8. QUERCUS AND STEPS: THE EXPERIENCE OF TWO CAL PROJECTS FROM SCOTTISH UNIVERSITIES

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INTRODUCTION

In response to the expansion of post-secondary education in the UK, the Teaching and Learning Technologies Programme (TLTP) was launched by the Universities Funding Council in February, 1992. The invitation to bid stated that "the aim of the programme is to make teaching and learning more productive and efficient by harnessing modern technology." To maximize the impact of the program on higher education, the invitation also stated that preference would be given to bids from consortia of several universities rather than from single institutions. In total, 160 submissions were made of which 43 projects were funded at an estimated cost of £7.5 million per year.

Two of these projects were primarily concerned with the teaching of statistics in service courses. Coincidentally, the lead sites for both projects were situated in Glasgow, Scotland. Glasgow University was the lead site for the Statistical Education Through Problem Solving (STEPS) project. Other members of this consortium include the universities of Lancaster, Leeds, Nottingham Trent, Reading, and Sheffield. The aim of the STEPS project was to produce problem-based learning materials suitable for integration into courses relating to biology, geography, business, and psychology (Bowman, 1994). The STEPS project received £659,000 over a three-year period and has released 23 modules of Computer-Aided Learning (CAL) material to date. [A module is defined as a piece of software dealing with a single educational topic, which can be run independently of any other items of software in the same package.]

The University of Strathclyde was the lead site for a consortium including Edinburgh, Stirling, and Heriott-Watt Universities. The aim of this project, which is known by its development title QUERCUS, was to develop a complete set of interactive courseware to tutor bioscience students in the basic techniques of data analysis and report writing (McCloskey & Robertson, 1994). Total funding for this project was £87, 000, and 12 modules had been realized by the time the project ended in January, 1996.

The result of the expansion of higher education in the 1980s led not just to an increase in the number of students but also a demand for demonstrably higher quality education. By 1992, all institutions involved in these two projects were already using computer technology in the teaching of statistics service courses. Students were taught to use statistical analysis packages and/or spreadsheets as part of their course work. As a result of earlier government initiatives, such as ITTI, some computer-based tutorials (CBTs) had been produced for statistics teaching by the Universities of Ulster and Dundee and had been widely distributed, which raised awareness of the potential of CAL. At the same time, professional authoring tools such as ToolBook and Authorware became available. These facilitate the development of high quality interactive software by people with little previous programming experience. The combination of these factors meant that when it was announced that large-scale funding was to be made available under TLTP there was already

considerable confidence that CAL materials could be used as an effective means of improving the quality of statistics learning while not increasing the teaching load on staff. The advantage of the funding provided by TLTP was that it allowed for the recruitment of research assistants (such as myself) to work as full-time software developers under the supervision of statistics lecturers already involved in the production of teaching materials. This paper reviews the aims, design, and assessment of these projects. I also offer my personal opinion on the future of the courseware we developed.

A COMPARISON OF STEPS AND QUERCUS

From the beginning of their respective projects, the different aims of the two consortia resulted in diverging paths in the development of CAL for statistics. The STEPS project was committed to producing resource material for integration into existing courses in a variety of subjects that have a statistics component. Because it was envisioned that the students using the STEPS materials would also be pursuing a basic course in statistics, it was decided that a problem solving approach, emphasizing the application of statistics, would be appropriate. The courseware was designed so that progression through the material in terms of speed and direction could be controlled by the user. By contrast, the aim of the QUERCUS project was to create a complete course in basic statistics aimed solely at bioscience students. Although the courseware could be integrated into a course with lectures, the theory component of each module was designed to be sufficient for students working in a self-teaching or directed learning mode. The style and content of the modules reflected a teaching-by-objectives approach. Typically, the students were expected to learn techniques, understand theory, and acquire skills. To this end, the structure of the modules was highly linear. To achieve the set objective, the student had to work though each section page by page, completing each task.

The two projects developed different approaches to the question of how best to use data analysis packages in teaching statistics. In a review of some of the earlier STEPS modules, MacGillivray (1995) questioned whether the advantages of introducing such sophisticated software tools outweighed the disadvantages to the students who then had the additional burden of having to learn how to use these packages. Although some of the STEPS modules use commercial statistics packages (e.g., Minitab), learning to use such software was not one of the aims of the project. In several modules, the XLISPStat package is integrated into the courseware to allow the dynamic analysis of data. Figure 1 shows the screen for one of the biology modules (“All Creatures Great and Small”). XLISPStat appears in a “child” (or inner) window within the module. By dragging the dotted area in the *Height* window, the user selects a class of observations for this variable, then the corresponding observations for *Weight* (top-left window) are highlighted as are the *Weight, Height* coordinate pairs in the scatterplot. This activity allows the user to interactively explore the relationship between two variables. The advantage of integrating XLISPStat into the modules in this way is that the users do not need to know how the package works and therefore can focus their attention on developing their understanding of statistical theory. From the outset of the project, the authors of QUERCUS appreciated that for some students learning to use a statistics package was a barrier rather than an aid to understanding. The authors chose to address this problem by making proficiency in using Minitab one of the major learning objectives of the course. Modules 2a (“Minitab Basics”) and 2b (“Working With Data”) deal exclusively with how to use Minitab. The other modules include instructions for users on how to perform their data analysis in Minitab. This advice ranges from simple hints in Help and hotword screens to complex animated diagrams. Figure 2 shows how QUERCUS is

designed to be used. The module "Residuals and Transformations" is open at the bottom of the screen. Minitab is open and the user has been prompted to load one of the datasets supplied with the package. After having been shown how to transform data, the user's ability to select an appropriate transformation is tested. The students get feedback on their chosen transformation for the data in the Minitab Worksheet by clicking on the appropriate button. Clicking on the text in red activates a Hypertext screen detailing Minitab commands.

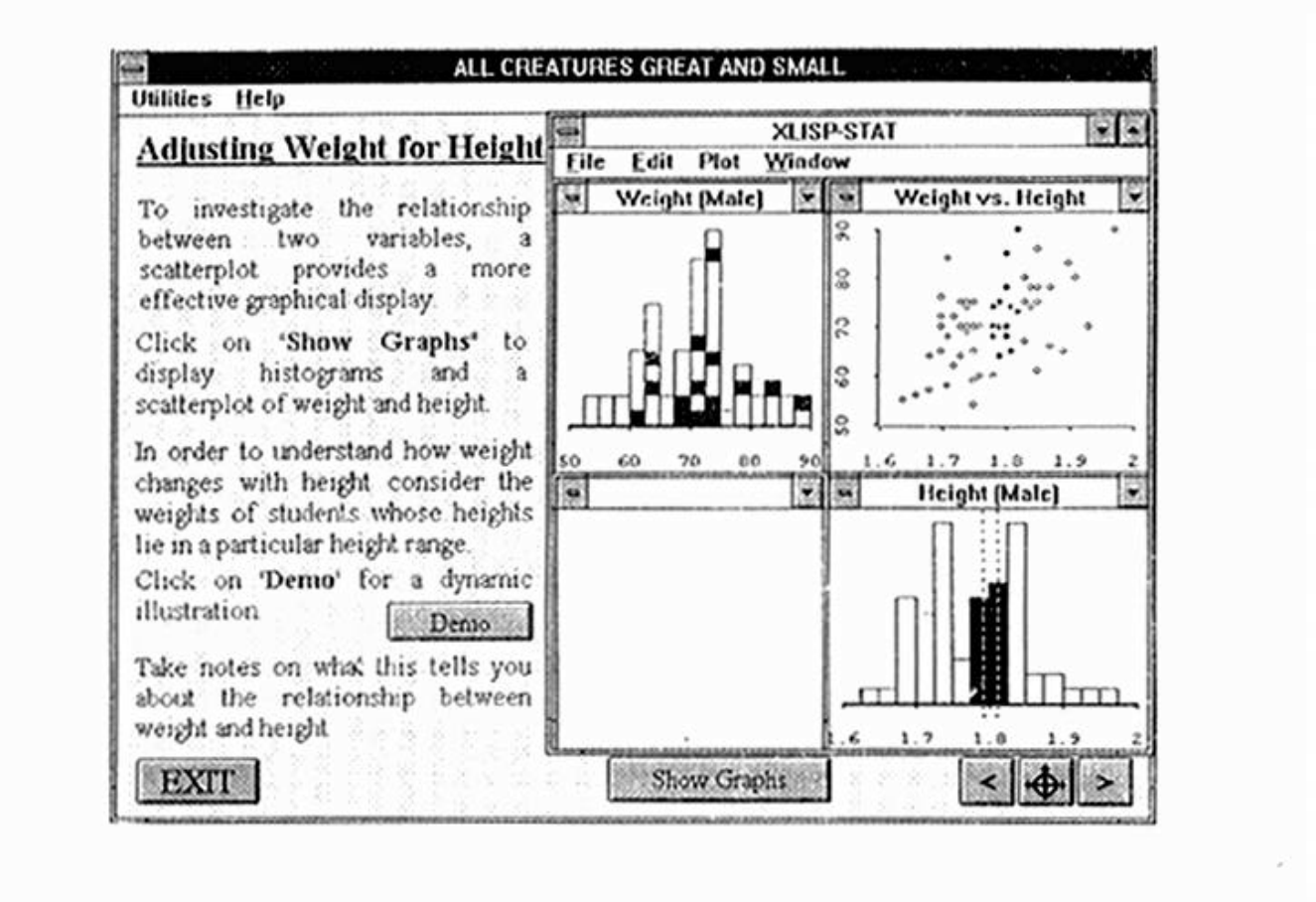

Figure 1: The conditional distribution of weight on height in a STEPS Module

In spite of the differences between the two projects in their approach to teaching statistics, it is interesting to note certain convergent trends in the style of the software and the way it was designed to be used. At the beginning, both projects intended to produce materials for Macs and PC; however, by the end of the projects only one Mac module had been released by STEPS and only PC versions of QUERCUS are being officially distributed. This is largely due to a lack of demand for Mac software in the higher education sector in the UK. Both projects adopted a modular structure for the software, reflecting the origins of the teaching material and the intention that both STEPS and QUERCUS were to be used under the direction of a course tutor/lecturer. STEPS and QUERCUS both use Windows; they share a number of other common features as well. Figure 3 displays typical pages from STEPS ("Skin Thickness") and QUERCUS ("Regression") modules showing common design features, such as Navigation buttons that always appear in the same place on screen, Help buttons, hypertext options (which appear in red), and graphics such as photographs (STEPS screen) or interactive animations (QUERCUS screen).

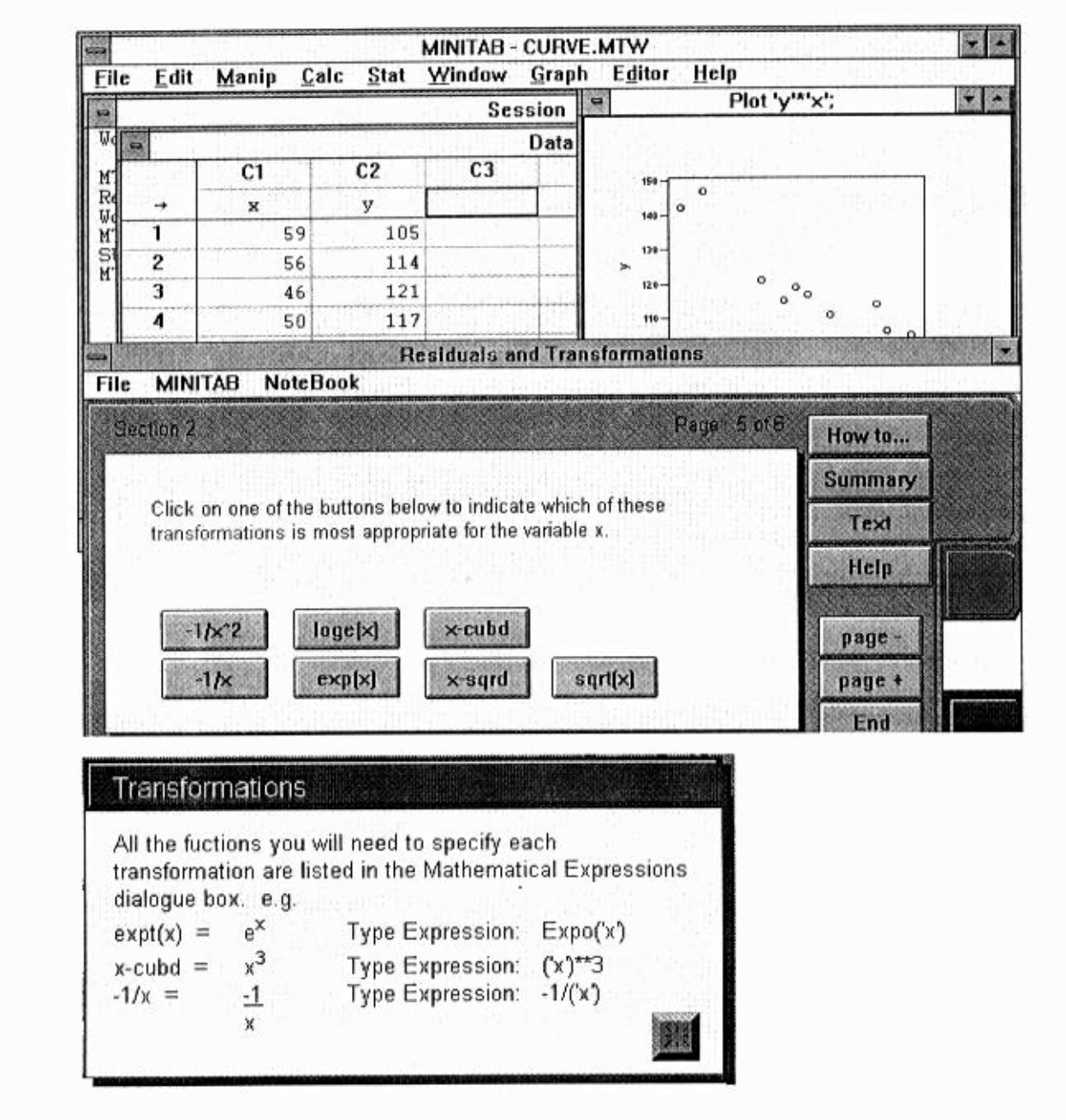

Figure 2: The QUERCUS module "Residuals and Transformations"

Both STEPS and QUERCUS are essentially text-based, but they are enriched with graphics such as photographs, diagrams, and animations that, where appropriate or feasible, have dynamic or interactive features. Thus, interactively testing students' knowledge or understanding is a major feature of both packages. Difficulties with analyzing text responses has meant that multiple choice questions tend to be the most common type of interaction. Both projects relied on the expertise of experienced statistics teachers to produce a context-sensitive Help feature in all modules. This means that on each page, or for each task, the

authors have tried to anticipate what problems the students will face or what mistakes they are most likely to make. By clicking on the Help button students can get advice on these specific problems or mistakes. Both the STEPS and QUERCUS projects have also chosen to produce paper-based materials (handouts, books), which suggests that both teachers and students are not yet convinced (comfortable?) about relying on computer-based materials as the focus of teaching and learning.

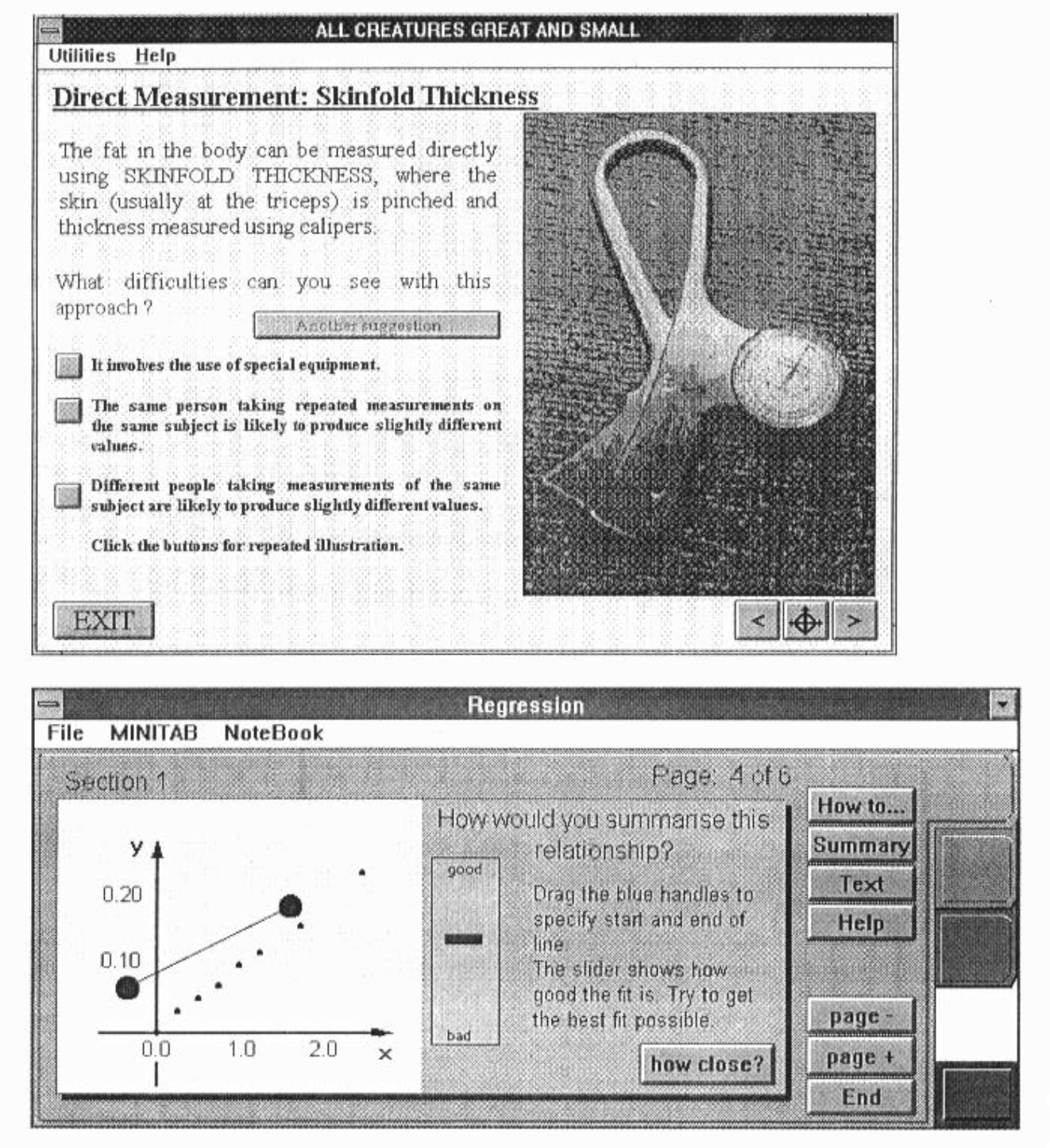

Figure 3: Typical pages from STEPS and QUERCUS

DESIGN AND ASSESSMENT OF CAL MATERIALS

Both the STEPS and QUERCUS projects designed evaluation programs to provide formative assessment of courseware throughout the development cycle. For both projects the design process began on paper. Module contents tended to evolve out of existing course materials such as lecture notes. The materials,

however, were never planned to be a "textbook on a screen"; that is, student activity and interaction was always a priority. The activity component of the courseware was based largely on experience of creating "stat-lab" materials--lists of instructions, worked examples, and illustrations. The software developers would then create "storyboards" of the material to indicate how best to exploit the visual and interactive potential of CAL to present the material and facilitate learning.

The STEPS project had a process of formal review of these paper-prototypes within the site where the material had originated, between sites within the consortium, and from an external evaluator, in order to ensure that the material was both correct and appropriate. Once paper-prototypes had been approved, prototype modules were developed by the software teams. These underwent a similar evaluation process by consortium members and student reviewers. Because of the large number of modules being developed at different sites (a process which is still continuing) and the fact that they were not meant to be used together, it has not yet been possible to test the educational effectiveness of all the STEPS modules. However, several of the STEPS modules have been reviewed by MacGillivray (1995), who concluded that as tools to aid students' understanding of the process of statistical problem solving they were likely to prove "invaluable in enriching introductory statistics courses" (pp. 13-16).

A formal evaluation of the educational effectiveness of the QUERCUS courseware began in the academic year 1993/1994 with the introduction of the first five modules into the introductory biostatistics course at the University of Strathclyde. The success of such assessment exercises depends on the choice and construction of appropriate evaluation instruments. These are as much a subject of research as the CAL materials they are designed to test. However, some guidelines, based on the experience of other CAL developers, had been published by another of the TLTP projects [the Teaching with Independent Learning Technologies (TILT) project (Arnold et al., 1994; Draper et al., 1994)]. Based on their recommendations, a program of class questionnaires, and small group testing and interviews was initiated. Based on test results and student feedback, some aspects of the modules were redesigned, and two modules were completely rewritten.

This evaluation process was repeated with the first eight modules in 1994/1995. Overall, we found that the response to the software was positive, and students were confident that they had achieved the educational objectives set for each module. In particular, the students reported high levels of satisfaction with the graphics and the presentation of factual information. The major criticism was that many of the examples and exercises, although appropriate to their level of understanding, were uninteresting. For a detailed report of the methods and results of the assessment program, see McCloskey, Blythe, and Robertson (1996).

More productive and efficient teaching and learning?

Note that the QUERCUS evaluation exercise was limited to investigating the effectiveness of CAL as a teaching and learning method. The failure to assess whether the stated aim of TLTP (i.e., "to make teaching and learning more productive and efficient…") had been achieved was typical of many of the projects funded under this initiative. Although CAL projects have been severely criticized for this failure, I would argue that there appears to have been little thought about whether this was a realistic goal for projects whose primary activity was to produce software. There is no culture of assessing teaching quality in universities, only student performance is assessed. When we attempt to assess the impact of a new teaching method, it is seemingly impossible to find clear definitions of "productive" and "efficient" in this

context. Not surprisingly, there were no guidelines for measuring productivity and efficiency and, therefore, no absolute standards against which we could measure the success or failure of CAL.

I do not wish to duck the issue, but without evidence I can only offer a personal opinion based on my experience of one CAL project. If by "teaching productivity" we mean an increase in the amount, variety, and quality of teaching materials produced (compared to the material used before), then yes we certainly achieved that goal. If by efficiency, however, we mean the amount of effort needed to help students achieve the same learning outcomes, then writing CAL materials is incredibly inefficient. On the QUERCUS project, there was one full-time software writer and two lecturers working part-time for three years who prepared teaching materials for a single course, which was normally the responsibility of only one staff member. Even for those teachers who "buy-in" course materials such as QUERCUS, there is overhead in terms of the costs of the equipment and the staff to run the computer labs; this overhead needs to be taken into account when measuring teaching efficiency.

I believe the greatest gains from CAL will be found in the effects on students. We need, however, to carefully define what is to be measured. We chose to measure the effectiveness of QUERCUS compared to the paper-based lab materials used previously. To do this, we kept the educational objectives, contact hours, and student assessment methods the same and looked for qualitative improvements in the work submitted by the students. Keeping the objectives and assessment strategy the same meant that we were unable to tell whether using QUERCUS made student learning more productive (i.e., that they learn more). It would have been possible to determine the efficiency with which the students learned the material (i.e., how much time it takes to achieve the learning objectives) if we had asked the students to keep logs of study time devoted to this course. However, we would have needed comparable data from a group of students not using QUERCUS in order to make an assessment. This raises another important issue; that is, is it ethical to run educational experiments on students whose grades may be affected by the quality of the teaching they receive?

To return to my original point, are those who write educational software the best people to assess its value? Again I can only speak for myself, and I question my own impartiality. In any case, it must be emphasized that CAL materials are only educational tools: Their effectiveness and efficiency are largely determined by the way and the context in which they are used. Software writers can only be responsible for the quality of the content and performance of the software. I believe that it is the responsibility of course managers, who decide to incorporate CAL materials in their courses, to have a clear view of what they hope to achieve, of how the materials are to be delivered (i.e., adequate provision of hardware), and of the level of support their students will need. The only way to make fair and meaningful assessment of a CAL package is to assess it *in situ*.

THE FUTURE - A PERSONAL VIEW

The STEPS and QUERCUS projects are now largely completed, and courseware is now available for downloading from their respective World Wide Web sites:

- STEPS: http://www.stats.gla.ac.uk/steps/release.html
- QUERCUS: http://www.stams.strath.ac.uk/external/QUERCUS

8. QUERCUS AND STEPS

No information is as yet available as to the distribution or use of the STEPS modules outside of the consortium. However, more than 120 copies of QUERCUS version 3.0 have been downloaded since it was released in January 1996, and we know that it was used in at least 10 universities in the UK and Australia in 1995/1996.

Requests for source code are routinely requested so that modules can be modified or customized. When TLTP began in 1993, it was not envisaged that the end products whould be customizable by the end-user. The process of writing courseware was regarded to be much the same as writing a textbook. Yet, when we consider the way in which university teachers use textbooks, selecting certain passages and mixing them with material from other sources, we should not be surprised that they would expect to exercise the same level of control and, thus, demand a certain level of flexibility when using CAL materials. Although allowing users access to the source code presents some problems regarding copyright, and may not be possible for commercially written courseware, it does open the possibility of a wider distribution of courseware than had originally been planned. For example, the QUERCUS courseware, which was designed solely for bioscience students using Minitab, is now being modified in three UK institutions outside the original QUERCUS consortium to create versions for use by bioscientists using STATISTICA, engineering students, and developmental studies students. Versions of QUERCUS for veterinary science and business studies are also under development at the University of Strathclyde. The cost of developing the original QUERCUS software was high, but it is unlikely that without such a large initial investment such a project could have been completed. By licensing out the source code in this way, we can allow other institutions, who do not have access to such funding, to create their own versions of a tried and tested product, while multiplying the output from the original project at no extra cost to the producers.

Based on the TLTP experience, it would appear that any new CAL project should have a high degree of customizability as a fundamental characteristic of the courseware. Anecdotal evidence from other software developers on projects that produced customizable courseware suggests that although their users had the option to change the courseware, very few ever did.

In this paper, I have described how two projects that originated from very different ideas about how CAL could best be used to teach statistics produced materials with striking similarities in terms of both software features and teaching style. I would argue that this is due to both projects originating from pre-existing teaching practices. It is my opinion that rather than introducing anything radically different, both of these projects represent a refinement of best practice in the teaching of statistics to large groups of non-specialist, statistics students. For those involved in the writing of CAL materials, a benefit has been the opportunity to intensively study the teaching and learning process. From my own experience in the QUERCUS project, I believe students have benefitted from this approach to developing CAL, by producing effective teaching materials and study aids. My experience, however, leads me to question whether if, in the future, CAL development is left to teaching staff we can expect to see significant innovation in teaching and learning practices. Note that neither project set out to produce self-teaching materials (i.e., to replace teaching staff or the traditional, structured course). Even the QUERCUS modules, which we hoped would eventually replace a significant part of the lecture component of our biostatistics course, could only do so if these were replaced by small group tutorials led by a member of the teaching staff. No material was designed to facilitate students working in study groups, although there is evidence to suggest that in mathematics, CAL support materials can be very effective in aiding group learning (Doughty et al., 1995). Neither project used the multimedia capabilities of the authoring software. Was this because there is no role for this

technology in the teaching of statistics or because traditional university teaching of statistics does not utilize video or sound?

A major stumbling block to production of multimedia teaching materials will be the cost. The cost should not be underestimated. As well as the cost of releasing staff for months or even years from other teaching and research duties, there is also the cost of supporting staff, such as administrators, programmers, and technicians. The project may require the services of a professional graphic designer and/or a human-computer interface consultant. There will be the costs of computers, specialist multimedia software, and sound and video production and editing equipment. Finally, it is likely that one will have to pay copyright fees for music and videoclips from commercial suppliers. In universities and colleges where financial support for producing new teaching materials is scarce, one option is to look for support from a commercial software publisher. Although they are unlikely to pay the development costs, they will often undertake market research to see if these costs are recoverable in the long run. The publisher may also pay any copyright fees you incur and may pay for publicizing and distributing the final product. They may even offer an advance. The disadvantage of commercial partnerships is that only projects that are potentially profit-making will be supported. The advantage is that it may "elevate" CAL development to the level of writing a textbook and will therefore be seen as a "bankable" academic activity.

The Teaching and Learning Technologies Programme (TLTP) was a timely and productive exercise in allowing those involved in teaching in higher education to expand their expertise into the area of computer-assisted learning. The STEPS and QUERCUS projects have successfully demonstrated different ways in which this technology can be used to enhance current teaching practices. Now that these projects have been successfully completed, this may be an opportune time to consider whether CAL has the potential to support new methods or models in the teaching and learning of statistics.

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