Matching students' technological thinking with the demands of a technology curriculum

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MATCHING STUDENTS' TECHNOLOGICAL THINKING WITH THE DEMANDS OF A TECHNOLOGICAL CURRICULUM

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Introduction

Whereas a lot of studies using Piagetian type frame-wprk which attempt to match the learning demands of the curriculum to the cognitive development of the pupils, have been done in many areas of the curriculum such as Mathematics [1], [2], Geography [3], English [4], History [5], [6], [7], [8], and traditional science subjects [9], [10], Technology subject remains an area of the curriculum into which similar studies are lacking and urgently needed. [11]

The urgency is not just because of the importance which has been attached to technology subjects in recent times, and the strong desire by teachers who teach them to want to know more about the processes involved with learning and understanding within the subject given its new conception, but also because of the apparent difficulty that majority of pupils who study these subjects have with learning some aspects of them in schools.

Thus, as an attampt to respond to this urgent need, this paper attempts to relate the psychological characteristics of the pupils to the demands of a technological curriculum. This it does by (a) estblishing a typical thinking skill (and level) in technology subject, (b) assessing the level of demands made on the pupils by technological activity. Whereas step (a) above will involve describing pupils' actual thinking as they are engaged in solving technological problems, step (b) will involve analysing the teaching, and curriculum materials. Both of these steps are important, because the notion of 'matching' presupposes that teaching and pupils' conceptual level have to be integrated well.

Describing Pupils' Technological Thinking

Strictly speaking, the fact that pupils' technological thinking is to be described, presupposes, that they have to actually do some technological tasks, and be observed. The opportunity will have to be created where the pupils will have to fall back to their own thinking when they meet a problem in technology. Thus, thinking which pupils use when they are solving technological problems, cannot be determined in advance, but only when they are actually engaged in technological activity. This is an important point, because in describing the phenomenon of technological thinking, it is inadequate to present a general picture of it in the same fashion as Piaget [12] did when he used formal operation to describe the logical processes which human beings use when they solve problem of every day life, eg., scientific, technological, historical. Although Piaget's description of scientific thinking refers to the kind of general framework that human beings may use, and describes it quite well, it does not do so to a finished conclusion.

As applied to technology, this means that for a 'good' description of technological thinking, it is necessary to get very close to the phenomenon. In effect, technological tasks or task will have to be designed and/or assembled, administered to the pupils, and a description of how they proceed to solving them be made. But initially, it is essential to examine briefly the concept of technology, so as to have a clue as to what technological thinking may involve.

Technology

Elsewhere [13], the difficulty in defining technology has been highlighted. Despite the complex and problematic nature of technology, it is apparent that 'knowledge' is implied when viewed from epistemological, anthropological, and sociological stand points. This 'knowledge' can be related to other forms of human knowledge especially, science. When it is so related, technology becomes practical activity, a way of acting or action, which involves some beliefs. This practical activity can range from skills derived from concrete experience [14], to a more general knowledge of how to cope with our environment [15]. Moreover, this knowledge appears to have a huge tacit component, which suggests, that much of it is inaccessible to formal academic study, but can be transmitted by personal contact. Here, the creative element of technology begins to surface. What seems to emerge from the above conception is, that both human activity and methodological procedure are involved in technology.

Schools have approached this concept of technology in such a way as to bring out its goal-directed and process nature; ie., design process and problem-solving characteristics. Most of these approaches adopted incorporate psychological description of the activities involved, for instance, identifying, and stating problems, analysing them etc., through to evaluation [16]. These approaches with their psychological description of the activities involved, are based on what the different people think are essential components or processes in schools' technology work. They may not correspond to how pupils or adults for that matter, actually think when they are solving technological problems. Attempts will be made to provide the evidence here shortly, after technological tasks/tests have been administered, and the results therefrom, analysed.

Test Instruments

The information above has been used to assemble tests/tasks, which will assist in ascertaining pupils' technological thinking. Furthermore, these tasks are based on known activities typical of technologists, eg, designing, manipulating systems or objects, dimensions etc. A summary description of the tasks/tests administered, is as presented below. Their detail description have been undertaken elsewhere [13].

Tests/Tasks		Activities Involved/Brief Description
(1) Design:	D1.0	[Understanding design concepts]: Pupils required to distinguish between objects which have been designed and those which have not been designed.
	D1.1	[Understanding design concepts]: Pupils make judgement as to whether an object designed is 'good' or

or 'bad' design. (seeing fits and misfits)

D1.3 [Problem-solving]: Designing instrument which will take a camera to a specific height above the school for an aerial photography.

(2) Manipulation: M-SR [Mental manipulation of shapes]: Rotating 2-dimensional figures; Visualization of 3-dimensional solids.

F/T [Fault Tracing]; On a sealed electronics box, is mounted a series of electrical components, eg. bulbs and bulb-holders; a number of terminals interconnected inside the box. The pupils are required to determine the internal connection of the components, by the use of test lamp.

A-C [Abstract-Concrete]: Emphasizes both aspects of creative thinking (convergent and divergent). 16 blocks of wood with about 4 or more different characteristics, are to be arranged in (a) 4 groups of 4, then (b) 2 groups of 8, both with and without the grouping criteria given.

(3) Science Thinking Sc.T [Piaget's Pendulum task]; Pupils required to sort out the effects of variables, eg. weight, length, and push of a pendulum.

Responses to some of the tasks (D1.1, D1.3), have been categorised in terms of their complexity. The scoring of the tests has been either right or wrong.

Subjects

The subjects (boys and girls) are from a comprehensive school in Sheffield, renowned for its high 'standards' and success rate. With its upper and lower schools 1½ miles apart, the school is mixed ability in intake, and the pupils who participate are between the ages of 12 and 16 years old, and of average intelligence.

All the staff involved with teaching these pupils in the CDT-department of the school, are qualified and/or experienced in technology subjects teaching. The pupils working in CDT-department, follow the Midland Examining Group (MEG) technology syllabuses. The aspects of technology, namely, CDT- technology, design and communications, design and realisation, are taught proper in the fourth and fifth years. Ten pupils (boys and girls) for each year group, making a total of fifty pupils, willing and interested in do ing the tests, have been randomly chosen to participate in the exercise.

Procedure

Free class periods provided the most favourable time for the exercise, and technology or science room (depending on which one is available), has been used. Ten subjects representing each year groups 1 to 5, will take the tests at a time. Each group will receive initial instruction on the tests and their purpose. The participants will be allowed to ask questions where they are not sure about what is required of them. Some of the tasks eg., fault tracing, will require a two pupils to sit opposite each other, to discuss how to solve the problem. A video camera (not hidden), will record all discussions and activities during the test sessions. Test completion time will not be limited, except for the A-C performance task. This will allow for sufficient thinking to be done by the pupils.

Analyses And Results

Analysis: Mindful of the purpose of this paper, which is to elicit the nature of technological thinking, the analyses to be done on the results of the tests, will include, psychometric, simple developmental, and qualitative. The results will also be correlated, one with another, and subsequently, factor analysed. Elementary linkage analysis [17], will be used here in view of the smallness of the sample size.

Results: The total[T] and mean [X] scores for each year group, are as presented in tables 1 to 5. These scores have been correlated one with another. [see table 6] Although the values of the coefficients are small, nevertheless, they are significant. It will be noticed, that thinking in terms of functions [S5], does not appear to relate to any of the other dimensions. Further analysis using Elementary Linkage Analysis to determine the underlying factors, [see table 7], namely, function/structure (bipolar), general intelligence, perceptual (visual analysis. Their definition and description, are as presented below.

(A) Function/Structure [Factor-I]

Pupils' responses to design tasks which require them to judge whether an artefact designed is a 'bad' or 'good' design, have been in terms of 'functions' and 'structure'. Some typical examples of pupil's responses to artefact (a coffee table) which has been designed and asked whether it is a 'bad' or 'good' design, are as presented below:

Yr.1-- "Good, it is some where to sit and drink. [Functional]
Yr.2-- "Good, because you can put things on it. It is square. [Functional/Structural]
Yr.3--"Good, because you would not have to put everything on the floor. It is strong and could hold heavy weight. [Functional/Structural]
Yr.4-- "Good, it is good so that you can put things on. [Functional]
Yr.5-- "Good, it is good so that you can put your coffee or tea on the table instead of on the floor. Strong and serves its purpose." [Functional/Structural]

The teachers tend to respond more in terms of 'structure' than 'function' of the coffee table. The apparent bipolarity of functional [S5] and structural [S6, S7], is superficial. A close examination of the nature of pupils' 'functional' and 'structural' responses to tests/tasks administered, reveals no such opposition, because, in technology we do certainly think in terms of functions.

However, pupils' responses have been in terms of what they can do with artefacts or objects given, more or less, in a concrete operational kind of way. So that functional response, can be interpreted as a concrete kind of response. This is ofcourse not a response that can throw out the whole functional responses. It is an immediate concrete operational response. By implication, 'structure', is perhaps an understanding of 'function' in a more comprehensive way.

(B) General Intelligence [Factor-2]

If the first identified factor is regarded as 'cognitive style', then the second factor can be regarded as 'cognitive' factor. Indeed, by examining the elements composing this factor, it is not difficult to conclude, that much of what is involved, is very much the traditional definition of intelligence, ie.,perceiving relationships between elements in a general sort of way.

(C) Perceptual [Visual] Analysis [Factor-3]

Again, the components of this factor, are principally visual, and include the ability to discriminate, differentiate, and coordinate, for example, dimensions.

Technological Thinking [An Empirical Definition]

The conclusion which can be drawn from the analysis above in relation to the definition of technological thinking is, that what is termed 'technoloical thinking' here, and judging from the tests/tasks results, seem to have three components, namely, 'function/structure', 'general intelligence', and 'perceptual (visual) analysis'.

It cannot therefore be said, that technological thinking is largely accounted for by scientific thinking, because, the first identified factor is not defined by Piaget's science thinking test. [12]

The importance of the above identified factors in schools' technology work, has been established through their significant correlation with pupils' technology examination scores. It is clear from the correlation matrix table-6, that pupils' examination scores [Sum-18] correlate significantly with an element in factor-1 [Sum-7], ·47 $p < \cdot 03$; an element in factor-2 [Sum-16] ·53 $p < \cdot 02$; and an element in factor-3 [Sum-10], ·81 $p < \cdot 00$.

Developmental Analyses

Having identified and described the factors of technological thinking, the question of how they change with increasing age emerged almost immediately, and has been tackled by carrying out a simple developmental analysis. This is done by plotting graphs of mean (grand) scores against the different year groups for each of the identified factors as shown [see table 8, and figures 1,2,3]

It is clear from the graphs presented, that pupils appear to think first in 'functional' terms, and then they go on towards 'structural' terms. The idea of pupils thinking 'functionally', is linked with the notion of the development of the intellect through doing things. That is, one develops intellectually by actually performing action upon objects.

Analysis of the Curriculum

The thrust of technology syllabus followed ie., Midland Examining Group [18] by the pupils, as well as the activities in which they are expected to engage, center around building or making some thing that works. For instance, in Electronics syllabus, the pupils are expected to build circuits using different techniques. Also in Mechanisms and Structures syllabuses, the pupils are expected to build a working models and devices using resistant materials and kits. It is apparent, that the activity of building or making things work etc., will involve the manipulation of dimensions, (sizes, shapes, colours, solidity, etc.) as in CDT- Design and Realisation, CDT- Design and Communications, or component parts, (transistors, capacitors, etc.) as in CDT-Technology (Electronics).

This manipulation is in terms of isolating, juxtaposing, categorising, and combining. The abilities needed to do these tasks will include perceptual discrimination, categorisation or setting up classificatory concepts. These abilities can be elicited by using a combination of Piaget's [12] protocol and Bloom's taxonomy in the manner shown below to subject the objectives of each of the syllabuses menttioned above, to further analysis.

Bloom's Categories	Piagetian Categories	Level
	Pre-Operational	1
Knowledge	Early Concrete	2
Comprehension	Middle Concrete	2
Analysis	Late Concrete	3
Application	Early Formal	4
Synthesis) Evaluation)	Late Formal	5

Assuming, that the way in which technology syllabus objectives have been written, is exactly how they are going to be taught, each of these objectives is first categorised according to whether it demands for instance, Knowledge, and the associated Piagetian category is ascribed to it. Thus, a particular topic is thought to make demands typical of any one of Piaget's categories, depending on which Bloom's [19] category is associated with it.

However, by meticulously studying the topics containded in technology syllabus, and their objectives, and at the same time examining the pupils' class work with respect to these topics [13], it is possible to arrive at a comprehensive analysis of the demands made by the curriculum.

In problems requiring the pupils to build circuits on spring circuit boards [see figure 4], it is interesting to note the series of instructions which follow. Simply by following these instructions carefully, pupils can succeed in building the circuit and testing it as well. Another problem within the syllabus topic of transistors as switches and as amplifiers, requires the pupils to design a case and control for a rain alarm. Analysis of how it has been approached from instances of pupils' own work, some of which have been presented here, reveals that they simply have to follow instructions as outlined in order to succeed. In Structures and Mechanisms syllabuses, where the pupils are essentially requried to build working models and devices using resistant materials and kits, the problems presented to pupils, can be successfull executed simply by their adhering to the teacher's instructions.

This being the case, the curriculum cannot be matched with any thing to the level of thinking of the pupils. The result from the above analysis clearly shows that for a significant part of technology curriculum which is concerned with building and making things work etc., the pupils can succeed by just relying on their teachers telling them what to do, and/ or remembing the instructions given. It cannot therefore be said that technology curriculum makes any demand functions, because, it appears as though pupils are required to follow instructions blindly if they are to succeed.

Summary and Concluding Remarks

Although our knowledge of the thinking processes used by the pupils in schools' technology work is still growing, we are in a position to say, that technological thinking involves dimensions such as function/structure, general intelligence, and perceptual (visual) anslysis. These have been defined in the preceeding sections.

Developmental analyses show that in technology, pupils' technological thinking tend to proceed from 'function' towards 'structure'. However, the analysis of technology curriculum reveals that for a significant part of the curriculum, the pupils can succeed by just relying upon what their teachers tell them to do, ie., by remembering or following instructions slavishly. This being the case, the curriculum cannot be matched with any thing to the pupils' thinking level.

One of the implications from the above results is that technology curriculum developers, will have to build on 'functional' rather than 'structural' responses. Furthermore, due to the importance of the skills identified here in schools' technology work, if teachers want to develop pupil technologists, then they ought to be developing these skills.

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