WHY DON'T STUDENTS DISPLAY DATA?

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This study investigates whether, for unsophisticated users of statistics, there is a relationship between the use of diagrams in everyday and in mathematical situations and the use of statistical displays in the early inspection of data. The study found a relationship between the use of statistical displays and the use of diagrams in mathematical situations but not in non-mathematical situations. However, for students, the best predictor of whether or not they used a statistical display was their demonstrated statistical knowledge.

INTRODUCTION

A classification of individuals as visualisers or verbalisers has a history dating back to the last century, with Francis Galton and Jean Martine Chariot examining imagery types (Richardson, 1977). More recently, Krutetski (1976) has stated that there are two factors in mathematical problem solving - a verbal or logical component and a visual component. Presmeg (1986) has distinguished visualisers and non-visualisers, with visualisers being individuals who prefer to use a visual method for solving a problem which may be solved by a visual or non-visual method. Bishop (1989) has reminded us of the variation in individuals in the "visuality of their problem solving approaches." Vinner (1989), in a study of calculus, found that tertiary students tended to prefer an algebraic proof rather than a diagrammatic proof even when the latter, as stated by the students, was easier to follow. However, he felt that this preference was largely based on the way that mathematics was taught at school.

In mathematical problem solving it is sometimes possible to use either a visual or a non-visual approach; however, in statistics both are needed. "We can be forced to discover things from a graph without knowing in advance what we were looking for" (Wainer, 1992). The initial step in any statistical analysis should be an inspection of the data. This should include a visual display of the data and some numerical summaries. However, many unsophisticated users of statistics do not use visual displays.

This paper investigates whether this reluctance to use diagrams might be related to an innate preference for a verbal or symbolic representation of a problem, not necessarily mathematical, as opposed to a diagrammatic or geometric representation. For example, are students who draw a map when giving instructions as to how get from A to B more likely to use a statistical display when initially investigating a set of data.

METHOD

The study involved more than 700 students in a one semester course in introductory statistics, with one lecture and an additional three contact hours per week, at an Australian university. There was an examination at the end of the course. The university does not have an engineering or architecture school, areas which are more likely to encourage visual thinking. The course is a "service" course and is taken by more than 60% of students, irrespective of the area in which they intend to major. About 65% of the students were born in Australia, 20% in Asia, 5% in Europe and the remainder were from other parts of the globe. This is not the group that we think of as "unsophisticated *users* of statistics" but it was felt that their lack of experience with real data and lack of involvement in tertiary mathematics might mean that they would react in the same way as young researchers in non-mathematical fields who either analyse their own data or request help with the analysis.

In week six of the course students were asked to answer a questionnaire which included requests for personal information such as student ID, place of birth, School of enrolment, age etc and three open-ended questions. Students were given the option of not being included in the study. Very few students opted for non-inclusion. The inclusion of student ID meant that subsequently their responses to the questionnaire could be linked to their results in the final examination. The three open-ended questions were designed such that either a verbal or algebraic answer would be as valid as a diagrammatic or graphical answer. These three questions are given in Appendix A. The first question asked for instructions as to how to get from A to B and the second required instructions on how to construct a box. The third question is that used by Campbell, Collis and Watson (1995) in their study of individual differences in different forms of visual thinking. This was a mathematical question and could be solved either algebraically or geometrically.

The final examination in the course included a question (Appendix B), which asked the students to comment on a data set of 36 numbers. The data set was bimodal and skewed to the right. The bimodality would not have been apparent without a graphical representation. Graphical displays were taught in the first week of the course and their importance emphasised throughout the course, however the students had not been given a question similar to the examination question in the course. The examination question

responses as well as receiving a numerical mark which contributed to the final examination mark, were also classified, for the purpose of this study, by whether or not the student used a statistical display. All students who attempted the question had their work marked by the same member of staff.

Only students who attempted the open-ended questions and answered the examination question were included in the final analysis. The questions were classified as "including a diagram in the solution or not including". These were coded '1/0'. Students classified as using a diagram may, in addition, have used algebraic or verbal reasoning.

ANALYSIS

The table below shows the percentage of students who produced a diagram or statistical display as part of their answer to the open-ended questions and to the examination question..

Table 1. Table of Percentage of students who used a diagram

Question type	Percentage	No. of students
Map	5.2	918
Box	79.1	895
Algebra/geometry	24.8	858
Exam. Question	52.1	854

Only 5% of students drew a diagram when asked for directions whereas 79% gave a diagrammatic answer for constructing a box. Of the 25% who drew a diagram in response to the algebra/geometry question, 62% provided a statistical display whereas only 50% of the 75% who did not draw a diagram gave a statistical display.

Campbell et al (*op cit*), in a study where students were classified as having high or low levels of visual imagery and high or low levels of abstract logical reasoning, found that of the high abstract logical reasoning group 50% of the high level visualisers and 46% of the low level visualisers used a diagram in their solution of the algebra question. However, of the low abstract logical reasoning group 15% of the high level visualisers used a diagram whereas none of the low level visualisers used a diagram. That is, it would appear that abstract logical reasoning ability rather than visual skills may be the key determinant of whether a diagram is used. The 24.8% of students in this study who provided a diagram for the algebra/geometry question is consistent with that result.

The table below shows the correlation coefficient between the pairs of variables representing responses to the four questions. While the correlations in excess of 0.09 may be statistically significant (because of their large sample size), they do not appear to be of much practical significance.

Table 2. Table of correlation coefficients

	Map	Box	Algebra
Box	0.091		
Algebra	0.090	0.079	
Exam. Question	0.037	0.032	0.099

Factors that might have an effect on whether or not the students used a graphical display in their examination question, apart from responses to the three open-ended questions, are age, sex, country of origin, the lecturer whose lectures they attended, School of enrolment and their performance in the remaining questions on the examination.

A logistic regression with response on the examination question as the dependent variable and the other variables as the independent variables found that only response to the algebra/geometry question ($z=1.98$, $p= 0.048$) and performance on the remaining sections of the examination paper ($z=5.80, p=0$) were significant. That is, country of birth, age sex, lecturer or School of enrolment did not have a significant effect on whether or not they chose to use a statistical display when answering the examination question.

CONCLUSION

Results from this study can only be tentative as the study group was students, not users of statistics, and because students who did not include a statistical display in their examination booklet may have drawn one of a separate sheet of paper or even in their head. Presmeg (1986) using interview-style research points out that while visualisers may use an image in their head they do not necessarily draw a diagram on paper.

Based on the logistic regression analysis above it would appear that rather than students' preference for diagrammatic representations being the best predictor of their use of a statistical display it is their demonstrated knowledge of statistics, as measured by the examination, which is the best predictor. The demonstrated knowledge could be a surrogate for attendance at lectures and participation in the course and hence an awareness

of the importance of statistical displays. However, their use or non-use of a diagram in answering the algebra/geometry question was also significant. The significance of the algebra/geometry question, given that statistical knowledge has already been accounted for (but not necessarily abstract logical reasoning) suggests that if students use a visual approach in mathematics then they are more likely to use a statistical display when investigating a set of data.

It would seem that to encourage unsophisticated users of statistics to display their data they need more exposure to modern statistics with its greater emphasis on graphics.

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APPENDIX A - THREE OPEN-ENDED QUESTIONS

1. You are at a party on Saturday night and you meet someone who tells you that on Wednesday they are to going to Macquarie University by bus and need to find the bookshop. Provide the information that you would give them.

2. Your ten year old neighbour wants to make a box without a lid out of flat piece of cardboard. In the space below provide instructions that she/he will be able to follow.

3. The blood alcohol readings of two drivers were recorded the morning after an accident. The readings were:

Mark	Wayne
6 hours after accident: 5 units	5 hours after accident: 7.5 units
8 hours after accident: 2 units	9 hours after accident: 5.5 units

Assuming a linear relationship answer the following:

(i) Who had the highest reading at the time of the accident?
(ii) When were their readings the same?

APPENDIX B - EXAMINATION QUESTION

Your friend has collected the following data on the length of time (in seconds) taken by 36 individuals to complete a task.

60	56	25	38	35	46	39	61
39	33	65	34	64	39	28	98
34	63	61	54	35	31	63	65
60	36	37	42	56	45	38	74
43	39	41	46				

He has asked you to comment on the data.