Using Mathematical Packages in Advanced Science and Engineering Units

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Introduction

Much of the subject material in high level science and engineering units is strongly based on advanced mathematics and requires a high level of mathematical skill on behalf of the students. This is particularly true of subjects like Signal Analysis, Electromagnetics and Control Systems. These skills are usually acquired during the mathematical strand of the course.

Previously, assignment problems presented in these subjects had to be solvable by hand, that is with algebraic manipulation and a calculator. This has two distinct consequences:

- For realistic problems, more time is spent on advanced but routine mathematical manipulations than on the conceptual principles of the subject material; and
- Problems that are solvable by hand (the problem must be carefully posed such that the solution will drop out in analytic form to second order, i.e. quadratic) are necessarily highly theoretical, simplified and unrealistic.

For these reasons it was thought that the routine use of an advanced mathematical package would transform these subjects from a mathematical slog to a higher conceptual level with the student putting the intellectual effort into mathematical formulation and analysis of problems with the package performing the mathematical grind. The use of such a package would address both of the above problems in that more time would be spent on addressing the conceptual material and would allow more realistic and complicated problems to be posed and addressed.

The Project

The project really began in 1996 with the development of some *Mathcad* worksheets for the Signal Analysis laboratory. There is a wide range of mathematical packages (*Matlab, Mathematica, Maple, C4*, etc.). *Mathcad* was chosen since, at the time, it was the only such package that "looked like" mathematics on-screen rather than a programming language and produces readable documents. The success of this pilot work led to an application for funding of this project through the University of Canberra Teaching Grants Scheme. A full set of worksheets and lecture demonstrations would be developed for the Control Systems subject, and also some worksheets and demonstrations, but not a complete set, for the Electromagnetics subject. The Control Systems work was considered a priority since it suffers significantly from the perception of being "maths-in-disguise" even though it is conceptually rooted in physical systems.

A second aspect of the project was that of flexible delivery. The use of any computer package and its associated electronic documents will have flexible delivery implications. The implementation of the materials produced in this project was to be used to assess the flexible delivery possibilities of such material and presentation.

The School of Electronics Engineering and Applied Physics funded the purchase of a 20 license laboratory set of *Mathcad 5* for student use in 1996. This was upgraded to version 6+ in 1997 to allow this project to be tested in the laboratory. The introductory laboratory worksheets for Signal

Analysis were used in semester 1, 1996, 1997 and 1998; the Control Systems material was used in semester 2, 1997 and 1998 and the Electromagnetics material was used in semester 1, 1998.

Achievement of Project Objectives

- *Devise a short training course in Mathcad to be used at the second year level such that students have the basic skills to be able to use the package effectively.*

The introductory worksheets used in the Signal Analysis laboratory work are effectively the training course. This set comprises an introductory supervised computer laboratory session in which the student uses the tutorial provided with the *Mathcad* package along with a few simple tasks to get used to the look-and-feel of the package and, in particular, the typography of equation entry in the worksheets. The student is then presented with three pre-prepared laboratory worksheets. The students use the worksheets for making specific calculations and modify the worksheets to perform other analysis. The introductory session has been modified in the light of experience but is still unsatisfactory. The package is significantly different from what the students have been exposed to by way of computer tools and it appears that they need a more structured and systematic approach.

- *Gradually introduce Mathcad into the engineering course starting in second year with training and light use and then fully in third year engineering units.*

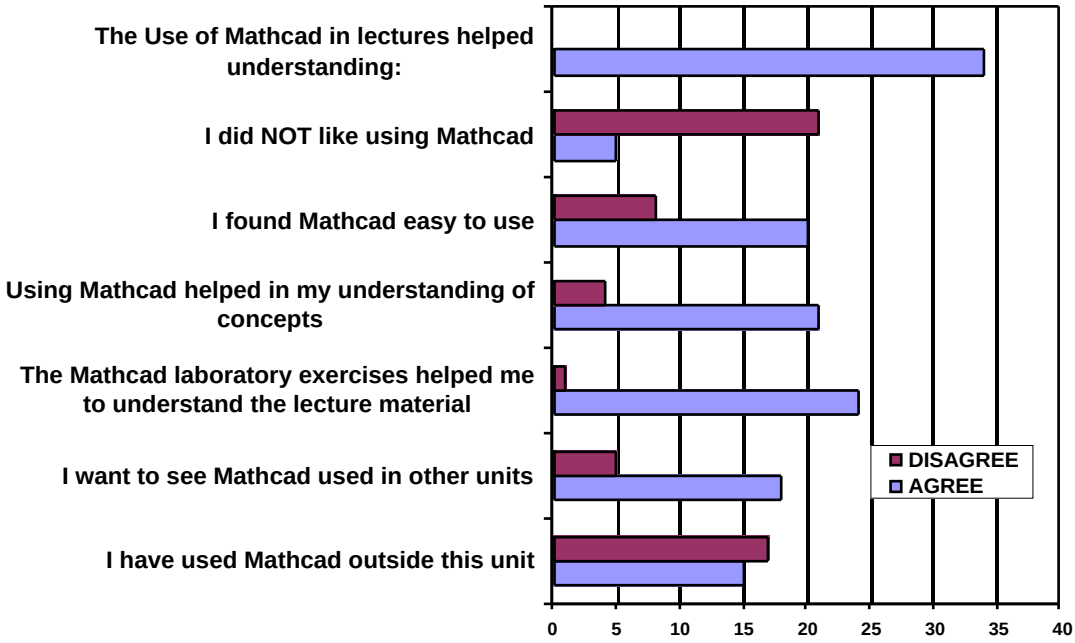
As a direct result of this project, *Mathcad* is now in formal use in the subjects Signal Analysis (2nd year), Control Systems, and Electromagnetics (both 3rd year). In addition the Mathematics staff are using it formally in the unit Numerical Analysis (3rd year) again for the reason that it is easy to read (like mathematics) but can perform complex numerical and algebraic tasks. The package is also used informally in Electronics Engineering 1 (1st year) and Electronic Instrumentation (4th Year). In addition the students who have been exposed to it tend to use it in all their units that require any mathematical analysis of any complexity. In particular they use it in their design projects for simulation purposes as they find it is much easier to use and more readable than programming in a standard computer language.

- *Devise a set of lecture demonstrations using Mathcad to dynamically illustrate the concepts under consideration.*
- *Devise a set of assignments and problems for selected modules of the third year engineering units that are realistic and that can be solved using the advanced features of Mathcad.*

A complete set of worksheets, assignment questions and lecture demonstrations have been developed for use in the subjects Signal Analysis, Control Systems and Electromagnetics. These materials were developed with the help of a recent graduate who was employed to construct the *Mathcad* documents from drafts and ideas developed by the author and the graduate. They have been used on several occasions and have been further developed in the light of evaluations from the students.

- *Evaluate the effectiveness of the use of the package in improving student performance and enthusiasm for what are highly mathematically based subjects.*

Evaluation of the use of *Mathcad* in these subjects was undertaken by surveying the students. The first survey was given to the students of Signal Analysis at the end of semester 1, 1996 after having been exposed to the trial use of *Mathcad.* Responses to selected questions are shown below.



The results indicate that the students feel that the use of *Mathcad* does help their understanding of the lecture material and that they found it relatively easy and enjoyable to use. There is strong support for *Mathcad* to be used in other units but, notably, only about half the students used *Mathcad* outside this unit. This is not surprising as it is their first exposure to the package.

A similar survey was carried out on the (fewer) students in Control Systems in 1998 after this project was complete. These students have now used *Mathcad* in three units in 2nd and 3rd year and are reasonably well versed in its use. Again the results indicate that the students feel that it is useful and does help understanding. Now, after two years use, the large majority of students are using *Mathcad* outside the units that formally use *Mathcad.* This is borne out by assignments that are not set in *Mathcad* being handed in as *Mathcad* worksheets and in particular in the number of students using *Mathcad* for complicated analysis in their 4th year projects.

- *Assess implications for flexible delivery of mathematically based subject material.*

The implementation of the project attempted to be flexible in that the students did not have to submit paper copies of their work. Indeed, because *Mathcad* worksheets are live, printing them defeats their greatest advantage. The assignment worksheets were posted on the unit web site so that the students could download them and work on them either at home or on the University network. *Mathcad* in fact has a built in web browser that automatically opens recognised *Mathcad* documents from the web. Assignment answers could be emailed to the tutor either directly from within *Mathcad* or as a standard attachment. The worksheets remain live so that the tutor can inspect, mark and annotate them and return them to the student. Complete worked solutions are posted after the due date. Similarly all lecture demonstrations were posted on the web so that the students could download and operate the demonstrations themselves.

This system worked well and was appreciated by the majority of students, particularly part time students. A few preferred to submit hand written solutions using *Mathcad* only for the final calculation and plotting. Once again this really defeats their purpose since any changes will have to be worked by hand and re-entered into the worksheet. These students are usually those who have not taken the time to become fully acquainted with the typography of *Mathcad* indicating again that better initial training in its use is required.

In the coming year further uses in flexible delivery will be investigated by including *Mathcad* worksheets in a *WebCT* site for the unit. The web can be browsed from within *Mathcad* and there is

a wealth of information, applications and discussion groups at the *Mathcad Collaboratory* site (http://webserve.mathsoft.com/mathcad/). A further tool is the existence of many electronic reference books that can be used from within *Mathcad.* These are relatively cheap, are live and can be edited to suit. They cover a wide range of science and engineering subjects.

Conclusions and Recommendations

All the objectives of the project have been achieved. Both formal and informal feedback from the students has been universally positive, many students purchasing a copy of the student edition of *Mathcad* ($99) for themselves. Students are using *Mathcad* for analysis and design work even when not formally required; it produces mathematically readable documents. The author now uses *Mathcad* for preparation of demonstrations and worksheets in all units that he teaches and the use of *Mathcad* is spreading to other units in the School and in the Faculty and is also being used by research staff for modelling purposes.

In order to extract the maximum benefit from the investments in the software and in the development of the materials to use it, the following is recommended:

1. That some time, early in the course, be allocated for formal training in *Mathcad.* The tool is useful and appreciated by the students, but a short tutorial session is not adequate to allow students transparent use of the package.
2. That a Staff Development program should be established to ensure that all appropriate staff are *Mathcad* literate. This will generate further expansion in the use of the package as well as generating efficiencies in the setting of assignments etc.
3. That further work be undertaken to evaluate the use of *Mathcad* in flexible delivery programs. The latest version of *Mathcad* (Version 8) is fully web compliant and offers wide possibilities in a flexible delivery program. These will need to be investigated and evaluated.

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