For high school teachers of the subject areas mentioned here, a high degree of statistical literacy is needed to teach the higher levels of the curricula. Teachers need to be aware of the tiers of statistical understanding that are relevant, to structure activities to allow for development in each, and to encourage students to move through each tier to reach a stage where they can coherently question statistical claims made in the wider society.

Conclusion

Over the years there have been a few voices calling for an interest in the issues address in this report. Ernest (1986) raised the importance of using the media in relation to the teaching of statistics. Bruni and Silverman (1975) stressed the importance of graphing as a communication skill, a point which is strongly supported in the context of the item discussed in this report. Being able to represent visually the claims made in print is a first step in being able to think about the implications of the claims. Now that the need for statistical literacy is firmly placed in the school curriculum, it is hoped that more voices will be raised to stress the importance of developing high level statistical questioning skills applicable in many contexts.

The cross-curricular nature of the data handling, representation and interpretation aspects of the curriculum is now being recognised at the middle school level (e.g., Hofstetter & Sgroi, 1996; Kinneavy, 1996; Spence, 1996). It is hoped that this interest and enthusiasm continues to develop in the later years of high school where higher levels of statistical literacy are required across the curriculum.

References

Australian Education Council. (1991). *A national statement on mathematics for Australian schools.* Carlton, Vic. : Author.

Australian Education Council. (1994a). *Health and physical education: A curriculum profile for Australian schools.* Carlton, Vic.: Curriculum Corporation.

Australian Education Council. (1994b). *Science: A curriculum profile for Australian schools.* Carlton, Vic.: Curriculum Corporation.

Australian Education Council. (1994c). *A statement on studies of society and the environment for Australian schools.* Carlton, Vic. : Author.

Australian Education Council. (1994d). *Studies of society and the environment: A curriculum profile for Australian schools.* Carlton, Vic.: Curriculum Corporation.

Australian Education Council. (1994e). *Technology: A curriculum profile for Australian schools.* Carlton, Vic.: Curriculum Corporation.

Batanero, C., Estepa, A., Godino, J. D., & Green, D. R. (1996). Intuitive strategies and preconceptions about association in contingency tables. *Journal for Research in Mathematics Education, 27,* 151-169.

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

Biggs, J. B., & Collis, K. F. (1991). Multimodal learning and the quality of intelligent behaviour. In H. A. H. Rowe (Ed.). *Intelligence: Reconceptualisation and measurement* (pp. 57-76). Hillsdale, N. J.: Lawrence Erlbaum.

Bruni, J., & Silverman, H. (1975). Graphing as a communication skill. *Arithmetic Teacher, 22,* 35-366.

Case, R. (1985). *Intellectual development: Birth to adulthood*. New York: Academic Press.

Curcio, F. R. (1987). Comprehension of mathematical relationships expressed in graphs. *Journal for Research in Mathematics Education, 18,* 382-393.

Ernest, P. (1986). Statistics and the media. *Mathematics in School, 15*(3), 14-15.

Gal, I. (1994, September). *Assessment of interpretive skills.* Summary of Working Group at the Conference on Assessment Issues in Statistics Education, Philadelphia, PA.

Hofstetter, E. B., & Sgroi, L. A. (1996). Data with snap, crackle, and pop. *Mathematics Teaching in the Middle School, 1,* 760-764.

Joiner, B. L. (1981). Lurking variables: Some examples. *The American Statistician, 35*(4), 227-233.

Kahneman, D., & Tversky, A. (1972). Subjective probability: A judgement of representativeness. *Cognitive Psychology, 3,* 430-454.

Kinneavy, K. (1996). Doing research together. *Mathematics Teaching in the*

Middle School, 1, 696-702.

Leinhardt, G., Zaslavsky, O., & Stein, M. K. (1990). Functions, graphs and graphing: Tasks, learning and teaching. *Review of Educational Research, 60*(1), 1-64.

Ministry of Education. (1992). *Mathematics in the New Zealand curriculum.* Wellington, Author.

Moore, D. S. (1991). *Statistics: Concepts and controversies.* (3rd edn.) New York: W. H. Freeman.

National Council of Teachers of Mathematics. (1989). *Curriculum and evaluation standards for school mathematics.* Reston, VA: Author.

Schoenfeld, A. H. (1992). Learning to think mathematically: Problem solving, metacognition, and sense making in mathematics. In D. A. Grouws (Ed.). *Handbook of research on mathematics teaching and learning* (pp. 334-370). New York: Macmillan.

Spence, B. S. (1996). The arcs of archaeology. *Mathematics teaching in the middle school, 1*, 688-693.

Tversky, A., & Kahneman, D. (1973). Availability: A heuristic for judging frequency and probability. *Cognitive Psychology, 5*, 207-232.

Tversky, A., & Kahneman, D. (1980). Causal schemas in judgements under uncertainty. In M. Fishbein (Ed.), *Progress in Social Psychology (Vol. 1)* (pp.49-72). Hillsdale, NJ: Lawrence Erlbaum.

Watson, J. M. (1994). Instruments to assess statistical concepts in the school curriculum. In National Organizing Committee (Ed.), *Proceedings of the Fourth International Conference on Teaching Statistics. Volume 1* (pp. 73-80). Rabat, Morocco: National Institute of Statistics and Applied Economics.

Watson, J. M. (in press). Assessing statistical literacy through the use of media surveys. In I. Gal & J. Garfield (Eds.). *The assessment challenge in statistics education.* Voorburg, The Netherlands: International Statistical Institute and IOS Press.

Watson, J. M., & Collis, K. F. (1994). Multimodal functioning in understanding chance and data concepts. In J. P. da Ponte & J. F. Matos (Eds.), *Proceedings of the Eighteenth International Conference for the Psychology of Mathematics Education. Volume 4* (pp. 369-376). Lisbon: PME.

Watson, J. M., Collis, K. F., & Moritz, J. B. (1994). *Authentic assessment in statistics using the media.* Report prepared for the National Center for Research in Mathematical Sciences Education : Models of Authentic Assessment Working Group (University of Wisconsin). Hobart: University of Tasmania, School of Education.