A response to the problems of teaching a highly technical subject to students without A-level Maths or Science

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Abstract

Brunel University offers a BSc in Industrial Design with a high technology content. Crucially we teach the Mechanics, Electrics and Materials in the same language as would be used to teach engineers. Ideally this course has recruited students who had A-level Maths as well as a good portfolio of Art and Design work, together with additional Science or D&T A-levels. It will be no secret that students of this background are an endangered species.

In order not to abandon the technological approach, the following long term strategy has been devised:

1) *An accelerated introduction to selected elements of the Maths Curriculum by carefully chosen tutors with a small targeted group of students.*

2) *The use of the Computer Aided Learning in Mathematics project to back up these lectures.*

3) *The development of Mechanics and Electrics CAL materials based on a unique combination of the constructivist approach to science pioneered by Driver and Osborne presented in a HyperCard environment.*

In late 1991, the CNAA published a survey of the CNAA validated industrial and product design courses in the UK1. A key recommendation of the report was that all students on degree and HND courses in industrial design should have a thorough grounding in core technological content. The review identified four different course types: Low Tech, Mini Tech, Mid Tech and High Tech[1]. University courses, such as ours, were not included in the survey, and in the terms used by the CNAA our BSc in Industrial Design would be classed as Very High Tech; we expect proficiency in the three engineering subject areas, and we teach these subjects in the language of engineering. Since we also demand similar standards of competence in the creative/aesthetic aspects of design, our subject entry profile is quite restricted.

For a number of years we have recruited students primarily on the basis of an A-level in Maths together with a good portfolio of Art or Design work, backed up by Science, Design and Technology or Art A-levels. Not all these students will have studied a physical science beyond GCSE.

Over a period of five years, the number of students applying to the course with the necessary qualifications seemed to be on a straight line trend to Zero in about 1995. We viewed this prospect with some alarm.

We were unwilling, at this stage, to abandon our very high technology approach to Design. It was our well defined market niche, albeit apparently shrinking in size, and we felt that it contributed to our students having particularly good records of employment on graduation.

The problem of Mathematics

We decided that it would be worthwhile to gradually lower the A-level Mathematics hurdle through A/S level, A-level fail and now post GCSE study in mathematics. At the same time we would attempt to devise an accelerated maths course covering just those topics that are necessary for our students. Our long term goal is to recruit numerate students, as demonstrated by a good pass at GCSE, who have not followed some sort of post GCSE Maths course.

For several years we had dealt with a handful of weak students, and this experience suggested that a number of factors were crucial to success:

the background and experience of the lecturer
the choice of syllabus
the mode of delivery.

In 1991 for the first time we recruited a small group of students with no post GCSE mathematics, and attempted to provide them with this accelerated maths course.

The course tutor

Our main Maths course for the A-level entry students is taught by a tutor supplied by the Maths department who has sympathy with the nature of the needs of our department; yet it has been our experience that "real" mathematicians and engineers do not always see problems in the same way, nor do they even use quite the same language. The handful of weak students that we have had for several years have been offered tutorials by the mechanics or electrics lecturers. They have the ability to express problems in a way that is meaningful to Design students, and to know exactly the mathematics that they need. However, they have no up to date knowledge of current Maths syllabuses taught at GCSE in schools.

The solution that was finally adopted included lecturing shared between mechanics and electrics lecturers and an A-level maths teacher from a nearby college of FE with tutorials by the Head of Department. This seems to have been a particularly effective combination.

The syllabus

We decided to include six topics:

- Basic Algebraic manipulation
- Exponents and logarithms
- Differentiation
- Integration
- Simple trigonometry
- Simple complex numbers

With hindsight, each of these topics needs to be carefully considered and rather precisely specified. The traditional teaching of Mathematics includes topics that are important to a full unfolding of a mathematical theme, but which will be of little direct use to practising designers.

To give a specific illustration, the work on integration was going surprisingly well; the students were confident and able to integrate a number of simple functions. This was until we covered integration by parts. This is never easy to understand, even in a more leisurely course, although it is a traditional part of most introductions to integration. It totally confused our students, and set back their grasp of even the more simple integration by several weeks.

The question is "Do industrial designers, even high tech industrial designers, need to be able to integrate by parts". In our view, they do not. The few key results, such as the integral of lnx and e^xsinx could easily be tabulated, and can easily be verified by differentiation. The need for integration by parts in other circumstances is unlikely.

Mode of Delivery

We chose a combination of small informal lectures and tutorials. We have installed the Computer Aided Learning in Maths (CALM) package[2] as a further support, but it arrived too late to benefit this particular group.

Eight students, with no post GCSE Mathematics, were taught for a total of 50 hours spread over about 15 weeks. Seven of the students attended regularly, and six of the students obtained good pass marks on a paper that was considered to be quite a stiff challenge.

Subjectively, success during the course seemed to depend strongly on determination and motivation; the small size of this group and special tuition helped drive the group along. This level of control would not be maintained with larger groups.

With hindsight, the paper needs to be very carefully structured with a group such as this to be sure that the students are given the opportunity to show what they "do know" and to cope with the range of different competencies.

Conclusion

We believe the exercise was a success. The students became surprisingly fluent in a short time, and exceeded our expectations. The single most important lesson to be learned is to exclude unnecessary material. Don't include topics just because they have always been included. Decide what your course really needs; be careful who teaches it and write the exam paper with care.

The problem of background Science

Over several years it has become increasingly clear that many of our students, who do not always have a science A-level, are scientifically illiterate. We are trying to teach electrical engineering to students without a proper understanding of electricity, mechanics to students without a proper understanding of force and materials to students without an accurate concept of atomic theory.

A number of staff at Brunel are qualified teachers and contribute to the Design and Technology with Education courses. In the course of this work we have become very familiar with the work of Driver[4] and Osborne[5] and have had several years experience using the lessons of the constructivist approach with small groups of student teachers, both at primary and secondary levels. This had convinced us that the constructivist model gave an excellent description of the problems facing mature learners who have not reached an adequate understanding of basic science concepts, as well as offering a sharply effective tool for bringing about change.

Unfortunately this method is rather staff intensive, since ideally students should work individually, each according to their own scientific models!
The "HyperCard" environment, pioneered by Apple Computers, seemed to offer the possibility of implementing a CAL package rather different from most of those in use at present. Normally it is possible to get the answer right, albeit based on false scientific models, and progress through the package. The aim of our system would be to explore an individuals underlying scientific models, and where necessary to direct the learner to predict the outcome of certain key experiments and then to contrast the predicted with the actual result.

The work has proceeded in several stages:

1. A small pilot package was prepared on the topic of electricity at a level appropriate to sixteen year olds, and this was tested in schools[3].

2. Experience with this package has led us on to work on a package aimed at the topic of forces aimed at the first year of a university course. Work has been proceeding on this package for about six months and we hope to have a complete unit ready to demonstrate in the not too distant future.

When this stage is complete we shall be looking for funding to implement a complete series of themes.

References

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4 Driver R, Guesne E and Tiberghein A *Childrens ideas in science*. OUP (1985).
5 Osborne R and Freyburg P, *Learning in Science*, Heineman (1989).