Assessment of Performance Unit, Department of Education and Science/National Centre for School Technology, Trent Polytechnic

Assessing Performance in Design and Technology*

The article which follows is based upon a report prepared by a special working group of the Assessment of Performance Unit of the DES which was asked to identify those aspects of an understanding of both design and technology most likely to be reflected in primary and secondary schools; to consider when and where abilities in design and technology appear in the school curriculum and to suggest how these aspects of pupils' development might be assessed.

This document, which was submitted to the Unit by the group, aims to share the findings of the group with all concerned with primary and secondary education and seeks, in return, the widest possible range of comments which should be sent to Mr. G. Hicks, HMI, Assessment of Performance Unit, Elizabeth House, York Road, London, SE1 7PH by 31 March 1982.

Abilities in Design and Technology

Before considering how pupils' performance in the area of design and technology might be assessed, one must first identify abilities that pupils might reasonably be expected to be able to demonstrate. Examples are shown in the table which covers the general area of 'designing, implementing and evaluating' but to put this into a manageable framework for assessment it is necessary to go further.

The dominant feature of activity in the area of design and technology is the bringing together of skills, experience, knowledge, understanding, imagination and judgement, whatever their limitations, in the execution of a specific task. In practice, it involves the integration of a complex of activities which are specific – because they relate to a particular need; inventive – because they call for a creative response; effective – because the end result should reflect a better fit of match between need and provision than existed formerly; and evaluative because the designer is called upon, throughout the process, to exercise value judgements of many kinds when arriving at the proposed solution. Evaluating the efficacy of the final solution against the original need is perhaps the most demanding task of all.

This complex of activities can be broken down for assessment purposes, if it is considered as a summation of skills, knowledge and values. Any ability selected for assessment should therefore combine one or more of the ranges of skills which are set out as part 1 of the framework for assessment, with one or more of the areas of knowledge forming part 2 of the framework and one or more of the sets of values forming part 3.

* Acknowledgements are made to the Department of Education and Science for permission to reproduce these extracts from a recent discussion document issued by the Assessment of Performance Unit.

DESIGNING, PLANNING AND IMPLEMENTATION

1. DESIGNING

1.1 FIT

1.1.1 Can a child *perceive* (describe, discuss or otherwise communicate) or *identify* through investigation a fit or misfit between an artifact or system and set of human requirements (desires, needs)?

1.1.2 Can a child *judge the quality* of the fit or misfit ('How well does it work?) and express this judgement?

1.1.3 Can a child *recognise* that something might be done to improve, rectify or change an artefact, *or* if there is a good fit, to leave things as they are?

1.1.4 Can a child *identify criteria* which are relevant to improving the quality of fit?

1.2 HOLISM

1.2.1 Can a child *analyse* a misfit ('Design problem') in such a way that he *takes into account* such factors and considerations as:–

i. Economic (cost, time, availability of materials).
ii. Social (awareness of others and of the effect of the designed artifact/system upon them).
iii. Ethical (morality of proposed change).

1.2.2 Can a child mould all the aspects of a design problem in a balanced, *interactive* way?

1.2.3 Can a child *fit* ends to means as well as means to ends?

1.3 FORMULATIONS

1.3.1 Can a child *state or restate* the design problem? (In order to arrive at its essence).

1.3.2 Can a child look at a particular solution and *work backwards* to reformulate the original problem?

1.3.3 Can a child *generate a variety* of possible provisions (solutions) to a design problem?

1.4 CONVERGENCY

1.4.1 Can a child *decrease* the variety of possible solutions and show commitment to a specific, practical proposal?

1.4.2 Can a child *explain and justify* the reason for his choice of one in preference to others?

1.5 DATA SEARCH

1.5.1 Can a child *recognise* the need for the collection of information which is appropriate to the problem?

1.5.2 Can a child *search* for, generate, collate and judge the reliability and usefulness of information?

1.5.3 Can a child *apply* the relevant information, which he has obtained, to aid the solution of the problem?

1.6 IMAGING OR COGNITIVE MODELLING

1.6.1 Can the child *conjure up* a description of an artefact, system (or parts of such things) in the mind's eye?

1.6.2 Can he *manipulate* the images? (Rotate, assemble, change colour or texture, cause interpenetration or change form.)

1.6.3 Can the child *express* these images? (Sketch, model, etc.)

1.7 DESIGN MODELLING

1.7.1 Can a child *demonstrate the purpose* of modelling? (Iconic, symbolic, analogue).

a. to simplify (by reduction to essentials)
b. to show correspondence (e.g. by analogy)
c. to give emphasis (e.g. to salient features)
d. to extrapolate (e.g. trends)
e. to stimulate (e.g. lighting change).

1.7.2 Can a child *detect the limit of usefulness* of a form of modelling? (e.g. when scaling down invalidates a model).

1.7.3 Can a child *translate* one form of model or simulation to another form or to reality? (e.g. circuit diagram to assembled components).

2. PLANNING, IMPLEMENTATION AND EVALUATION

2.1 PLANNING

2.1.1 Can a child *cost the production* of an artefact or system? (In terms of use of material resources, time, energy, social effects).

2.1.2 Can a child *distinguish* between the difference of producing a single artefact or manufacturing for bulk production?

2.1.3 Can a child *plan a sequence* of operations in an appropriate order which will lead to the production of an artefact or system?

2.2 IMPLEMENTATION

2.2.1 Can a child *demonstrate* that he is alert to the possibility that an *unforeseen difficulty* may arise during making which may indicate an *alternative* means of realisation or production?

2.2.2 Can a child *deal effectively* with such difficulties by acquiring new strategies, information or skills?

2.2.3 Can a child *execute a task* with due regard to the need for *safe* practice?

2.2.4 Can a child *choose* and *use* appropriate tools, materials and appliances to achieve his purpose?

2.3 EVALUATION

2.3.1 Can a child *evaluate* and offer a continuing *critique* on the *process* and *progress* of his design?

2.3.2 Can a child *re-evaluate* at the conclusion of realisation (after a suitable interval of time) the quality of the *match between design and need?*

2.3.3 Can a child *analyse* and evaluate the approach and solution adopted by *other* designers?

Framework for Assessment

In interpreting this framework it should be remembered that both the acquisition of an understanding of design and technology by a child, and the detection of that understanding. In a child are contingent on the child's engagement in purposeful and comprehensive activity. In order to assess performance, therefore, it is necessary to examine activities. It is not yet clear whether it is possible to carry out an adequate assessment of the understanding of design and technology on the basis of conventional assessment procedures or, indeed on the basis of the examination of records of project work. This requires further investigation.

Part 1: Skills

The skills that are used in design and technology activity are distinctive and can be grouped into four categories:

INVESTIGATION; INVENTION:
IMPLEMENTATION: EVALUATION

These tend to overlap and to follow one another cyclically and repeatedly. Taken together, they constitute the process of recognising a need and matching available means with desired ends.

Taking each one separately, the skills of INVESTIGATION include the ability to recognise the existence of a problem which might be amenable to solution through design and technological activity; the ability to perceive, or identify through investigation, how far a given thing or system meets the stated need; the ability to look for information and resources and generate information through observation or experiment and to judge how relevant, sufficient and reliable are the information and resources obtained; and the ability to employ a balance of knowledge, analytical skills and judgement in reaching conclusions in the face of ill-defined problems.

The second category, the skills of INVENTION, includes the ability to initiate and develop ideas and images of proposed things or systems, and to manipulate, rotate and transform those images: the ability to think of alternative configurations for a desired thing or system and to adapt, transform and select from these to meet given needs; the ability to express these images in various ways, such as sketching, drawing, diagram making, constructing, or through the use of notation or language, and thus to communicate information about them to others; and finally the ability to examine the integrity and coherence of a product or system, how well it matches its requirements and how well the requirements themselves are appropriately defined.

In the third category, the skills of IMPLEMENTATION include the ability to plan a practical activity and to see it through; the ability to select from available resources the most appropriate means for gaining the desired effects; the ability to use tools, instruments, materials, components, appliances and appropriate energy resources; and the ability to monitor and measure the effects of operations and to control their outcome.

In the final category, the skills of EVALUATION include the ability to discern the context within which the designed product or system is to be considered, and to identify the related criteria by which it should be judged; the ability to choose the measures appropriate to given criteria and to devise practical or logical tests to determine the performance of a given product or system in relation to them; the ability to form judgements about the balance or merit of a given thing or system in respect to given criteria; the ability to distinguish between needs of different sorts and to assign different degrees of importance or priority to given needs in different circumstances; and the ability to appraise the efficacy of a given design activity.

Children of pre-secondary school age show evidence of these skills – to a greater or lesser degree – whilst engaged in activities which a teacher might not instantly recognise as being technological. They can be described as such when they rely upon technological concepts as decribed in the 'knowledge' component of the framework which follows.

Part 2: Knowledge

The essence of design activities is that they seek to resolve specific practical problems throughout the integrated use of a wide range of knowledge and experience. The designer does not need to know all about everything so much as to know what to find out, what form the knowledge should take, and what depth of knowledge is required for a particular purpose. It is more important, for design purposes, to know how a system works, or might work, and how different disciplines relate to each other in practice, than it is to have detailed knowledge of a single discipline in isolation. Also, for design purposes, knowledge needs to be in a form that can be applied to the creation of a device or a system which works.

In one sense, every sort of design activity is built upon a related form of knowledge, specific to the type of problem involved – in other words, upon its relevant technology. Most people, however, would recognise that some design activities are more technological than others, in the sense that they rely more upon information about the nature and behaviour of materials and processes, particularly of the more resistant materials and the more power-using processes. Whilst much of this report is applicable to other areas of design-related activity in schools, the emphasis is on this more explicitly technological activity, as can be seen from the detailed analysis of the knowledge component of the framework proposed here.

Designers are continually called upon to make decisions which require information from other disciplines. The form in which this information is needed means that the questions may differ in kind from questions which would arise from a study of those disciplines themselves. For example, although scientific information may be needed when designing, the form in which it is needed requires the generation of new concepts – i.e. technological concepts.

The essence of an understanding of design and technology lies in three groups of technological concepts:

CONTROL; ENERGY; MATERIALS

To exercise CONTROL over the man made environment, it is necessary to know how systems, static or dynamic, can be created for a specific purpose. As ENERGY in some form must be involved, knowledge is required of sources, costs and forms of energy; of methods for storing and transmitting energy; and of efficiency and the conversion of energy. Similarly, as design involves the selection and use of appropriate MATERIALS, knowledge is also required of their sources and costs; of their useful properties and limitations; and of the appropriate methods by which they may be processed, manipulated and connected.

The application of the skills listed in Part 1 (investigation, invention, implementation and evaluation) can be called technological when those concepts are involved. Involvement in the activities helps in the acquisition of the concepts, while possession of the concepts helps with involvement in the activities.

Children in school can be observed applying technological concepts at a variety of levels, particularly when working empirically towards design solutions. It is not necessary, therefore, for these concepts to be CONSCIOUSLY possessed by pupils before they can be used.

For instance, 10 year-olds may begin to acquire the concepts of energy, energy transfer, power and power matching. They can experiment with energy by storing it in raised weights and in stretched or twisted elastic, then devise ways to use this stored energy to project a missile, propel a vehicle, make a noise, or make something go round. Later they can work out how to use the stored energy to meet more precise requirements such as maximum range, highest speed, longest duration of travel, etc. At a later stage they may begin to quantify the energy; to measure, estimate and record; to anticipate and even determine what will happen. The design decisions will become more definitie, more mathematical. At about this time the pupils may develop an understanding of the nature of energy in its different forms, mechanical, electrical, thermal, etc, and by analogy may begin to relate these concepts across the different energy fields.

In this example, knowledge is not derived from any single curriculum area. It illustrates how a technological solution to a problem arising in one part of the school curriculum will almost certainly need to draw on knowledge and design skills acquired elsewhere, and may also require specialist facilities from other subject areas for its successful implementation. When undertaking assessment, therefore, it is important to distinguish the technological PURPOSE, which might be provided by any individual school subject, from the technological KNOWLEDGE and SKILL of the pupil and the overall opportunity offered by the school for technological IMPLEMENTATION OF DESIGN.

Part 3: Values

Participation in activities relating to design and technology can rarely be entirely free from the exercise of value judgement. The questions always arise: What are the 'right' ends to be striven towards in this case? Which would be the 'better' approach? What should be a 'good' result? Sometimes the answers to such questions will be expressed in terms of technical efficiency or economic cost. Sometimes they will be concerned with ethics, aesthetics or social responsibility. A child needs to be able to recognise the different values underlying different problems and to apply appropriate reasoning to those values. The framework therefore identifies four areas within which values might be assessed, namely:

TECHNICAL; ECONOMIC; AESTHETIC; MORAL

In design and technological activity these usually overlap and are seldom considered in isolation, as a decision made in any one necessarily affects the others. The problem is compounded if the design activity is centred on the needs of a particular individual, for in such cases the individual's own scale of values is also relevant.

Looking at each separately, TECHNICAL values involve an appreciation and application of the following concepts: efficiency, and the ways in which input is compared with the resultant output; robustness; flexibility and the ways in which the performance of a man-made object or system might be sensitive to change; precision, and the qualities of fit and of fitness to purpose, valued either for their own sakes or as a means to an end; confidence, and the ways in which the possible reliability or unreliability of information is taken into account.

ECONOMIC values involve an appreciation and application of the following concepts: the broad distinction between the ideas of use-value, intrinsic value and value-in-exchange; the distinction between value, price and cost; the marginal value of one product or product variation over another; the effects of variation in supply and demand on availability and price.

The pursuit of AESTHETIC values involves an awareness of the structures proportion and colours to be found in the natural and the man-made world; of the importance of aesthetic factors in all forms of human communication and self-expression; of the inter-relationship between workmanship, tools and the aesthetic quality of the resulting environment or artefact.

Finally, MORAL values involve an awareness of mankind's impact on the natural environment and his responsibility for its and his own future survival; of the inter-relationship between the man-made world and religious, social, economic and political philosophies; of the needs of individuals in society and ways of meeting them; of the importance of ethical values in carrying out design activity and evaluating the effects of technology.

As stated earlier, it is when the three components of this framework come together in one activity that it can be termed 'technological'. However, whereas all types of design activity share the three components it is when the knowledge component is analysed in detail that the activity assumes a greater or lesser technological significance.

The survey

Those with design ability in the area of technology will play an increasingly important role during the years ahead and the successful development of this ability within schools may make a vital contribution to the nation's future well-being.

The development of an understanding of design and technology is, as was noted earlier in this document, both subject-based and cross-curricular. It does not stem from a single area of the school curriculum, but from several. Thus it may not be as easy for schools to assess pupil's performance in this field as in mathematics or foreign language.

Further investigation will be necessary before the Unit can judge the desirability of development assessment materials for this important area. As a first step, the DES has commissioned a survey to determine how, when and where the abilities listed in this document appear in the average school curriculum. The survey team is expected to report by the end of 1982.

The survey to be undertaken by the National Centre for School Technology* at Trent Polytechnic under the direction of Professor G. Harrison will be approached on the following bases:

a) that technology is, itself, an integrator of disciplines in that it brings together human resources of knowledge and skill in support of creative and inventive activities, engaged in for the purpose of improving the human condition. Disciplines which have the potential to contribute to this integrating vision of technology are found throughout the school curriculum.

b) that engagement by pupils in schools, in this integrating activity of technology, often takes place without the word 'technology' being used or implied and that it is the *activity* which needs to be discerned rather than the title 'Technology'.

c) that, frequently, school pupils' engagement in technology involves only part, or parts of the activities of technology rather than a total battery of competencies.

d) that technology, being an iterative and re-iterative process, can involve all its competencies, to some extent at least, in small scale examples of technology. However, for full coverage, complete technological problem solving projects are necessary, requiring problem identification and specification, investigation and invention, and implementation and evaluation.

These four points mean it is sometimes difficult to locate, in objective terms, just when technological competencies are being demonstrated. They also raise difficult questions about fragmentation and integration and whether a series of dislocated fragments of 'technological competencies' can justifiably be arbitrarily grouped together and called 'technology'.

It is the experience of staff of NCST, however, that, provided the criteria for recognising, identifying and observing technological behaviour are adequately stated, and stated in such a way that they can be adjusted and interpreted to meet any case in question, it is possible validly to identify such examples in many parts of the school curriculum. The extent to which such examples explicitly relate to each other and thus constitute parts of a coherent whole should be illustrated by the outcome of the survey.

* We are grateful to the National Centre for School Technology for permission to reprint excerpts from their survey programme.

In addition to the somewhat covert, or subconscious, forms of technological behaviour in schools, there are many instances of deliberate, structured (and even self-conscious) approaches to providing a curriculum which is technologically) comprehensive. This happens when individual teachers or groups of teachers, with the support of head teachers and LEA advisers, have developed taaching schemes, employed some of the new examination syllabuses, developed links with industry and the world outside school, or taken other steps to break from a traditional curriculum specified in purely academic terms.

Any survey of Design and Technology activities in schools should be so structured that these factors are taken into account. Concentration on either the generalist or on the structured approach would produce a seriously distorted picture of reality.

Two parts to the Survey

It is therefore recommended that the survey of 'Design and Technological Activities' in the School Curriculum will be designed in two parts, with different methods of sampling, different criteria for observation, and different procedures for enquiry. These two parts will, separately, identify and analyse the 'covert' (subconscious) or generalist approach to Technology (Survey A) and the deliberately structured manifestations of design and technological activities (Survey B).

The Surveys

Survey A:

Method

a) Postal questionnaires will be addressed to representative samples of schools taking pupils in the range of age groups spanning 9-16 years. The questionnaires will be based upon the APU Technology Working Group framework as set out in the Annexe to the APU brief and its parent document 'Competencies in Design and Technological Understanding'. The content and style of the questionnaire will be determined by the Centre but the National Federation for Educational Research will advise on technical matters such as layout and coding of responses.

b) Visits will be arranged to a sub-sample of schools to verify questionnaire responses and to extend that information by gathering case-study details.

Sampling

The sample composition will be NFER's responsibility. Appropriate populations of schools will be defined for England and Wales. In the case of secondary schools, the population for the survey will include all schools with pupils in the 13+ age group except for schools taking only particular types of handicapped pupils. The APU will be consulted about the desirability of including schools which have contributed to recent surveys of performance in Mathematics, Science and Language. The population will be stratified i) by regions (in England), ii) by maintained/independent status, iii) by with/without 6th form provisions iv) by size. A 10% sample (Secondary Sample (1)) of this population will be identified using random selection within strata. Thus the designed sample will be representative of all secondary schools and the survey results generalisable to the population with standard error of approximately 5%. A limited number of reserve schools will be identified as replacements for schools unable or unwilling to take part. This sample of secondary schools will amount to approximately 450 schools.

A 10% sub-sample of participating schools will be identified for visits by specially briefed teachers, advisers or college lecturers drawn from the network of development groups known to the Centre. The tasks to be undertaken by those visitors will be defined by the Centre; NFER's responsibility will be the production of an unbiased sub-sample.

Samples of schools will also be needed to provide curricular information pertaining to pupils in the lower secondary/middle school age-group, i.e. 12+ in September (Lower Secondary Sample (2)) and the upper/primary middle deemed primary age-groups i.e. 10+ in September (Primary Schools sample (3)). The NFER register of schools and stratification data will be used to provide these two further representative samples of 450 schools. Adjustments will be made to ensure adequate coverage of differently based middle schools and to avoid duplication of schools. These will be asked for questionnaire data only.

Survey B:

Method

This survey will produce information about the competencies and activities to be found in schools where a clear commitment to the development of technological competencies has been established. The population will be specified from information available to the Centre and other bodies, such as the external examining boards, Schools Council, SATRO's and HMI. It is estimated to include approximately 1,000 secondary schools. Each of these will be asked to complete a short questionnaire so that different types of involvement with school technology can be identified (see para 2.3). The curricula of a small sample of each group of 'typical schools' will be the object of this enquiry. It is thought that a sample of 50 schools will be adequate. Information will be gathered by visitors briefed specially for their role.

Sampling

NFER will advise on the population definition and will subsequently identify the sample of schools to be approached. It should be noted that the inclusion of a school in the Survey B sample will no not lead to its exclusion from Survey A; to do so will introduce undue bias into Survey A.

It is envisaged that the duration of the surveys will be from 1st January 1982 to 31st December 1982.