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Learning undergraduate statistics: The role of the graphics calculator

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The graphics calculator has found many advocates impressed with its capacity to support student learning related to algebraic functions and calculus. In this paper, we suggest that the graphics calculator may well be a useful alternative to the computer statistics package for student learning of statistics, especially in the early undergraduate years. This is not to deny the importance of students learning statistics eventually becoming familiar and competent with computer use; rather, we suggest that the graphics calculator may provide a more convenient and effective place to start.

Changes in the statistics curriculum

Statistical analysis has undergone a revolution, in a remarkably short time, primarily as a result of developments in computing. Three aspects of this revolution merit comment. Firstly, statistical computations have come to be performed by computers rather than by people armed with devices such as mechanical calculators, table books and slide rules. Secondly, statistical analysis has become much more visual, as computers have acquired capabilities to represent images as well as perform calculations. Thirdly, much statistical analysis has become more speculative and exploratory than previously, rather than being pre-determined, because of the flexibility provided by computer software. Computer software for statistics has become widely available and is now routinely used in applied work. It thus seems inevitable that the undergraduate statistics curriculum will be influenced by these developments as well.

In parallel with these changes (and perhaps even partly as a consequence of them), statistics has continued to increase in significance in the undergraduate curriculum. For example, Moore *et al*, (1995 p.259) reported that statistics enrolments at US two-year colleges had risen from 10% to over 50% of calculus enrolments in 25 years. While there are still many undergraduate students who undertake first and second level calculus courses to support other undergraduate majors, there is an increasing group for whom the study of some statistics is the main, or even the only, mathematics they encounter after secondary school. Although many students undertake courses offered by mathematics and statistics departments, there are also many students who study statistics in courses within the natural sciences, the social sciences, education and business.

It might seem inevitable in these circumstances that undergraduate statistical study should routinely incorporate work with computers; however there have been some difficulties in doing so successfully in practice. Not the least of these has been the provision of sufficient access to computer hardware, especially in large introductory units at the first year level. Frequently, students have had access to computers mainly in formally scheduled laboratory sessions; security and scheduling issues have tended to reduce opportunities for student work outside regular classes. In addition, large, flexible and multi-purpose software packages, such as Minitab, Statistica, SPSS and SAS are relatively expensive to purchase in bulk and maintain, as well as being time-expensive in the sense of requiring student learning time devoted to operating the software effectively.

Calculators for statistics

It is generally accepted, even expected, that all students studying undergraduate statistics have access to a scientific calculator with statistical capabilities. Such calculators certainly changed expectations and the learning process for many; before their availability, a great deal of time was spent by students essentially doing arithmetic and substituting values into formulae to compute such statistics as variances, standard deviations, correlation coefficients and linear regression coefficients. Despite these advantages, scientific calculators have several limitations for data analysis relating to the detection and correction of data entry errors, visual display of data and access to inferential tests.

Graphics calculators, first available around twelve years ago, offered very significant improvements. These stem mainly from the fact that data were stored in the calculator and thus could be examined, edited, deleted, transformed or augmented relatively easily. Data could be simulated using calculator commands as well as entered directly. A stored data set could be analysed in more than one way, allowing and expecting students to make choices about what kind of analysis is appropriate. As the name suggests, the graphics calculator also opened the possibility for analyses to involve graphical displays, such as scatter plots or histograms, as well as numerical ones.

These advances made the graphics calculator an attractive device for secondary schools, which have long included the rudiments of descriptive statistics in mathematics curricula, at least in countries such as Australia and the UK. (For example, about 20% each of Kissane (1997) and Kissane, Bradley & Kemp (1997) is concerned with data analysis and probability simulation for secondary school students.) However, the recent addition of inferential capabilities to the suite of statistical commands available on graphics calculators has bridged the gap between upper secondary and lower undergraduate requirements. Modern calculators produced by three major companies (Casio, Texas Instruments and Sharp) include a variety of commands for inferential tests (such as z, *t*, F, ANOVA and c2) and associated confidence intervals, as well as access to tables and graphs of the relevant probability distributions. The programmability of calculators allows users to customise a calculator by adding additional tests (such as non-parametric tests or two-way ANOVA, for example).

At first glance the prospects for acceptance of this new generation of calculators into the undergraduate learning and teaching of statistics appear promising, especially when issues of access and economics are considered. The portability of the calculators potentially overcomes one of the main difficulties with access to computers on campus, at home, in the field and in examinations. The costs of calculator access are very much less than those of computer access; further, as students are increasingly likely to already own or want to purchase their own calculator, the costs to institutions may be significantly eased. Since calculators have inbuilt software, software purchase and maintenance costs are also saved.

There are some evident disadvantages associated with graphics calculator use as well. Large data sets cannot be handled, the range of analyses offered is limited, printing of results is awkward (although not impossible) and the small screen resolution is relatively poor and monochromatic. It is clear that even a modern graphics calculator can never be a complete substitute for a modern statistics package on a computer, although it may serve as a useful learning and teaching aid for introductory work.

Prospects for change

In order to gauge the likely place of graphics calculators in undergraduate courses involving statistics at Murdoch University, we have canvassed the views of a range of University teachers. The courses involved include toxicology, animal behaviour, tourism, social science research methodology, business and statistics itself. Our discussions have been both informal and informative, but certainly do not reflect a rigorous statistical sampling process. Our intention has been to identify issues of importance, rather than make secure generalisations about them.

Interviewees were generally very familiar with statistical software on computers but most were generally unfamiliar with graphics calculators, and few reported any personal experience with them. Consequently, they were not yet able to make informed decisions about the potential place of graphics calculators in their courses. It seems likely that opportunities for personal use and exploration with graphics calculators would be needed before significant student use would be contemplated.

Despite this unfamiliarity, those interviewed were enthusiastic about the prospects for calculator use in the early undergraduate years, once they were acquainted with sample graphics calculator models and their operations. A brief analysis of the statistical content of the courses concerned suggested that the capabilities of modern calculators in almost all cases met student data analysis needs, both for practical purposes and for learning purposes. It seems that the few exceptions would be fairly easy to program into the calculators. New opportunities for teaching and learning might arise if staff felt that they could take advantage of technology, rather than being constrained by limited student access to it.

Although many students owned computers, many others did not, and so it was necessary to provide on-campus access to computer software for teaching and assessment purposes. Several interviewees expressed concern about the costs of providing students with adequate computer access, especially in courses with large enrolments. At least one course was contemplating using a sophisticated spreadsheet program (Microsoft Excel) for data analysis in preference to a dedicated statistics package, because it was more likely that students would have access to it at home as well as on campus. The graphics calculator was seen as providing an economical alternative to computers for data analysis, and to potentially provide a more significant use of technology in student activities within a course.

Despite the attractions of graphics calculators, it is clear that computers will continue to be important in courses at this level. Computers provide access to capabilities not easily available on graphics calculators (such as web-based databases). While graphics calculators might be useful devices for helping students to learn about statistics, they could not be expected to replace entirely the need for students to learn to use computers for data analysis purposes. Indeed, it was reported that some employers of graduates routinely expected competence with computer data analysis.

None of the interviewees reported student use of computers during formal examinations. For examination purposes, it seems that graphics calculators may have a clear advantage over computers, due to their portability and potential accessibility to all students. Some preference was expressed for examination questions that did not involve students in conducting analyses from raw data, since these might create potential risks of exaggerating differences in key-punching abilities among students. To date, examinations often have been designed to reduce calculation demands and to focus on interpretations, partly for the same reason. Some interviewees reported that they expected students to develop some expertise at interpreting computer printouts, a common expectation in several fields, and noted that their examinations reflected this. Such problems (and solutions) are less evident with other forms of assessment, such as assignments and projects, for which the time constraints are less important. In these situations, students are frequently expected to deal with raw data, both choosing and carrying out suitable analyses, for which a graphics calculator may be a suitable alternative to a computer.

Conclusion

In summary, the case for use of the new generation of graphics calculators at the early undergraduate level seems to be a strong one. The prospects of students learning more about statistics seem promising, and the fresh opportunities for good teaching seem at least as promising. While it is very unlikely that technology of this kind will replace computers and statistical software for undergraduate learning, it seems that it may provide a very useful adjunct to existing practice. To realise this potential, it seems clear that many university staff are likely to need some help to become familiar with the nature, operations and educational uses of modern graphics calculators.

References

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