Using Computers to Deliver a Mathematics Course, to Increase Recruitment and Retention Rate of Non-Traditional Students and Reduce Staff Workload

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Abstract - This is a longitudinal case-study (over 12 years) which discusses the conversion of a basic mathematics course for technology students to Computer Aided Learning and Computer Aided Assessment. This was easier than expected because suitable off-the-shelf software was available. The change also enabled the maths admissions requirement to be relaxed, thus increasing access to the degree programme for non-traditional students. A scheme of work has been developed to cover all required mathematical concepts and computers are used to deliver the curriculum and assess students’ knowledge and understanding. Staff workload is reduced as they no longer lecture or assess but act as tutors working alongside students individually. Students like this method of learning as they study at their own pace and attempt tests when they feel ready. Retention rates for class sizes of 50+ are similar to those of using small group didactic teaching.

Index Terms - Basic mathematics teaching, Computer Aided Assessment, Computer Aided Learning, Improved recruitment and retention rate, Reducing staff workload.

INTRODUCTION

The mathematics course under discussion is part of an Initial Teacher Education programme founded to produce teachers of technology for Scottish schools. This four year Honours degree called the Bachelor of Technological Education (BTechEd) was established in 1987 with a view to making teaching an all graduate profession in Scotland. Up until then technical teachers predominantly entered the profession after obtaining a Diploma in Technical Education and many of the teachers came from a trade background. The degree prepares students to teach the four technology subjects, Craft and Design, Graphic Communication, Practical Craft Skills and Technological Studies. To put the development of the mathematics course into context, the background to the restructuring will be explained by:-

- presenting a brief description of the changes in technical education in Scotland over the past 20 years,
- briefly describing the subjects taught,
- discussing the uptake of the subjects in schools,
- describing the degree programme and the changes brought about by external influences, and
- discussing the kinds of students choosing to teach technology.

An overview of the mathematics course and its development over the last twelve years is presented explaining why Computer Aided Learning (CAL) was introduced followed by the implementation of Computer Aided Assessment (CAA). Finally a discussion of the benefits and drawbacks of this method of teaching is offered.

BACKGROUND

Changes in Technical Education since the 1980s

Until the middle of the 1980s the subjects taught in the technical departments were mainly woodwork, metalwork and technical drawing with a few schools entering students for engineering science examinations. With a shift towards making teaching an all graduate profession and consequently raising the status of technical subjects within the school system a dramatic curriculum and cultural change took place within technical departments. Mainstream craft subjects were phased out and replaced by two new subjects, Craft & Design and Technological Studies. Technical Drawing continued to be taught for several more years but it was due to be discontinued and appropriate elements of its subject content incorporated into the two new subjects. Many of the technical teachers in post at the time, who had neither training nor expertise in design and technology, had these changes thrust upon them. They were required to put considerable effort into continuing their professional development. A number of the older staff were unhappy with the changes and, to stop any further erosion of their domain, campaigned to keep technical drawing as a separate subject. Thus a third subject, Graphic Communication, was introduced into the technical curriculum, in the early 1990s, replacing Technical Drawing. Further pressure from the same group resulted in a fourth subject, Practical Craft Skills, being introduced about five of years ago. This in many ways brings the technical curriculum back to where it was 20 years ago, with a few interesting additions.

Technology Subjects Taught in Schools

- **Craft & Design**: covers some craft skills, woodwork and metalwork, and introduces design. In the mid 1990s the
subject was revised, to make it more academic, by increasing the importance of design and reducing the emphasis on craft skills.

- **Graphic Communication**: incorporates many of the elements of the original technical drawing qualification, but also includes sketching, layout drawings and use of computers for 2-D and 3-D representation and CAD.
- **Practical Craft Skills**: teaches woodworking and metalworking skills.
- **Technological Studies**: this subject builds on Engineering Science and is regarded as the most academic and difficult of the four subjects. Its curriculum covers electricity and electronics, structures and materials. NOTE: this is the only subject of the four that requires any substantial mathematical input.

### Uptake of the Subjects in Schools

Radical changes took place in the technology curriculum in the 1980s but since the mid 1990s there has been a slow but subtle change in its emphasis. From 1995 [1] to 2000 [2] there was a reduction of 9% in the number of students opting to take Higher Technological Studies, whilst at the same time Higher Graphic Communication and Higher Craft & Design each showed an increase in uptake of 44% and 32% respectively (the Scottish Higher Grade Examinations are regarded as an entrance qualification into University). The numerical figures for students opting to take Graphic Communication and Craft and Design are roughly equal, but Technological Studies now represents less than one sixth of the pupils taking Scottish Higher Grade Examinations within the technical/technology departments. The curriculum change has attracted different pupils into technical departments and in particular has changed the gender balance. The percentage of girls studying Graphic Communication increased from 17% to 25% of the total between 1995 and 2000 whilst Craft & Design, with its revised syllabus requiring a greater emphasis on design, increased from 19% to 30% over a similar period. In Technological Studies, however, only 6% of its uptake are girls and this has not changed.

The significance of this is that Technological Studies, which has raised the status of technical departments and is often regarded as the most demanding and academic of the four subjects, has been dropped from many of the schools in the West Coast of Scotland. Technological Studies is a very good preparation for students wishing to study engineering and some universities have recognised this and requested it as an entrance qualification into University. The numerical figures for students opting to take Graphic Communication and Craft and Design are roughly equal, but Technological Studies now represents less than one sixth of the pupils taking Scottish Higher Grade Examinations within the technical/technology departments. The curriculum change has attracted different pupils into technical departments and in particular has changed the gender balance. The percentage of girls studying Graphic Communication increased from 17% to 25% of the total between 1995 and 2000 whilst Craft & Design, with its revised syllabus requiring a greater emphasis on design, increased from 19% to 30% over a similar period. In Technological Studies, however, only 6% of its uptake are girls and this has not changed.

The change in emphasis within the technical departments away from Technological Studies to more design and drawing orientated subjects has resulted in a rise in applications from girls who want to teach these school subjects. The percentage of girls joining the course has increased from an average of 22% of the first year intake (varying from 8% to 34%) over the first ten years of running the degree to an average of 36% of the first year cohort (varying from 26% to 62%) over the last seven years.

### The BTechEd Degree Programme

Whilst all these changes were taking place in the school technical curriculum the course team had to adapt the degree programme to supply quality teachers of technology to cope with teaching all the school technology subjects.

The original remit was to produce teachers of Craft & Design and Technological Studies for Scottish schools. The programme was a four year Honours degree which included the curriculum content for Technological Studies, Craft & Design and Education along with periods of school experience and an industrial placement. Sufficient depth was introduced, particularly in technology for accreditation with Institute of Production Engineers in the early 1990s. Mathematics at Scottish Higher Grade level was an entrance requirement to enable the students to cope with the mathematical content within the degree programme, originally taught over three years, and also required for the engineering/technology subjects. As the changes in the school curriculum were implemented, particularly the greater emphasis being placed on design and graphics, the degree programme was adapted to include considerably more skills development in drawing and designing. Initially the degree programme also contained a high number of student contact hours and an excessive student workload. There has been continued pressure to systematically reduce both contact hours and workload, resulting in an overall reduction in the technology curriculum and a consequent reduction in mathematics content. Another radical change transpired when the original providers of the mathematics course withdrew and a rapid solution was required. Initially the students joined the first year engineering maths course with a view to completing it over two years. The results were not as good as expected so the possibility of using Computer Aided Learning (CAL) was investigated [3] and has now been used for ten years. Computer Aided Assessment (CAA) was introduced four years ago [4].

### The Students

For the first nine years of the degree more mature students than school leavers joined the course (varying from 54%-90% of the cohort). Initially Technological Studies was the predominant subject students were being prepared to teach so most of them came from an engineering background with either Higher National Certificates (HNC) or Higher National Diplomas (HND) in Mechanical or Electrical and Electronics Engineering (non-degree level tertiary qualifications). Some
mature students joined after following an ‘Access into Higher Education’ course run by Further Education Colleges to encourage mature students without any qualifications to enter Higher Education. All of these courses covered sufficient maths for the students to cope with the maths and technology courses on the degree programme. All school leavers had a qualification in Higher Grade Mathematics.

During the 1990s government policy to increase participation in Higher Education meant that the previous system of grants for students was replaced with loans and extra bursaries for mature students also disappeared. Older students who did not want to shoulder a burden of debt stopped applying for the course and the percentage of mature students to school leavers dropped to as low as 15% in session 1998/1999. It has never really recovered and hovers around the 30-40% level.

Meanwhile our graduates are now out in schools encouraging their pupils to consider technology teaching as a career. Also the popularity of Craft & Design and Graphic Communication with girls as well as boys has increased applications from school leavers. Very few applicants have studied Technological Studies at school, about half a dozen at most each year, whilst many of the remaining school leavers have studied the other two subjects, and only a few have passed Higher Mathematics. Also a significant number of the mature students now come with carpentry or design qualifications and, therefore, have little or no mathematical background, but can offer other skills to compensate for this shortfall. By continuing to insist on Higher Mathematics as an entrance qualification many potential students with other skills, who would make excellent teachers, were being turned away. Using CAL and CAA enables students to work at their own pace, thus when joining the degree they can compensate by devoting more time to mathematics and less time to their areas of expertise.

**The Mathematics Course**

Over the past seventeen years the mathematics course has undergone considerable change to keep up with the developments in the rest of the degree programme. It began in 1987 with a course taught didactically to small groups (maximum of 15 students) and the curriculum was covered over three years. The content and level of the course has been progressively reduced to enable it to be covered in one year with larger classes. Many of the changes have been extensively evaluated and documented [3, 4].

There was a dramatic change in course delivery in the mid 1990s when the original course provider withdrew their services. It seemed like a good idea for the students to do the same mathematics course as the first year engineering students as they had similar entrance qualifications ie Higher Mathematics or its equivalent, but the students struggled with the course and it interfered with other coursework because it was taking up too much time. It must be noted that the engineering students fared no better with the course than the technology students. It became necessary to seek a way to deliver the mathematics course without substantially increasing the workload of the course team.

In session 1994/95 a Computer Aided Learning (CAL) package, CALMAT [5] developed by Jean Cook [6] and colleagues at Glasgow Caledonian University was bought with the intention of using this as the sole method of delivery for the first year maths course [3, 7]. The introduction of CAL for the course was evaluated by members of TILT Group E evaluation team [8], as part of the TILT project run at the University of Glasgow. TILT (Teaching with Independent Learning Technologies) was part of the first phase of TLTP (Teaching and Learning Technology Programme) a national initiative to look at the use of IT for teaching in Higher Education. Maths was taught using CAL with a tutor available at all times and assessed by two class exams and a main degree exam. If a student obtained an average mark of 60% or greater (and not less that 40% in either class exam) they were exempt the degree exam. This was the same method of assessment as the engineering maths course. Evaluation was essential to be sure that students were not being disadvantaged by the introduction of CAL instead of using conventional lecture delivery. In reality, however, the students pass rates improved quite dramatically over the previous year where they had been part of the class of 200 engineers.

A number of evaluation techniques were used throughout the year, such as questionnaires, focus groups, checklists, plus an initial diagnostic test and final exam marks. The final pass rate improved from 71% in session 93/94 to 81% in session 94/95 (after taking the resit marks into consideration - the initial pass rate after the first degree exam in 93/94 was only 38%, compared with 76% using the CAL package in 94/95). When questioned about the use of CAL for teaching, positive comments from students included; ‘being able to learn independently’, ‘work at own pace’, ‘get immediate feedback on work done’, ‘they could help each other’. Some of the more negative feedback included; ‘occasionally the computer gave incorrect results’, ‘this was only one method of teaching’, ‘wished for more tutorial support when struggling’.

In response to the students’ feedback a basic textbook [9] was recommended for the following session. It was chosen because it was good for self teaching and students could use it to learn from, instead of the computer, for some topics if they wished. Weekly tutorial sessions covering a separate topic each week were also arranged.

CALMAT is updated each year and many of its original problems have been ironed out over the years. Students can buy CALMAT for use on their personal computers, and many of the students who are having difficulty with maths spend more time working on it at home. After introducing the improvements requested by the students, from session 95/96, the pass rate for the first year maths course for the next two sessions increased to 100%, which was more like the pass rate before the students were put in with the first year engineers i.e. between 90-100% - see Table I. Data from sessions earlier than 91/92 was not readily available.
TABLE I
PASS RATES COMPARED WITH TEACHING AND ASSESSMENT METHODS

<table>
<thead>
<tr>
<th>Session</th>
<th>%pass - main diet</th>
<th>%pass - total</th>
<th>% &gt; 60%</th>
<th>Teaching method</th>
<th>Assessment method</th>
</tr>
</thead>
<tbody>
<tr>
<td>91/92</td>
<td>85</td>
<td>90</td>
<td>60</td>
<td>Small class (15)</td>
<td>Exam + resit</td>
</tr>
<tr>
<td>92/93</td>
<td>86</td>
<td>100</td>
<td>45</td>
<td>Small class (15)</td>
<td>Exam + resit</td>
</tr>
<tr>
<td>93/94</td>
<td>38</td>
<td>71</td>
<td>24</td>
<td>Large class (200)</td>
<td>2 class exams + main exam + resit</td>
</tr>
<tr>
<td>94/95</td>
<td>76</td>
<td>81</td>
<td>43</td>
<td>CAL</td>
<td>2 class exams + main exam + resit</td>
</tr>
<tr>
<td>95/96</td>
<td>96</td>
<td>100</td>
<td>65</td>
<td>CAL + tutorials</td>
<td>2 class exams + main exam + resit</td>
</tr>
<tr>
<td>96/97</td>
<td>94</td>
<td>100</td>
<td>41</td>
<td>CAL + tutorials</td>
<td>2 class exams + main exam + resit</td>
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<tr>
<td>97/98</td>
<td>76</td>
<td>86</td>
<td>52</td>
<td>CAL + tutorials</td>
<td>2 class exams + main exam + resit</td>
</tr>
<tr>
<td>98/99</td>
<td>93</td>
<td>93</td>
<td>74</td>
<td>CAL + tutorials + MCQs</td>
<td>2 class exams + main exam + resit</td>
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<tr>
<td>99/00</td>
<td>96</td>
<td>96</td>
<td>79</td>
<td>CAL</td>
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<td>CAL</td>
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<td>90</td>
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<td>CAL</td>
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<tr>
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<td>100</td>
<td>100</td>
<td>85</td>
<td>CAL</td>
<td>CAA</td>
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After much pressure to reduce the curriculum content for the whole degree, in session 97/98 the total maths content for the students was reduced and put into the first year of the degree course only, resulting in a slight drop in the pass rate to 86%. The following session, 98/99, the students were given work sheets every week for different topics and completed a short multiple choice test when they were ready. The overall pass rate increased to 93% and the percentage of students obtaining more than 60% in the exam increased to 74% from an average of below 50%. This was quite an important improvement as the students are required to be competent in all topics and not miss any out. The higher the score obtained the more likely the students are to be competent in all the topics, and understand all the required concepts.

After discussion with the students it was obvious that they liked being tested in this way as they could sit the tests when they felt ready. As a result the assessment technique on the course was changed from the class exams and degree exams to a set of 10 tests, each covering a different topic. The only way to introduce this without dramatically increasing the lecturer’s workload was to use Computer Aided Assessment (CAA). CALMAT has an associated tutorial and assessment system TASMAT which was used for the tests. Students can tackle these tests as tutorials and when they feel confident in that topic they can sit the assessment. Questions and numbers are randomly chosen, so each student sits a slightly different test – see Figure I for an example of the TASMAT screen.

![Figure I: Example of a TASMAT Screen](image)

DISCUSSION

When comparing the results, the outcomes for using CAL as the delivery mode are not dissimilar to those obtained using small group teaching. Classes in sessions 91/92 and 92/93 were reduced to no larger that 15 in number, whereas in 93/94 the class size was over 200 with a one hour tutorial per week of about 30 students. From 94/95 onwards CAL was used for course delivery and up to 50 students can be catered for. There were differences in curriculum coverage over the years with largest amount being covered in the one year slot from session 97/98.

Using CAL and CAA for course delivery and assessment of a basic mathematics course such as the one for technology students offers many benefits [10,11], such as:-

- the time spent setting and marking exams has been dramatically reduced, and so has the pressure on the lecturer to teach classes.

![Figure I: Example of a TASMAT Screen](image)
the improvement in retention rate of students entering with no mathematical background.

- being able to take students from diverse backgrounds because the they can work at their own pace.

- students no longer being able to avoid tackling topics they find difficult, do not understand or like. They have to gain at least a pass mark in each topic.

- students getting immediate feedback on their results.

- students preferring to tackle assessments in this manner, as they feel it reduces the stress of degree exams.

Some of the main drawbacks appear to be that:-

- the students can take too long over preparing for the assessments and reach the end of the session without having completed them. Introducing a final test, covering all topics, seems to have alleviated this problem slightly as some of the students may see as a final exam to work towards.

- the lecturers have to move quickly between topics when giving help.

- CAA only gives credit for the final answer. There are ways round that problem, such as insisting that the students keep all their working on paper.

It would appear, therefore, that using CAL for course delivery has all the benefits of small group teaching without the drawbacks of staff effort, and using CAA can force students to cover all topics whilst reducing staff time on assessment.

CONCLUSION

Changing the course delivery to CAL and then introducing CAA was much easier than expected, mainly because a suitable off-the-shelf computer programme, CALMAT, was found to satisfy both needs. Developing in-house teaching packages requires much more effort but there are aids, such as the Blueprint for Computer Assisted Assessment [12] to assist with CAA. Being forced to make the change in course delivery enabled us to relax the entrance requirements, thus allowing us to take students with lower maths qualifications if they could offer expertise in other areas of the curriculum. Setting a series of tests to be passed forces students to tackle all topics and not avoid those that they do not like or find difficult. Using CAL to allow students to work at their own pace and then sit tests when they feel ready means that they are more likely to complete the course and continue with the degree, thus offering an outcome which is similar to that of small group teaching. The reduction in staff effort on lecturing and assessment, and also student satisfaction with their learning experience is well worth the effort of making the change.

REFERENCES


