

Materials and processes within A/AS-level Design and Technology: a study of implementation

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Abstract

Planned progression from the National Curriculum, through GCSE and 16+ pathways and onto higher education is an often stated policy objective. This paper seeks to show that 'loose fit' policy statements are an ineffective approach to achieving such an outcome. It is essential to deal with the subject matter of courses at a detailed level. Recent debate has concerned a new model for A/AS-level design and technology. Issues relating to the implementation of the 1986 model have been highlighted in order to demonstrate the need for the development of consensus on areas of detail if the new model is to be effectively implemented. The detailed area chosen is materials processing and selection at A/AS-level. The implementation of the 1986 common core is discussed in order to highlight the reality that crucial decisions were actually taken during implementation and not during the formulation of broad policy statements.

Introduction

Those engaged in defining the nature and content of design and technology A/AS-level syllabuses have never found the task easy. There is extensive evidence of the complexity of the task, e.g.

- the variety of syllabuses available prior to the introduction of the 'common core' syllabuses in 1986 (Norman, 1993, p.43);
- the length of the textbook written to cover the majority of the 'common core' syllabuses (Norman et al, 1990);
- the extensive debate that has been provoked by the recent review of the subject core for A/AS-level design and technology.

It would certainly appear that it is easier to reach consensus concerning other A/AS-level subjects. It was the agreement on the 'common core' in 1986 and its introduction in 1988 that made the potential market size large enough to risk writing and publishing a textbook in 1990. Nevertheless, the completed work was the longest book ever published by Longman Education and was

one and half times the length of the then current A-level chemistry textbook. When the second edition was produced in 1995 a further 100 or so pages were added to cover weaknesses indicated in feedback from teachers. Although a core had been agreed, the interpretation of that core during the process of syllabus construction had led to a very broad spectrum.

The process of implementation of an A/AS-level syllabus involves a large number of people and agencies – teachers, examiners, authors, SCAA, Examination Boards etc. All of these can give their own slant to the agreed core through entirely legitimate interpretations of its meaning. 'Design' and 'technology' used separately and together (as the composite noun 'design and technology') can have a range of meanings. This paper has been written to make a case for the importance of the process of implementation. Whatever general principles are established for progression from National Curriculum technology to GCSE to A/AS-level (or equivalent pathways at 16+) and onto higher education, there will always be discontinuities unless proper attention is paid to the details of implementation. This is illustrated here in relation to materials and processes, but a similar paper could have been written in relation to a number of technologies. In the recent report on the consultation concerning the new draft core SCAA reported 83.1% of respondents agreeing with the question:

Do you consider that the whole A level core (section 3) provides an adequate basis to allow for the progression through A level to HE courses in this or related subjects? (SCAA, 1997)

A basis there may be, but it is the interpretations made during implementation that will largely determine the outcome.

Why materials and processes?

Designing essentially concerns the creation of the material culture. Many people become involved in such creative activity e.g. artists, sculptors, architects, engineers, craftspeople and designers in different areas of the design field. They all engage with technologies and it is through this interaction

that their creativity is expressed and they develop characteristic ways of knowing and thinking which underpin their practice. In considering issues related to design education, Thistlewood writes as follows:

... there is another component of design teaching to be acknowledged – technology, or rather technologies. This is of course fundamentally necessary learning. It directly embraces methods of manufacture and fabrication, from handicraft to mechanical and industrial processes; and it also indirectly deals with technologies that are 'packaged' in product design. For example, audio-visual home entertainment systems, within a given range of performance ... The same is true of all manner of domestic appliances. Because there is often a surprisingly loose fit between contents and container, the latter may be designed independently in education as it often is in professional life. (Thistlewood, 1990, p19)

Design and technology at A/AS-level very much reflects this idea of directly embracing methods of manufacture and fabrication and indirectly embracing packaged technology. It is, however, a slightly simplistic interpretation of the relationship between designing and its associated technologies. It is not only methods of manufacture and fabrication that are directly embraced, it can also be, for example, areas of mechanics – structures or machine theory – where they are directly related to the form of the design. Equally, a structure, machine or mechanism can be packaged technology. The crucial matter is the directness of the relationship between the technology and the product form.

Although it would be possible to examine a number of technologies in order to expose the relationship between designing and the associated technologies, materials and processes are directly linked to the creation of form and, hence, to the designers' primary goal. Artists, craftspeople and engineers also learn and know about materials, and there is also, therefore, the potential for epistemological comparisons, which might reveal significant issues in relation to new focus areas e.g. food and textiles.

Materials and processes in the 1986 common core and the new proposed subject core for design and technology

In 1986 an Inter-Board Working Party was set up to develop a response to a CNAA initiative 'A-Level Design and Technology – The Identification of a Core Syllabus'. This group must have faced great difficulties because of the wide range of design traditions represented by the different A-level syllabuses available at that time. However, a model was agreed which identified two key areas – designing and resources. Materials and processes was a feature of both. For example, designing included two sub-sections on synthesis and making. When describing synthesis 'modelling of design solutions and part-solutions in appropriate media' was stipulated (Design and Technology Inter-Board Working Group). Making was seen as including 'the manufacture of mock-ups, models and prototypes as well as the final artefact or system' (ibid.).

Resources also had two sub-sections – resources for design and technology and constraints on design and technology. Under the 'resources for...' sub-section technological understanding was required of 'materials, processes and components: characteristics, properties, performance, market forms, costs, manipulative and joining techniques' and the 'environment: physical, social, biological, economic, historic' (ibid.). An aesthetic awareness was required of '... texture in natural and made forms' and the development of 'understanding of the relationship that exists between aesthetic and technological factors when designing and showing an ability to interpret with sensitivity' (ibid.). And in the 'constraints on ...' sub-section 'displaying awareness of design and manufacture in industry' and the 'application of technological, scientific, economic, aesthetic and moral values to situations within the designing process' (ibid.). This is just to pick out those elements which have a bearing on materials and processes, but it can be quickly seen that few stones had been left unturned. The syllabuses offered by different boards defined these matters in different ways and to varying extents and thereby gained some of their distinctive characteristics (Norman, 1993).

So what changes in guidance has the 1995 review brought about? The first draft was produced by SCAA in September 1995 and clearly one of the driving forces was the intent to enable smooth progression from National Curriculum technology through A/AS-level and onto higher education and employment. This first draft included the idea of 'focus areas' in order to provide some match to developments in GCSE syllabuses e.g.

specify focus areas in which the range of skills, knowledge and understanding:

- i. is sufficiently broad to ensure that candidates are able to use ideas and technologies across related design areas;
- ii. has enough depth to ensure that candidates understand relevant ideas, facts, concepts, laws and theories and are competent to use their knowledge in a variety of design situations; (SCAA, 1995)

Instead of leaving no stone unturned, the approach now seems to be to use broad, catch-all words and phrases, so that nothing will be excluded. The general lack of specificity is a concern, but perhaps more disturbing is the notion of a 'variety of design situations'. This has echoes of the ideas of progression (later largely discarded) that helped to shape early drafts of National Curriculum technology. The discussion of this issue is developed in later sections of this paper. The draft produced in December 1996 did make a further attempt to define the term focus area:

This term refers to specialist fields within Design and Technology *for example, Systems and Control technology, Resistant Materials Technology, Food Technology, Textiles Technology and Graphic Products*, through which the core requirements can be delivered, and in which the range of skills, (as above) (SCAA, 1996, p.3)

What has specifically been said in the SCAA draft proposals about material and processes? Designing and making have now been separated (no doubt to match the

latest version of National Curriculum technology) and under both headings comments related to materials and processes appear. Under 'designing' students are asked to consider 'maintainability and ease of production' and 'modelling techniques should include graphical, mathematical, computer-based and 3-D methods' (ibid., p.4). When 'making' students should develop and apply knowledge, understanding and skills to:

- (e) select and use materials and components, processes and equipment to produce models, prototypes, products and systems, considering suitability, availability and the scale of production;
- (f) implement a proposal to the point where it can be fully evaluated in relation to the specification (including its function and appearance and within such constraints of cost etc. as may have been identified);
- (g) apply safe principles and safe working practices, including identifying hazards, making risk assessments, deciding how to minimise risks, and using appropriate sources of information. (ibid., p.5)

The difficulties that the artificial split between designing and making are storing up is evident, but it is also apparent that the attempt to use 'generic' language is ultimately going to result in a document which has been perfected in its vagueness. It is inevitable, but nevertheless curious, that having identified the need for focus areas – addressing different technologies – the attempt has still been made to find wording which can embrace them all. For example, attempts are made to define the 'knowledge and understanding which has particular relevance to the focus area including:

- (a) the characteristics of designing and making in the focus area;
- (b) the characteristics and properties of materials and components, equipment and processes;
- (c) the use and application of hand and machine manufacturing methods;

...

(g) applications of IT, including its use as an aid to designing, ... and computer aided design/computer aided manufacture (CAD/CAM) systems

(h) the appropriate use of resources and the environmental implications of technological decisions;

(i) relevant moral, economic, social, cultural and environmental issues; (ibid., p.5)

This seems to cover almost everything already (and is only the requirement for AS level). However, in addition – amongst other requirements – A-level students should:

(c) develop an understanding of current industrial and commercial practice, which includes design and manufacturing processes, production systems, quality assurance and control, stock control, research and development ...' (ibid., p.6)

This is all very well, but does any of it actually indicate a realistic requirement for what should be taught to 16+ students concerning materials and processes? There are vague indications, but the real emphasis seems to be on avoiding leaving anything out, making any decisions and offending any of the parties to the debate. An interesting strategy, but one that actually means that all the key decisions will be taken during implementation, and not, as you might expect, during the process of policy formation. Unless, of course, that is the policy.

The nature of learning and progression in design and technology – a personal view

I was not writing the designing, materials processing and material and process selection chapters of *Advanced design and technology* from a 'neutral' or 'detached' viewpoint, but from a developed theoretical position, which had evolved during my career in design and technology education. The intention of this section is to explain my views concerning the nature of learning and progression in design and technology, which should clarify their influence on my

contribution to the implementation of the 1986 common core. The textbook *Advanced design and technology* begins with a quote from Bronowski.

Man is distinguished from other animals by his imaginative gifts. He makes plans, inventions new discoveries, by putting different talents together; and his discoveries become more subtle and penetrating, as he learns to combine his talents in more complex and intimate ways. (1973, p.20)

This quotation was selected because it elegantly expresses the essential nature of progress. Progression lies in the complexity of the synthesis of a variety of issues in the resolution of a design. Some of those issues might be quantitatively based (e.g. fuel consumption and acceleration of a vehicle) and some might be qualitatively based (e.g. styling and environmental impact). Nevertheless, a designer brings all these issues together and reaches decisions in order to make progress – in much the same way that a purchaser decides which car to buy. The designer is, however, modelling what might be, rather than assessing something that exists. Progression might be seen both in terms of the number of issues being addressed and the disparate nature of those issues. It is not represented by the capability to perform at the same level in a variety of contexts, but rather by the capability to develop design concepts fluently within a process of synthesis of ever-increasing complexity. (For a fuller discussion of these matters see Norman and Roberts, 1992).

It is necessary to recognise designing as a fundamental human capability – essentially holistic in nature. A number of models have been proposed over the years by which it can be 'retrospectively described', but none of these satisfactorily represents the activity. Even splitting 'design and technology' into 'designing' and 'making' is an essentially arbitrary division. It remains a commonly held view that designing is an activity which lies within the field of 'Technical Rationality' – the pursuit of well-defined ends through equally well-defined (and, perhaps, scientifically proven) means. Schön has presented a contrasting viewpoint.

When someone reflects-in-action, he becomes a researcher in the practice context. He is not dependent on the categories of established theory and technique, but constructs a new theory of the unique case. His inquiry is not limited to a deliberation about means which depends on a prior agreement about ends. He does not keep means and ends separate, but defines them interactively as he frames a problematic situation. He does not separate thinking from doing, ratiocinating his way to a decision which he must later convert to action. Because his experimenting is a kind of action, implementation is built into his enquiry. Thus reflection-in-action can proceed, even in situations of uncertainty or uniqueness, because it is not bound by the dichotomies of Technical Rationality. (1983, p.69)

This is much closer to my understanding of design and technological activity – an exploration of the resolution of a design during which ends evolve as means are employed. Developing a product design specification is an on-going process throughout the design activity, not simply something which happens at the beginning. Gathering information can occur at all stages of designing not just at the start. A variety of modelling methods will be attempted – some will be successful, some will not. It is not about thinking then doing, it is about thinking (and learning) by doing.

Implementing the 1986 common core

The Myerson investigation concerning the range of technological content found on product and industrial design courses in UK higher education and was published in 1991. Consequently, it was not available when the textbook was being written, but it nevertheless provides a good reference point. Myerson's study identified four areas of technology being taught relating to materials and processes – workshop practice, materials, processes and manufacturing (p.27). These technologies are being taught for different reasons. Workshop practice is taught so that designers can make models and prototypes of their product concepts. Materials is being taught to expose the range of possible materials and approaches to their selection. Processes are included because these

undergraduates are being taught to design for mass manufacture and not for craft production. Manufacturing systems are being taught to enable issues like design for assembly and disassembly to be addressed. How does this relate to what A/AS-level students are required to know? It can be seen from the earlier section that the 1986 common core was not very specific – syllabus statements turned out to be little more helpful. Recent examples are shown in Figure 1 (a) – (c) for syllabuses covering the broad spectrum of design and technology at A/AS-level.

All these statements derived from the same common core, but because the original document was 'loose-fit', it may not be immediately apparent. Does such a plurality of syllabuses actually matter? In principle, of course, there is a vast number of potential syllabuses that 16+ students could be asked to study. They would all have different strengths and weaknesses, which would make them more or less suitable for different schools, teachers, pupils, environments etc. Such diversity could indeed be argued to be a strength. However, if higher education and employers are going to make effective use of prior learning they have to have some means of knowing what it is that has been learnt. If teachers are to be trained to teach A/AS-level design and technology there has to be a relatively easy way of assimilating the requirements (Examination Boards will, of course, make some provision). Most importantly in this context, if resources are to be developed to aid implementation, an understanding has to be reached of common requirements. It is these kind of issues which have driven people over the last two decades to strive to reach agreement concerning the 16+ design and technology curriculum.

Writing the materials processing and selection chapters for advanced design and technology

Neither the syllabus statements nor the guidance material for teachers supplied by the Examination Boards at the time of writing (~1986/87) was sufficient in order to derive a 'common requirement'. The decisions about what was included and what was not, were actually being taken by examiners as papers were set.

Figure 1(a) Syllabus statements concerning manufacturing processes and the means of production for A-level Design and Technology (Design) (University of Oxford Delegacy of Local Examinations, 1991, p.6)

2. Manufacturing Processes

Candidates should be familiar with a range of tools, systems and manufacturing processes suitable for the materials studied. This knowledge should be related to actual design situations.

Candidates should examine the reasoned selection of manufacturing processes appropriate to a variety of products made from a variety of materials.

First-hand knowledge of production derived from carefully structured industrial visits will be helpful. The use of materials is not restricted simply to industrial processes and candidates should appreciate the contrasts between this use and the use envisaged in craft activities.

The range and nature of the skills in the different types and scales of manufacturing should be understood.

3. Means of Production

- Characteristics of one-off, batch, and volume production; mechanization and automation: reasons for adoption of each and the differences between them.
- Computer-aided design (CAD); computer-aided manufacture (CAM): implications of these on designing, economy and scale of production, quality of product, reliability and employment.
- The influences on the cost of a product: designing, research and development, selection and procurement of materials, manufacturing, distribution and selling and the general economic climate prevailing.

Figure 1(b) Syllabus statements concerning materials processing for A-level Design and Technology (Joint Matriculation Board, 1993, p.606)

2. Materials processing

Candidates should have an understanding of the following processes which, as far as possible, should be acquired by first hand experience of hand and machine methods of working commonly used in school.

- (a) Wastage: hand and machine methods of cutting and abrading.
- (b) Addition; fabrication techniques, to include thermal, mechanical and chemical techniques.
- (c) Redistribution; forming, casting and sintering e.g. cold and hot working of metals, hot (steam) bending and laminating of timber, common methods of thermoforming plastics materials and hand lay-up of GRP.
- (d) Finishing processes to include: applied surface coatings e.g. electrical deposition, plastic coatings, veneering, painting, polishing, glazing and water proofing. Methods of self finishing. Methods of surface decoration.
- (e) Safety: candidates should be aware of the possible hazards found in a workshop environment. Safe procedures and working practices: reference should be made to the DES publication *Safety in Practical Studies* and appropriate BS 4163 recommendations.

Figure 1(c) Syllabus statements concerning the processing of materials, joining processes and decay for A-level Design and Technology (Technology) (University of Cambridge Local Examination Syndicate, 1994, p.46)

5 PROCESSING OF MATERIALS

Practical experience of processes – selection of processes

demonstrate having practical experience, as far as is feasible, of the following processes and be aware of their applications; compare and select suitable processes for the design and production of artifacts:

Processes

fabrication/joining, casting, compression moulding, injection moulding, vacuum forming, blow moulding, cutting, laminating, dip coating, lost wax, etching, reinforcement, machining i.e. milling, turning, drilling, shaping, grinding

Other industrial processes

show awareness of the industrial uses of the above processes along with the following: continuous casting, forming, die forming, drawing, rolling, extruding, sintering

6 JOINING PROCESSES

Metal to metal

soldering, brazing, welding, their limitations, efficiency and reliability

Adhesives

select and use adhesives suitable for application in a school situation for joining the given materials.

show an awareness of the industrial application of adhesives.

show an awareness of their efficiency and reliability in varied working situations.

7 CORROSION AND DECAY

Causes

show an understanding of the reasons for materials degrading and the basic principles of how weather, chemical and biological degrading occurs.

Implications and prevention

consider the economic, social and design implications of corrosion and decay and consider methods of their prevention.

Consequently, the content was derived by cutting up all the available specimen and past papers and arranging the questions in 'ordered piles'. It was possible this way to begin to get a picture of the commonly held understanding of materials and processes at 16+. Examiners are often experienced teachers and, through the papers they set, something of their understanding of practice is revealed. It was also necessary to separate out those areas of materials and processes which were aspects of 'designing' and those which aspects of 'resources' (if the text was to be structured to match the 1986 common core).

Given that some measure of the content had been established from examination practice there still remained the issue of the approach to take. There were two significant influences on my thinking at this time. Firstly, the work of Prof. Wingfield at the Royal College of Art. He had produced a draft version of a text entitled *Essential information for product design* (1979), which was undoubtedly influential concerning the balance of content in the materials processing chapter. The second influence was the following quotation:

Like other skilled behaviour, designing is a 'whole business'. A designer attends simultaneously to many levels of detail as he designs. The level of attention encompasses the range of design considerations from overall concept to small particulars such as materials and dimensions, and as a skilled designer is adept at recognising when concept and particulars clash. A naive designer characteristically allows particulars to intrude or to dominate, to the detriment of the overall design quality. Many of the small particulars of a design actually appear to be dealt with, or 'attended to', by the skilled designer in a subconscious way. They only surface to be dealt with consciously when they become critical. This is typical of all kinds of skilled behaviour; if the small particulars become dominant then the 'organised patterns' of the skill are lost. (Cross, Naughton and Walker, 1986, p.29)

The crucial matter is to present the information in such a way that the overall

design activity is not unduly disturbed – preferably enhanced – taking proper account of the level of skilled design behaviour that can be expected at 16+. It is not necessary to include significant details from the textbook here, but the following extract from the materials processing chapter demonstrates the strategy adopted and the judgements made.

... *A designer's view of manipulating materials*

... Designers will tend to think of extruded sections in aluminium or perspex and rolled sections as alternatives and hence these have been included in the same section. Again, designers will often think about die-casting and injection moulding together and it is not unknown for experimental injection mouldings to be made from the same tools as those used for die-casting metals. For the same reason the lamination of wood and GRP (glass reinforced plastic) and the pressure forming of timbers, plastics and metals are linked together.

Information about manipulating materials could be arranged in the traditional manner according to the material classification ... Such a viewpoint has the virtue of emphasising the differences associated with particular material properties, but fails to generate the kind of overview a modern designer needs ... In the early stages of the design process, it is an overview of what can be achieved which is necessary: a much more specific kind of knowledge is required for detail design. Design students should develop an overview of material processing, and at least know where the specific knowledge they need for detail design can be found.

(Norman *et al.*, 1990, p.181)

This quotation exposes the broad approach which was taken but there are a number of related matters which need to be detailed. Firstly, the separation of issues between designing and resources. Those issues crucial to making cost-effective decisions concerning the manufacturing route during the early stages of design activity were included as 'designing'. In particular, the four key areas identified by Roberts (1975):

the selection of materials and components, the designed shape, the standard of dimensional accuracy and the surface finish. Detailed information was regarded as 'resources' and consequently included in the materials chapters. Secondly, a judgement was made concerning the balance of content, which is most easily explained in relation to the Myerson report. The areas identified as materials, processes and workshop practice were considered to be equally important to 16+ students as to undergraduates. Details in relation to these matters were largely determined by examination practice for A/AS-level, but there was no deliberate imbalance in their treatment. The issues Myerson grouped as 'manufacturing' were not, however, strongly represented in the examinations or syllabuses of the time, which was taken to reflect the reality that A/AS-level students were designing largely for one-off, school-based manufacture and not for mass manufacturing. Planning and costing did appear on the fringes of A/AS-level (and were, therefore, included as 'designing'), but systems issues like design for assembly, just-in-time (JIT) manufacturing, total quality management (TQM) etc. were not being examined. There was no great demand from teachers relating to these issues in the feedback obtained for the second edition (1994), but there is undoubtedly an increasing strength of feeling that they should be given more attention next time. The other key decisions taken concerned a 'visual taxonomy' for manufacturing processes and a 'sequential process' for material and process selection. These reflect the view taken of designing skill at 16+, and hence have been discussed together in the next section.

A view of designing skill at 16+

The inclusion of the overview of the key issues concerning the selection of the manufacturing route in the designing chapter reflected the hope that students would be thinking that far ahead. The author was, however, quite aware, that this could not be taken for granted. Professional designers may well be considering 30 or 40 factors simultaneously (see for example Pugh's plates (Cooke et al, 1984)). In the author's experience A/AS-level students are more likely to be considering 3 or 4 and third year undergraduates 6-10. As

Thistlewood implies form is normally one of them, but it is less easy to say what else is being considered in parallel. It could be ergonomics, styling, performance etc., but it could also be the material and processes. It is unlikely to be areas like design for disassembly at A/AS-level, but it could be. There was a working assumption that A/AS-level students would have seen a large number of demonstrations of manufacturing processes – in school and on industrial visits – and watched video programmes (e.g. the BBC series including forging, sandcasting, die and investment casting, rolling, heat treatment, presswork, manufacturing with plastics, welding techniques etc.) The processes chapter was configured to attempt to provide a structure into which all of this learning could be embedded and which would promote the consideration of the manufacturing route whilst determining form. Consequently, processes were grouped into five areas – four for making (forming, casting, wasting and fabricating) and finishing. There was no attempt to include the traditional sub-divisions e.g. metal processing, wood processing, polymer processing etc. Interestingly, the Open University textbook, which must have been written in parallel, 'Manufacturing with Materials' (Edwards and Endean, 1990) approaches the area in much the same way – using the terms casting, forming, cutting and joining – but, of course, goes into much greater depth. It also includes aspects of the mathematical modelling of processes. The intention of providing such a limited number of categories is to facilitate recall and the cognitive modelling associated with design activity.

The approach would not be as appropriate in a text written for manufacturing engineering students. Information might then be better presented in the traditional way through material classification and then by process – primarily because the information would need to be at a greater level of detail. It is also because a scientific taxonomy, based on material characteristics, and not a design taxonomy, based on form, would better promote the required intellectual activity. Skilled designers will be considering the manufacturing process, material and the form required to meet the design requirements in parallel as part of

the process of synthesis. This requires the development of an 'internalised overview', from which details can be derived at a later stage. Hence, processes were grouped according to a design taxonomy i.e. methods for the creation of similar forms. The detailed technical information has not been altered, but it has been organised in a designerly way.

Having taken an 'optimistic' view of processes – a taxonomy intended to promote parallel processing – a more sequential or 'pessimistic' view was taken of material and process selection. This is illustrated in the following quotation taken from Chapter 6.

There are a number of factors leading to the selection of a material – the most important ones being the cost and properties of the material, the service requirements, the environmental effects, the energy consumption and the design implications. Some of the design implications will, in turn, be related to the manufacturing process, but others will be largely dependent on the properties of the material, for example, mild steel will normally require a surface finish to avoid corrosion whereas this is not necessary with stainless steel ...Ultimately the designer must reach a decision which achieves the service requirements in the most cost-effective manner – cost in this case being taken to include environmental cost.

Selecting the manufacturing process is really a secondary decision and is subject to three additional factors; the market size, the available manufacturing resources and the social implications. It is normally the less significant choice because, although there is no guarantee that any product form can be made in any material, it is probable that means can be found to create most shapes from most materials. ... As with all other aspects of the design process, material and process selection concerns the careful synthesis of potentially conflicting factors, which is ultimately the art of good design.

(Norman *et al*, 1990, pp.266-8)

This essentially sequential view shows the decision I made concerning a realistic approach to materials and process selection at 16+. It is not sensible to expect professional standards of skilled performance at A/AS-level. The decision-making process is not hierarchical when carried out by skilled designers, but there are simply too many issues for novice designers to consider at once. Skilled performance depends on the development of appropriate values, which enable the consideration of such multi-dimensional problems. The design taxonomy of the materials processing chapter is an attempt to facilitate appropriate learning of the required information in order to become an aspect of such multi-dimensional decision-making. The sequential viewpoint associated with material and process selection reflected my position concerning what can realistically be expected at 16+.

A look forward to 1998

A major attraction of choosing materials and processes as the technology for this case study was the potential for epistemological comparisons. Different disciplines have different ways of looking at the same matters. For example, musicians and scientists both look at sound waves, but have very different ways of describing what they 'hear' or 'measure'. Artists and engineers similarly look at materials in very different ways. Artists might be more concerned with colour, texture, reflections, contrasts, translucency and patterns etc. Engineers might be more concerned with surface roughness numbers, refractive index, conductivity, resistivity, tensile strength and the modulus of elasticity. These traditions represent different ways of knowing about materials. Designers straddle these disciplines. If their area of activity is closer to art, then they might be part of the art and design tradition. If their area of activity is closer to engineering, then they might be operating in one of the design areas e.g. industrial design, product design or design and technology. Design epistemology will also need to straddle these areas of human understanding.

What then of the potential introduction of focus areas in textiles and food? Are the knowledge, skills and values associated with the development of food and textile products

related to those relevant to design and technology as embodied in the implementation of the 1986 common core model? Does the concept of a taxonomy of processing techniques based on form have any meaning for these focus areas? This is not to imply any measure of superiority or inferiority for any design focus area, but simply to enquire about similarities. These issues are closely related to the notion of transferable skills in designing. If the view of progression being presented here is accepted, then progression depends on the development of knowledge, skills and values in a focus area, which facilitate the synthesis and resolution of multidimensional design problems. Knowledge, skills and values relevant to resistant materials may well be irrelevant, or even detrimental, to operating effectively in other design areas. It is interesting that this has been recognised to the extent of identifying the need for focus areas, but then apparently ignored by the inclusion of the requirement for students to operate within a variety of design areas. What model of progression does this represent?

If the debate were to remain at the superficial level of regarding 'food' and 'textiles' as just 'other materials', then the chances are that none of the significant issues would have been resolved in the initial policy statements concerning the review of 16+. The crucial decisions would be taken during implementation. Teachers would be making 'informed guesses' concerning what is required, and their decisions would be confirmed or not as examination practice emerges. Those developing new syllabuses and examinations must ensure that adequate detailed information is provided to ensure the quality of the education offered to future generations.

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