

## Abstract

This paper reports on the results of a survey conducted within the Department of Design and Technology, Loughborough University, UK, in response to increasing concern over the quality and effective use of 2D modelling by design undergraduates at all levels. A survey, in the form of a questionnaire supported by ongoing tutorials, was conducted in an attempt to establish the underlying reasons why there was a perceived drop in manual drawing standards. Focusing on the use of manual draughting skills and formal engineering drawing, the survey includes a summary of academic backgrounds, experiences of 2D modelling in secondary education, student perceptions of the use of CAD and the importance of manual drawing skills, and the aspirations of students when embarking on tertiary education. The majority of the student entry for the Industrial Design and Technology programmes for the academic year 2001-2002 took part in the survey, numbering 120 students.

## Introduction

In response to increasing internal censure concerning the quality and effective use of 2D modelling used by undergraduates at all levels, a survey was conducted in an attempt to establish the underlying reasons why a decline in manual drawing standards was evident. Although the quality of drawing was questionable for different aspects of drawing, it was decided that a focus on the use of manual draughting skills and formal engineering drawing was appropriate. This area was selected for three main reasons.

- 1) Students tend to find this the most arduous graphics subject to tackle.
- 2) Students follow a structured course in engineering drawing as part of the first year of the degree programmes, which enabled the monitoring of basic skills and progress.
- 3) The radical changes in engineering drawing practice now defined by the British Standards Institution in BS 8888.

It was decided that the survey should include a summary of academic backgrounds, previous experiences of 2D modelling in secondary education, student perceptions of both the use of CAD and the importance of manual drawing skills, and the aspirations of students when embarking on tertiary education. The majority student entry for the Industrial Design and Technology programmes for the academic year 2001-2002 took part in the survey, numbering 120 students.

There have been many publications on the study and use of 2D modelling in the design and technology field (see Garner, 1989, for example). These publications have highlighted the need to understand the use of such design tools when developing creative ideas, experimenting with form and communicating them to others. A specific and vitally important area of 2D modelling that has received less attention is the more formal discipline of engineering drawing. A reason, perhaps, why this area has received less attention could be attributed to the fact that it may be considered a less creative method of graphic communication in comparison with freehand sketching. However, the importance of engineering drawing in a design process must not be underestimated. It is the primary method of presenting the true geometric shape and technical manufacturing detail, unambiguously. Indeed, engineering drawings, from initial layouts and general arrangements through to final detail drawings, can be used extensively to experiment with scale and fit-up of components. It further enables a more effective planning technique for product assembly, materials specifications and geometric tolerances.

With these criteria in mind, it could be argued that the designer has, in fact, to be more creative whilst using such a modelling tool as it forces the designer to work within specified production and manufacturing constraints without compromising the overall design. It encourages the designer to adopt a concurrent engineering approach by forcing the consideration of production and manufacturing engineering techniques, appropriate materials selection and product costs.

More recently, the emergence of CAD has enabled the generation of repetitively accurate engineering drawings, with the added advantage of providing almost seamless links between 3D graphics generation, photo-realistic renderings and CAM capabilities. The digital format enables compact storage and much more rapid communication than its hardcopy predecessors. There is no doubt that the development of CAD over the last 15 years has revolutionised drawing offices and the way in which designers work graphically. As a consequence of this, further questions regarding the educational requirements and levels of competency in the use of technology without compromising key skills needs to be raised. This paper is aimed at adding to this debate.

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### Design visualisation and modelling

The skill of a designer is multi-faceted, but a fundamental role is that of a communicator, facilitator and catalyst for the generation of ideas and solutions to ill-defined problems.

'The most essential thing that any designer does is to provide, for those who will make the artefact, a description of what the artefact should be like. Usually, little or nothing is left to the discretion of the makers; the designer specifies the artefact's dimensions, materials, finishes and colours. When a client asks a designer for 'a design', that is what they want, the description. The focus of all design activity is that end point.' (Cross, 1990)

The *description* of the design that Cross refers to entails the selection and presentation of the most salient features of the design solution by use of the most appropriate modelling techniques. These can vary from crude sketches to detailed engineering drawings, 3D mock-ups (appearance models) and complex 3D CAD models, through to fully functional prototypes.

In the 2001 DATA lecture, John Smith provided a comprehensive overview of the use of modelling for design development and visualisation (2001) and defines a model as:

'a representation of something that exists, or in the case of design and engineering, something that could be produced. A model has only some of the attributes of what it is representing. Different types of models can represent different attributes and some can demonstrate particular attributes better than others.' (Smith, 2001: 6)

The lecture continues listing a basic and long accepted taxonomy of modelling methods as:

- a) **symbolic models** – using abstract code such as mathematical descriptions
- b) **analogue models** – using symbols and schematic representations
- c) **iconic models** – representing an aspect of physical appearance of a product such as a drawing, or 3D model.

Clearly, engineering drawing fits into the 'Iconic' category, albeit in a much more formal, structured way than could normally be associated with modelling methods. Engineering drawings are a precise method of communicating the technical detail of geometric dimensions, assembly, materials and manufacturing processes to production engineers. The languages of engineering drawing, the symbolic representation of physical characteristics of a component, the

semantics and the instructions these convey have been developed over many years through a system of standardisation.

As mentioned earlier, the emergence of CAD systems has provided assistance in reducing the labour intensive and often time consuming methods of producing engineering drawings. However, the language remains the same. To use CAD to produce engineering drawings still requires the knowledge and basic skills of understanding the standardised language. It could further be argued that the introduction of CAD could initially be more labour intensive as these complex tools have a relatively steep learning curve associated with them. However, it is understood that in the longer term, the advantages of CAD are distinct and valid.

### The importance of standards in engineering drawing

It should be readily accepted that standards have made a major impact upon educational and industrial design practices. Although the origins of standardisation were primarily concerned with ensuring uniformity of goods, today the implications run far wider and include major issues of quality and fitness for purpose. The main aims of standardisation can be summarised as:

- 1) provision of communication among all interested parties
- 2) promotion of economy in human effort, materials and energy in the production and exchange of goods
- 3) protection of consumer interest through adequate and consistent quality of goods and services
- 4) promotion of the quality of life: safety, health and the protection of the environment
- 5) promotion of trade by the removal of barriers caused by differences in national practices (Parker, 1991)

From a design and technology perspective, all these areas are extremely relevant. But, in particular, standards relating to engineering drawing practice require special attention. The standards of drawing practice are double edged, not only are they a standardised means of effective communication but they also have a direct bearing on the quality of the overall design of a product, by facilitating the detailed production planning and accuracy of manufacture.

For many years the adopted standard within British industry centred on BS 308. Apart from specific and specialised areas of design



and manufacture, such as the defence industry (often using a combination of NATO and service standards e.g. British Admiralty Standards), BS 308 provided the core definitive guidelines for the production of engineering drawings. An abridged version of the standard was also made available for schools and colleges in the form of BS PP7308.

### The future of drawing standards

In 2001, the BS 308, covering practices for engineering drawing, was formally withdrawn. In its place has emerged the BS 8888 Engineering drawing practice. In schools and colleges also, PP 888-1 has now replaced the original abridged educational version of BS 308. The aims of this new standard are to provide an internationally recognised, unified technical standard encompassing both BS and ISO documentation. Within the new global economy this is an understandable, though major, undertaking. The changes have been further fuelled by the emergence of CAD applications within industry, and the need to address standards in communication and CAD file format, as well as the graphical visualisation. However, to achieve the global consensus required for the standards to be accepted it will necessitate major changes in working practices.

The following summarized criteria have been listed as the principal changes that have been adopted by BS 8888:

- 1) **BS 8888 is prescriptive.** BS 308 can be presented in a number of different forms. Identification of a requirement is conventionally achieved by the use of the word 'shall', as in 'shall do'. BS 8888 is a specification for the preparation of a technical product document, e.g. product specifications. As a specification BS 8888 consist largely of clauses that are identified as being normative, i.e. prescriptive. The withdrawn BS 308 provided recommendations that acted as guidance. The prescriptive nature of BS 8888 is useful because completeness of specification, elimination of ambiguity and universal application are of importance in today's manufacturing environment. This is an environment in which the demand for highly sophisticated functionality of work pieces at a competitive, commercially viable cost is increasing. Many companies demonstrate an increasing tendency to:
  - pursue legal settlement of dispute;
  - favour the introduction of quality management systems (e.g. BS EN ISO 9000)

- opt for outsourcing or subcontracting in preference to in-house manufacture;
- depend on digitised information transfer and computer aided processes.

- 2) From drawings to technical product specification: BS 8888 now provides a more holistic approach to documenting components for manufacture, irrespective of the medium selected for presentation. (BSI, 2000: 1)

The fundamental point of the new standard is one for the need of strict compliance. Methods of communicating the specification of a product design needs to be explicit and the new BS 8888 will elevate the status of engineering drawings to legally binding documents. The implications of this are, of course, wide ranging but importantly the quality of design and presentation will be forced to improve and there will be an increased responsibility on the designer to get it right. In the past, practising designers adhered, more or less, to the guidance offered by BS 308. This 'guidance' was often interpreted as 'flexibility' in the standard, and used quite openly to generate idiosyncratic or even stylised engineering drawings. The explicit nature of BS 8888 means that this is no longer possible.

### Modelling and engineering drawing in the National Curriculum

The QCA document relating to Key Stages 3 and 4 of the National Curriculum relating to subjects in design and technology considers the use of modelling in terms of effective communication in the following ways.

In Key Stage 3 (& 4)

*'Pupils should be taught to:*

.....

*use graphic techniques and ICT, including computer-aided design (CAD), to explore, develop, model and communicate design proposals...'*

and for Key Stage 4;

*'Pupils should be taught to:*

.....

*design for manufacturing in quantity...'*  
(DfEE and QCA, 1999: 136-139)

Although the use of modelling is specifically stated, the use of *appropriate* modelling is only alluded to. However, the importance of CAD use is stressed frequently within the document.

It should be understood that engineering drawing and the basic fundamental skill of



geometry and geometric/technical drawing is an effective modelling method. And, indeed, provides the necessary foundations in being able to understand the rudiments of CAD work.

#### **The relationship between CAD and manual drawing**

With an increasing reliance on computer aided design systems for the presentation of design solutions, the necessity for design students to acquire manual draughting skills could be questioned. The accelerated development of CAD technology has certainly changed the way designers utilise their drawing skills, however, as with many new technologies the impact could lead to the acceptance of the technology as a panacea for design methods and the misapprehension that basic drawing skills, technical knowledge, and understanding of the formal language of engineering drawing are no longer required in detail.

To argue that this is the case would also mean that other key skills such as mental arithmetic could be considered redundant since the invention of the electronic calculator, or that grammar and spelling are no longer key requirements since word processors, with their sophisticated checking software, have become more ubiquitous.

In addressing the effective teaching of ICT activities, for instance,

'Any learning experience needs to start with a concrete (familiar) experience before moving to the abstract (unfamiliar). As good teachers are aware, new experiences, which are unfamiliar, are based upon what is already familiar. If this principle is forgotten then the learners will find the work too difficult. This is not because it is too demanding, but because of the conceptual jump over the divide between what can be done already and what is to be done now. This principle is often overlooked when using ICT resources because computers may not be considered as abstract.' (Zanker, 2000)

In keeping with what is more likely to be familiar to pupils, namely 2D sketch modelling, it could be concluded that the abstract leap required to facilitate effective design via CAD will necessitate a strong foundation in the key skills associated with engineering drawing by hand. It is important to understand that technology should be used as a tool and an aid to designing, and not a substitute for the key skills required to undertake the act of designing.

#### **The industrial design and technology programme at Loughborough University, UK**

The degree programmes for Industrial Design and Technology BA/BSc Degree course follows a well-established curriculum that has developed over the last 20 years. Year one aims to develop abilities in physical, graphical and mathematical modelling and includes such subject areas as Design Practice, Design Contexts, Materials Science and Processing, Foundation Technology, Ergonomics and Design, and Graphic Modelling. In year two, skills in research, planning, modelling, building and evaluating are encouraged. Short design projects are undertaken alongside the lecture programme and longer-term projects. Subject areas cover: Design Practice, Design Studies, Computing, Materials Selection, Presentation Techniques, Product Analysis, and Sustainable Design. Final-year students undertake client-based projects and a dissertation on an aspect of design. This involves researching appropriate literature, discussing the topic with people in the subject area and gaining first hand experience of the chosen topic. The design projects may be linked to industry, hospitals, social needs or research. Subjects include: Design Practice, Design Project, Product Semantics, Design Research, Dissertation, Management and Marketing, Information Technology, Product Analysis (Systems and Environments), Inclusive Design, Materials, and Computer-Aided Modelling and Manufacture (CMM). (D&T, 2002)

Student entry requirements for the programmes vary depending upon previous industrial experience, academic performance and the content of a design portfolio. Prospective students are expected to attain a 260 point score with a minimum of a 'B' pass in A' Level design and technology or related topic.

All programmes have a common first year, and as part of a 'Design Practice' module, students are expected to undertake a series of seven coursework assignments over the two semesters, aimed at developing graphical communications skills in engineering drawing. This is supported by 25 hours of lectures and tutored drawing practice.

#### **The survey methodology**

The survey was conducted using a combination of questionnaire and tutorial/interview contact. The aims were:

- 1) to identify the experiences of students in the area of formal engineering/technical drawing



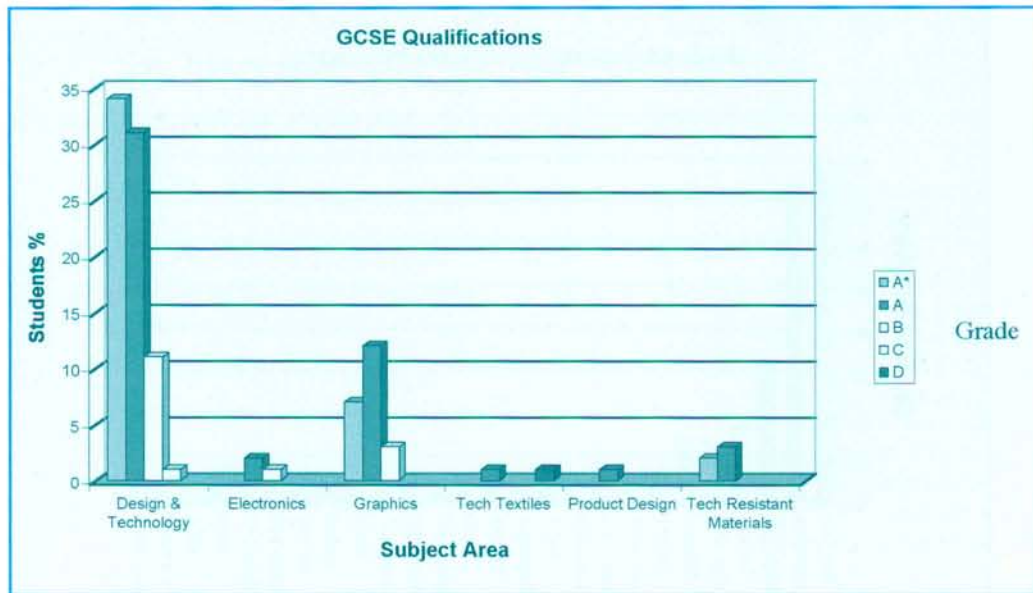


Figure 1: GCSE Design & Technology related qualifications of student intake, 2001 (Loughborough University, Department of Design and Technology).

- 2) to review the students' perceptions of engineering drawing practices
- 3) to identify student aspirations towards engineering drawing methods
- 4) to assess student competency in engineering drawing practice.

Each student, under guidance, completed the questionnaire. Following a review of the completed questionnaires, salient information was collated and a cross-section of the student population was interviewed to validate the answers. All the students were then engaged in the lecture/tutorial sessions in formal engineering drawing practice, and their competency and progress monitored via coursework assessment and tutorials.

### Results

#### *Student academic and industrial experience*

The student intake for the academic year 2001-2002 consisted predominantly of school leavers who had undertaken GCSE, AS and A' Level routes into tertiary education. It is worth noting that this entry were the last year taking A' Level as opposed to the new A2 qualification format. Eight percent of the intake had received vocational training in the form of work placement during a gap year. The work experience varied from interior design such as pub interiors and kitchens to electro-mechanical manufacture and assembly and architectural offices. Only one student had taken vocational qualifications (GVNQ Advanced Engineering and NVQ Electrical

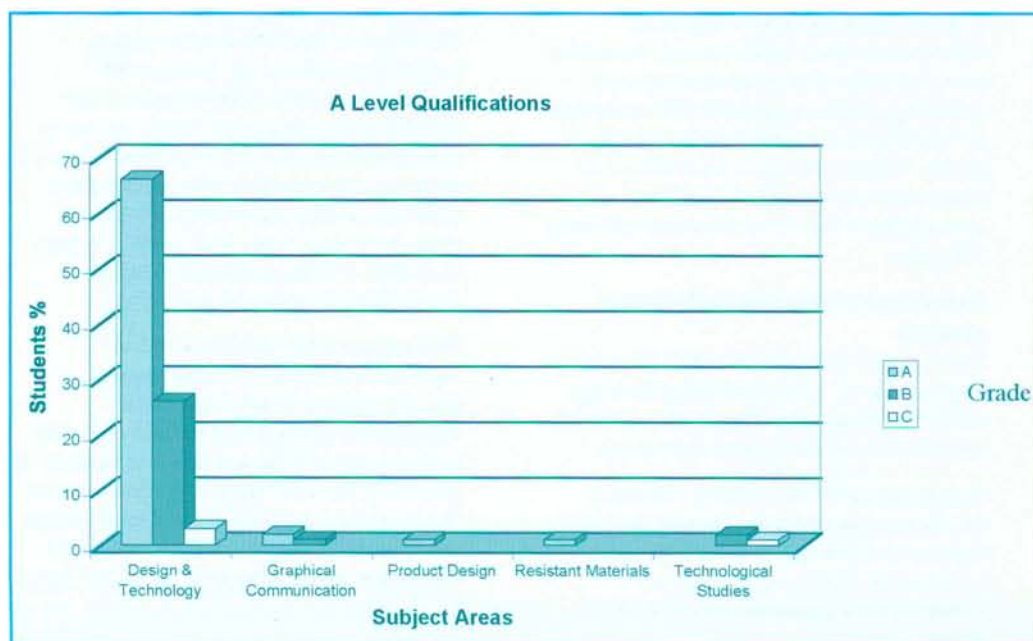
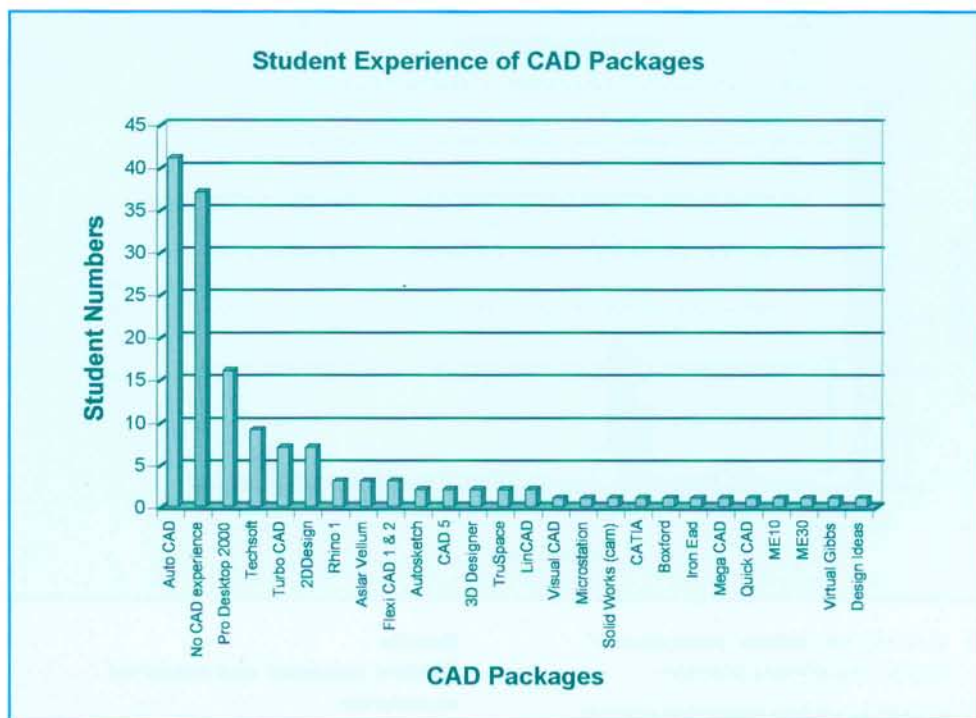


Figure 2: A' Level design and technology related qualifications of student intake, 2001. (Loughborough University, Department of Design and Technology)

Figure 3: Common CAD packages used by students within secondary education for student intake, 2001. (Loughborough University, Department of Design and Technology)



Installation) leading to one completed year of a HND in Mechanical Engineering prior to university entry, and one further student had taken a BTEC General Engineering route into university.

Twenty-six percent of the intake had received work experience either as a short-term summer placement or on a more casual basis, with 23% having design/manufacturing/architectural office experience.

In terms of a purely academic background, 92% had taken the conventional A' Level entry route to university, having had a wide-ranging set of qualifications. Figures 1 and 2 illustrate the design related academic achievement of the student cohort. As can be seen, the majority excelled in design and technology subject areas with 34% achieving A\* at GCSE and a further 30% achieving A grades. Within A' Level almost 70% of the intake received A grades with all but approximately 4% of the remainder achieving a B grade.

#### **Experience of engineering/technical drawing**

The majority of the cohort (84%) claimed to have experience with engineering drawings within secondary education as part of GCSE, AS and A' Level design and technology.

Twenty percent of the students claimed to have had contact with engineering drawings within a professional environment, which corresponds closely to the levels of industrial/work experience of the student intake.

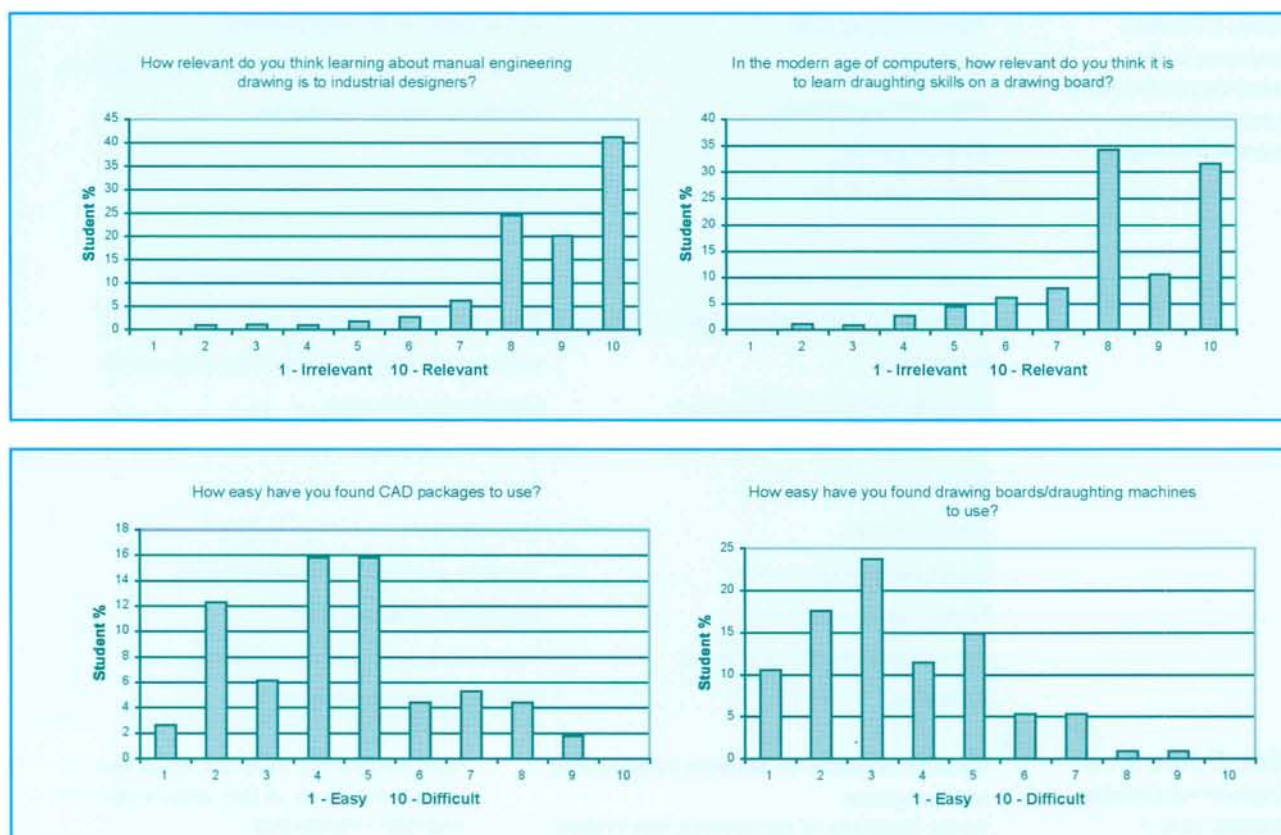
When questioned about the levels of standards they had been taught within secondary education, only 4% had heard of, or were familiar with the concepts of engineering drawing contained in BS 308 or the educational equivalent PP7308. The remaining 96% claimed to have had received no formal tuition in accepted British Standard conventions in engineering drawing practice.

#### **Experience of drawing and design methods**

Seventy percent of those who had been taught engineering or technical drawing within school had commenced their education on drawing boards using manual skills, with 2% claiming that their first introduction to engineering drawing was through the application of CAD. Sixty percent of the cohort had also progressed within school to gain experience with CAD packages. Figure 3 illustrates the common CAD packages that had been used by the students. By far the most common package was AutoCAD, with over 40%, with the nearest rival being Pro/DESKTOP, with just over 15%.

Four percent claimed to have had no experience in the use of either manual drawing skills or CAD. Upon closer examination of this 4%, it became clear that half had taken GCSE and A' Level subjects in art and IT for entry to their university course. However, the remaining 2% had taken design and technology subjects and had achieved high-grade passes at both GCSE and A' Level.





### Perceptions of CAD and manual drawing skills

The student cohort was questioned with regard to their own perceptions of the relevance of adopting a specific method of creating engineering drawings. In general, regardless of previous experience, the majority concurred that learning both CAD and manual drawing skills were a necessary skill for their educational and professional development. The overall results are illustrated in Figure 4.

### Perceived levels of difficulty in drawing methods

The enthusiasm to learn specific methods of engineering drawing practice can often be gauged by a combination of past experience and the level of difficulty perceived in using that method. The students were asked to give an estimate on levels of difficulty in generating engineering drawings by both manual and CAD methods with the results illustrated in Figure 5.

The overall perception of difficulty linked closely with past experience, with most students with CAD experience tending to believe that this was a more straightforward method to adopt. Similarly those without CAD experience tended to perceive manual drawing as a relatively easy skill to master. Whatever their past experience, the majority considered the CAD option as being a priority

skill to pursue, with the main reason cited being future employability and the use of such technology in industry.

### Advantages and disadvantages of specific drawing methods

When asked to discuss the advantages and disadvantages of adopting a specific drawing method, either CAD or manual drawing on a drawing board, the student cohort had equal perceptions of relevance for the industrial design and technology course. A summary of typical answers is given in Table 1.

### Student progression in engineering drawing practice

The taught module for engineering drawing aimed to cover the basic hand skills and familiarisation of current British standards in the subject area. Although BS 8888 was at this point in force, the explicit nature of the new standards were, at that time, considered to be too advanced for use in developing basic drawing skills. Therefore the basic conventions of BS 308 were used.

Table 2 gives an overall summary of the subject content for the engineering drawing module and the assessment criteria of the coursework.

Figure 4: Student perceptions of drawing methods.

Figure 5: Student perceptions of difficulty in specific drawing methods.



Table 1: Student response to the advantages/disadvantages of CAD and manual drawing.

Advantages of CAD	Advantages of Manual Drawing
More accurate.	Helps to understand what CAD is trying to achieve.
Increased repeatability.	Broadens drawing capabilities.
More universal.	Cheaper.
Better quality finish.	More versatile.
Quicker!	Improves hand-eye co-ordination.
Easier to correct mistakes.	Don't have to learn a computer package.
Easier storage and transportation of drawings.	Can express ideas quicker and easier.
Networking.	Hard copy available if technology fails/crashes.
Less possibility of human error.	Can develop own style.
3D modelling links.	Shows more designerly skill.
Rendering links.	The creative sense is not lost.
Animation links.	More control.
Easier parts list generation.	Easier to construct compound shapes.
Widely used in industry.	Quicker to generate ideas.
Mathematical modelling possible.	Easier to visualise the whole drawing.
CAM links.	Non-reliance on technology.

Table 2: Summary of Engineering Drawing module, year 1. (Loughborough University, Department of Design and Technology)

## General remarks on student competency and progress

At the beginning of the course it was evident that most students had a rudimentary understanding of orthographic projection and in particular the generation of third angle views. Over 60% of the students were, however, confused over how such projections

were constructed. Only 2% of the student group were aware of first angle projections and their construction.

The spatial skills of the students, and the ability to visualise 3D objects in 2D and vice versa was generally good when given 3D objects to work from. More difficulty was evident in manipulating images mentally to

Session	Lecture	Practical
1	Introduction to Engineering Drawing and Design	
2	Principles of Orthographic Projection	Using sketching and solid modelling to work through given exercises.
3-5	Drafting Techniques	<b>Assignment 1</b> Line work skills test developing line work skills through given exercises.
6	Project Points and Lines	Developing skills in orthographic projection through given exercises.
7-8	Types of Drawing 1 (Assembly)	<b>Assignment 2</b> Developing line work and projection skills through producing an orthographic view of a chosen product.
9-10	Types of Drawing 2 (Layouts)	<b>Assignment 3</b> Developing line work and projection skills through producing an assembly drawing of a selected mechanical product.
11	Principles of mechanical design	<b>Assignment 4</b> Design of mechanical product to include idea generation, solution development and communication.
12	Types of Drawing 3 (Detail)	Developing detailing skills through given exercises.
13-14	Principles of Dimensioning	<b>Assignment 5</b> Developing line work, projection and dimensioning skills through preparing a detailed drawing of a product component.
15	Limits and Fits	<b>Assignment 6</b> Dimensioning skills through preparing a detailed drawing of a product component.
16	Allocating Dimensions for manufacturability	<b>Assignment 7</b> Preparing a detailed drawing according to the needs interchangeability and cost of fits, interchangeability and manufacture.



construct 2D views when dealing with purely 2D drawings. The cognitive modelling needed to transpose images without physically constructing an object in 3D was an area in which the students required continuing support and guidance. Figure 6 illustrates the general concept of cognitive modelling and the ability to construct 2D drawings via imagining and manipulating 3D images from 2D representations.

Basic manual drawing skills were wide and varied. In some cases difficulty was experienced in providing consistent line quality and accuracy. Over 70% of the students found difficulty in adopting a formal and rigorous approach to their drawing with many assuming that free-hand construction of complex curves was acceptable. Most were unaware of the many draughting tools available, including French curves, templates and stencils or how to use them effectively.

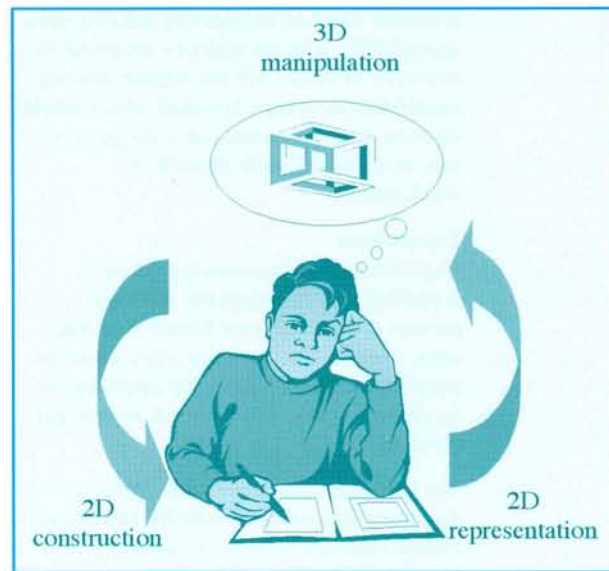
Elements of technical drawing and the understanding of basic geometry were seen to be lacking as a skill by many of the students. Drawing isometric views, cycloids, helices, oblique planes and the construction of basic shapes including ellipses and conics were difficult for the students. Very little experience of the fundamentals of geometrical drawing was evident in students entering the Department.

Student progression overall was good in terms of understanding the more formal concepts of the British Standard conventions. The use of specific symbols, standard layouts, line types and dimensioning conventions were readily understood and used within assignment submissions. However, it was evident that problems in constructing shapes, accurately and of consistent high quality, remained a problem for many students.

The main point of student concern received as feedback from the module was that of the time required to complete assignments. The subject area demands a considerable amount of time and effort, as it is primarily practice-based. The tutorial and lecture time aimed to address the immediate concerns and understanding of the students, but the diligence required to produce high quality drawings is inherently time consuming.

#### Points for discussion

Past experience of engineering drawing and manual drawing skills played an important role in determining the students' competency in drawing practice at tertiary level. It is interesting to note that although approximately 96% of the student intake had taken formal GCSE/A' Level in design and technology subject routes to tertiary



education, general competency in geometric drawing was not high. There is also evidence to suggest that it is possible to achieve high grades in design and technology subjects at both GCSE and A' Level without experience of any formal method of engineering drawing practice either through CAD or manual drawing. Although these cases may be in the minority, the situation raises important issues as to the learning and use of geometric/technical and engineering drawing within secondary education.

The advantages and disadvantages of CAD and manual drawing methods given by the student cohort were very perceptive. The advantages of CAD were seen as providing a distinct link to manufacturing through CAM as well as enabling easier manipulation of images to form specific views. The image manipulation issue could be interpreted as providing an easier solution to what the students found most difficult, cognitive modelling. The ability to imagine and manipulate shape and form 'in the mind's eye' is an important key skill for designers to develop, and one that might diminish due to over reliance on CAD technology. This is certainly an issue for further research.

It is interesting to note that the perceived advantages of manual drawing focussed particularly on the idiosyncratic, for instance enabling a better sense of creativity and freedom of expression. However, the emergence of the new BS 8888 may be responsible for eliminating this in future. The new standard with its strict compliance issues will introduce a further reason to use CAD, thereby increasing the reliance on technology, possibly to the detriment of key manual and cognitive skills.

Figure 6: Cognitive modelling of 2D to 3D and back to a 2D.



Students' views of engineering drawing were encouraging, with the majority accepting the relevance of both CAD and manual drawing capabilities as being a key skill, which would improve their competency as a designer, as well as improving their chances of employment.

## Conclusion

Engineering drawing is a very valuable modelling tool for designers. Although perhaps considered more formal than many other modelling methods, as a discipline for communicating effectively the intentions of the designer to manufacturers, it is vital and indispensable.

The language of engineering drawing, namely the standards associated with the area, is set to change radically in terms of flexibility. The new BS 8888 will, in many ways, de-humanise the production of engineering drawings making CAD based methods a more attractive proposition. The new standards will apply increasing pressure on students to be better rehearsed in the rudiments of the area to satisfy the requirements of future employers. This, of course, produces a further strain on educators to provide the appropriate level of educational output.

Many of the technical issues of CAD and engineering drawing practice can and are being dealt with within tertiary education, however, a basic competency in technical and geometric drawing on entry would provide a better foundation for students and enable them to improve the overall standard of engineering drawing. The survey results provide some evidence to suggest that the desired background and experience in many areas of geometry and technical drawing of first year undergraduates is presently inadequate and provides a severe learning barrier for the improvement of engineering drawing quality at later stages of education.

## Acknowledgements

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