
Mathematics and Computing

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This article will consider part of the role of mathematics in the computing curriculum. It considers some of the close links between, and common problems encountered by, mathematics and computing in HE. Whilst many of these links are based on academic content, these links go further in the modern HE environment, where issues at the pre-university level are affecting the uptake and attainment of University level courses.

Background - the common nature of the disciplines

To start with, what do we mean by a discipline? My current contract depicts me as a lecturer in Computer Science, although my original degree was in joint Mathematics and Computer Studies, and my PhD was in Applied Mathematics. However, many of these discipline boundaries are quite arbitrary – my actual mathematical research was closer to pure mathematics than applied mathematics, and the Applied designation on my PhD certificate is more a feature of my supervisor's departmental position than any actual reflection of the academic content of my thesis.

These difficulties in definitions extend to Computer Science itself, which covers a broad range of topics. Historically, many computing departments were named Computer Studies, but changed name to Computer Science in order to emphasise the scientific nature of the subject. This has been a common occurrence throughout UK (academic) computing departments, and reflects the change in identity within this discipline. Many Computer Science departments began life within Mathematics departments, but later broke away as an independent specialism [1]. A minor consequence of this history is that Computer Science texts are usually catalogued as a subset of Mathematics, which is now causing severe problems in indexing, especially now that the volume of computing texts has become so large. This separation of Mathematics and Computer Science has not happened in all universities; in some, Mathematics and Computer Science have remained together in a single department or school, in other institutions the separation has been reversed and there are many departments of Mathematical Sciences which include computing.

The boundaries of Computer Science are fuzzy, and Computer Science can be seen as a mixture of technology, pure science and social science. Generally, Computer Science seems to fall somewhere between pure science and technology - with subgroups of Computer Science tending more towards one area or another (for example, quantum computing is close to applied physics, but real time systems is very much an engineering/technology subject). A succinct description of modern Computer Science can be found within the QAA Benchmarking Statement on computing [2]. This statement itself mentions mathematics or related words six times, five of which relate directly to curriculum issues. Computing is concerned with the understanding, design and exploitation of computation and computer technology - one of the most significant advances of the twentieth century. It is a discipline that blends elegant theories (including those derived from a range of other disciplines such as **mathematics**, engineering, psychology, graphical design or well-founded experimental insight) with the solution of immediate practical problems; it combines the ethos of the scholar with that of the professional; it underpins the development of both small scale and large scale systems that support organisational goals; it helps individuals in their everyday lives; it is ubiquitous and diversely applied to a range of applications, and yet important components are invisible to the naked eye.

Reflecting the points above, teaching within Computer Science can really be divided into two distinct areas - those topics which are purely Computer Science, and those topics which are nominally under another discipline, but which are so fundamental to Computer Science that they are embedded within a Computer Science programme. Because of the natural and long connections with mathematics this is a particular area where these boundaries are least well defined. For this reason, we will later look in detail at the particular issues of teaching mathematics within a Computer Science degree. Whilst this article will concentrate on the discipline itself, teaching the discipline depends on many external factors. In particular, financial pressures have led to low staff to student ratios, and this is affecting the way Computer Science is being taught. Other aspects that affect Computer Science teaching are the vocational nature of the subject, the rapid changes in content, and the role of accreditation [3]. Many university Computer Science programmes are accredited by the British Computer Society (BCS), which makes certain demands in the content of a computing degree, and requires certain types of skill development, for example the requirement for a substantial project.

Teaching mathematics within Computer Science

As previously mentioned Mathematics plays a fundamental role in Computer Science, and this is reflected in the syllabus of a typical Computer Science programme. There is often a difference here between "old" and "new" universities. This is reflected in the Benchmark Statement for computing, which does not specify a minimum amount of mathematics for a computing degree. While courses at pre-92 universities appear to contain a greater number of explicitly mathematical modules, there is usually a substantial amount of embedded mathematics in many other modules.

Although Computer Science students are generally quite well motivated in the study of explicitly Computer Science modules, they can be very negative about the mathematics they have to learn. In my experience, using concrete examples of the application of mathematics to computing problems can help alleviate this. Unfortunately, in some cases suitable examples – being both accessible and simple enough to incorporate at an early stage – are hard to find, and the actual applications of the mathematical concepts to computing can be difficult to elucidate.

Historically many departments required A-level mathematics for entry. However, with the relative drop

in popularity of A-level mathematics, this requirement is being dropped at a number of institutions. Partly this reflects the changing staff profile, partly the changing content of Computer Science, and is also due to competition in the sector. Of course, such a change in intake requirements will have fundamental effects on what and how we teach. The perceived declining mathematics ability of students is seen as an increasing problem across science generally, and the concern this is causing has resulted in a number of national initiatives [4]. Regardless of whether this is a definite drop in mathematical ability, or is symptomatic of a growing gap between what is taught pre-university and what Universities expect, the effects are the same. It does appear that the structure of GCSE mathematics, along with changes in AS and A-levels, has created a number of problems [5]. One aid we have to deal with this is the introduction of diagnostic testing.

Mathematics has the benefit that many topics are quite amenable to automated testing. This means that the use of software to test students' knowledge is feasible and worthwhile. For this reason, my own institution uses diagnostic tests for many science departments, and we now arrange them for our entire Computer Science intake. This can be done with paper-based tests, but a more efficient method is to use computer-based tests. I have used the *Diagnosys software* package [6], which offers group and individual profiles on basic mathematical skills and knowledge. Of course, the usefulness of diagnostic testing depends upon suitable follow up support. In my teaching, I use a number of techniques. Students' tutors receive the summary sheets for their individual students, and so there is an opportunity to discuss the results and to identify appropriate follow up activities. These activities can include self-learn materials and direct assistance (for example provided by our local campus-wide mathematics support co-ordinated at Hull by our Study Advice Services, who employ a mathematics graduate to provide help with core mathematics topics such as algebra [7]), support from the tutor, and also some additional lecture support. This last is most suitable where there are common difficulties for a substantial number of students within a module – something easily identified from a group profile. A successful technique appears to be involve brief coverage of the material in lectures, followed by workshops including appropriate questions.

Cross discipline links

Gordon [8] considered some of the issues that are common to several science subjects that rely on a large amount of mathematics, and identified some of the following issues that link these issues:

- Static number of A-level mathematics students with a rising number of places on mathematics-related degrees is reducing the market;
- Computing is still seen as a highly mathematical subject. School level advisors often recommend Further Mathematics – or at least Mathematics – at A-level in order to study computing at degree level [9]
- The introduction of AS levels has encouraged students to drop “hard” subjects. Mathematics and computing/IT are two of the worst subjects at AS level in terms of student achievement (these subjects have swapped between last place of 31 subjects between 2001 and 2003) [10]
- Finding good Computing and Mathematics teachers at schools is a major problem. Expertise in both these subjects is valued at a premium, and staff with such expertise are often lost from the teaching profession, leaving both subjects to be taught by non-experts.
- Both disciplines have seen a decline in student application rates

Unfortunately, subject independence can mean that one discipline misses opportunities in another. For example, the Undergraduate Mathematics Teachers Conference (UMTC [11]) has typically appealed to staff in mathematics departments. However, a brief read through the list of recent chairs shows that most were either from departments of mathematics and computing, or purely from computing departments (as in my case). UMTC offers an environment where the importance of teaching mathematics in computing and other programmes can be emphasised. For example, at the UMTC 2001, a working group looked at “*Innovations in Teaching Discrete Mathematics*”. UMTC 2003 included a working group considering how to provide foundation level mathematics in a University environment, and looking ahead to September this year, UMTC 2004 is likely to have a working group considering methods of teaching mathematics to computing and engineering students, and some different approaches to encourage their engagement in these subjects. The 2001 working group consisted mainly of mathematicians teaching this material to computing students. This type of event provides a useful forum to discuss the issues and problems in this topic, and the resulting report is available for other colleagues to make use of. Personally, some of the main benefits from attending this type of event are in identifying new and appropriate textbooks or other resources to use, as well as identifying some useful sources of examples. The issue of computer-based learning packages was discussed, and the chance to discuss directly different experience is valuable in identifying material worth trying. Of course, the LTSN

Maths, Stats & OR Network [12] is another good source for information on such materials, but finding time to embed such materials into your own teaching is still a real problem for many staff.

Conclusions

Having experience of both Mathematics and Computer Science, I find teaching mathematics within a Computer Science programme challenging yet enjoyable. The role of mathematics in computing is changing, and could prove to be a major block in increasing intake to Computer Science degree programmes. Some universities now run summer schools to provide potential students with the chance to do GCSE level mathematics to enable them to enter certain computing programmes. This may provide an answer, although the long-term success of these students on traditional computing programmes is more debatable.

Personally, I would have expected more innovative use of computer technology in the teaching of Computer Science. However, in practice it seems that often the only difference is that computer departments adopted technologies a little earlier than other departments, but there seems little evidence of innovations in common use. As time and resources allow, this is an area that should expand, and the growing links between the LTSN centres for Mathematics, Statistics and Operational Research, and the centre for Information and Computer Sciences [13] offers many opportunities here. As a closing remark, the 2004 Grand Challenge in Computing Education [14] will include a grouping considering mathematics and formalisms and may identify future directions for these related subjects.

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UMTC The University of Birmingham
1st - 3rd September 2004
Undergraduate Mathematics
Teaching Conference

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The thirtieth Undergraduate Mathematics Teaching Conference (UMTC) will be held from 1st to 3rd September 2004 at the University of Birmingham. UMTC is a working conference which provides an annual opportunity for lecturers to meet colleagues from different universities to exchange ideas, experiences and anecdotes about the teaching of mathematics at undergraduate level.

The conference includes plenary sessions - the invited speakers this year are Joe Kyle, University of Birmingham, and Neil Challis, Sheffield Hallam University - and presentations by delegates. However (for those unfamiliar with UMTC) the main focus of the conference is the small working groups, which aim to produce a report on a brief concerning a current issue relating to learning and teaching in undergraduate mathematics for publication in the conference proceedings.

Briefs for UMTC 2004 are as follows:

1. Undergraduate project practice - organisation and assessment;
2. Teaching mathematics in an interactive classroom, to be led by Michael McCabe;
3. Teaching statistics to non-specialists: principles, practice and politics, to be led by Neville Hunt;
4. Action research into effective student support in mathematics;
5. Subject based CPD - how to make it successful in mathematics;
6. Customisation of student profile project material for mathematics, to be led by consultants from Employability Works;
7. Goal orientation in mathematics education of computer scientists and engineers, to be led by Alexander Khait.

There is an exciting and varied collection of briefs for deliberation at this year's conference; brief 1 links in with the Maths, Stats & OR Network Project *Use of Projects in Mathematics*. Michael McCabe, University of Portsmouth, will be demonstrating a Mobile Interactive Classroom Kit (MICK); delegates will have an opportunity to try out the technology as part of brief 2. Brief 6 aims to customise, for mathematics, the generic employability skills template, designed as part of the LTSN Generic Centre *Profiles of Student Employability Project*. Alexander Khait from Jerusalem College of Engineering makes his first visit to the conference to lead brief 7. Full briefs are available on the web site <http://www.umtc.ac.uk/umtc2004>.

Fees for UMTC 2004 are £275, including two nights accommodation, or £200 excluding accommodation, with a reduction of £25 if you book before July 18th 2004. Electronic registration forms and further conference details are available on the web site. If you have any queries or suggestions for this year's conference please contact chair@umtc.ac.uk.