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TURNING SYSTEMS INTO ARTIFACTS (PROGRESSION USING ELECTRONICS IN DESIGN AND TECHNOLOGY?)

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Abstract

The various phases of a project involving electronics are reviewed. It is suggested that, even when the design is being "translated" into a printed circuit to create an artifact, it is essential to maintain a "systems" viewpoint. Two recent approaches, designed to aid in this process, are described and evaluated.

Progression and Continuity

The progress of electronic design

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AT1          AT2          AT3          AT4
Explores    Specify system  Test system  Appraise

Sub-system
Select sub-systems  Integrate

Components
Select components  Build sub-systems

Layout
Design pcb
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A project in electronic engineering can usually be described diagrammatically in phases which broadly correspond to the attainment targets of Design and Technology.¹

Just as in other aspects of technology, the designers' knowledge of components and systems will influence their early investigations; but the picture, with all its crudity, is not a bad approximation.

In essence the movement is a progression to finer and finer levels of detail (each level represented by different forms of documentation and diagrams), followed by successively broader levels of integration and testing.

In the author's view, key stage 4 pupils involved in Design and Technology are best served if we enable them to approach projects by employing this type of framework when they need to use electronics. Their detailed appreciation of devices and concepts will clearly be limited, but that does not mean that we should impose a different process on them.

However, if descending through a series of levels of detail is appropriate at key stage 4, in a project occupying "twenty-four to thirty-six hours", it is probably unrealistic at key stage 2, in projects of shorter duration.
Approximate number of sub-systems/components

A possible model for progression is shown in the above figure. In essence this proposes that for the average pupil, at key stage 1, their experience of electronics should largely be with complete systems (such as electronic toys, "turtles", etc.), at key stages 2 and 3 pupils should use in the main electronic systems kits (such as Electronic Sentences, Microelectronics for All, System Alpha, the E & L Systems Kit, etc.) with both a broadening of the range of electronic processing that they encounter and a widening of the range of contexts in which they deploy electronics.

At key stage 4 it is suggested that it is appropriate for most pupils to extend this experience to include work with components. I would not want to argue that under no circumstances could components be encountered at key stage 3 but merely that the predominant emphasis should be on a systems approach (as is indeed required by the statutory orders for Science in the National Curriculum).

Work with components does not involve abandoning a systems viewpoint. That would represent a failure to capitalise on experience at key stages 2 and 3 and would run counter to good practice as it has been developed both within industry and education.

The purpose of this paper is to present an educational case for such a pattern of progression and to suggest ways in which this could be supported.

When is an Artifact a System?

Having sat through many interminable discussions on the matter, I am grateful that the Working Party did not give us their own "definition" of Design and Technology but instead sought to identify the general characteristics and activities that they consider would be associated with Design and Technological work.

But there is an aspect of the report in which some degree of definition is needed. In Section 2.24 (v) the Working Party state "the additional extended project for GCSE should not involve the same type of making activity as the major project of the core (ie if an artifact is designed and made as the extended project in the core programme, the extended project for GCSE must have as its main outcome a system or an environment);". The Concise Oxford Dictionary defines an artifact as "a product of human art and workmanship...". In other words an artifact is the outcome of some "type of making activity" which necessarily encompasses all project work in Design and Technology. The Concise Oxford Dictionary further defines a system as "complex whole, set of connected things or parts, organised body of material or immaterial things...".
Necessarily, therefore, any Design and Technological activity that involves electronics (and indeed many other aspects of Technology) will necessarily be a system and an artifact. The categories are not mutually exclusive and the point needs some clarification.

It may be that the intention is to distinguish between making activities where there is little or no "craft" work (perhaps involving merely connecting together construction kits, electronic systems kits, etc.), as distinct from an activity where a range of fabrication and joining skills involving resistant materials, design and production of printed circuit boards, soldering, etc. are involved. Hopefully, this is a point which the non-statutory notes for guidance will clarify.

**In Praise of Pizza and Pipe Racks**

There are a number of reasons why it is valuable for pupils to progress to work with components. One is related to some of the benefits associated with traditional Design and Technological activity - the ability to take home something which the pupil has made and which he or she can use themselves, give or sell to others and take a pride in. In addition, of course, this activity vastly reinforces the significance of appraisal and evaluation. By their very nature electronics systems kits cannot be incorporated in an artifact which can be taken home and used.

**Beyond the Electronic Prototype**

Systems kits have a number of substantial benefits. They allow a wide range of alternative solutions to be quickly explored; they encourage a clear and systematic identification of inputs, process and outputs (which is the key to systems thinking in electronics and many other aspects of technology) and they allow relatively trouble-free work by pupils.

The conventional way of proceeding from a systems kit prototype to a dedicated circuit (produced on strip board or printed circuit board) is first of all to identify a suitable circuit for each of the sub-systems. It is essential to ensure that each of the sub-systems is compatible in terms of its current and voltage requirements for the signal input and output. The total circuit is then redrafted as a printed circuit, showing the copper connections. The essential reason for the need for total redrafting is that the copper connections must never cross each other, whereas the connections on the circuit diagram suffer from no such restriction. This process of transfer from a circuit diagram to a printed circuit is a skilled process and, for circuits of even modest complexity, can be a difficult one. In industry, of course, the process is usually carried out by engineers working with computer-aided design workstations costing upwards of £50,000.

In attempting to allow pupils to "translate" from their systems kit prototype to a printed circuit board a "modular printed circuit board system" was developed by Alan Giles, as part of a project called Microtechnology Resources 7. In essence the principle is that for each sub-system there is a corresponding transfer. The transfers can be rubbed on to copper-clad board, joined together and then etched and the circuit so formed carries out an identical function to the original system.

The approach is successful in so far as it does remove the difficulty of "translating" from the circuit to the printed circuit by pupils.

There are two particular issues which were not fully appreciated when the original modular pcb system was developed. The first is due to the fact that a typical systems kit involves a total of about thirty or forty different types of sub-system. If we had sought to produce a different rub-down transfer for each possible sub-system then a large number of transfers would have been required. The course that was adopted was to develop multi-function transfers which could (depending upon the components used) provide different functions, depending upon the components used and their position on the printed circuit. Unfortunately, this had two unforeseen consequences. The first was the wide range of components that, in consequence, schools needed to stock; the second was
sometimes pupils would place the wrong components in the wrong holes.

The second problem was a consequence of unrealistic optimism. In the notes to pupils we suggested that they simply produced their printed circuit board, insert the components, solder them in place and all would be well. Mainly in consequence of the number of options described above, problems can and do occur. However, a teacher involved in providing inservice (Jim Cunningham) hit on a much better approach. If each of the sub-systems is made individually (in the order in which the signal flows through the system) and is tested before the next sub-system is built then any fault can be quickly isolated and rectified.

Clearly the ideal solution would be computer-based (as is in industry) and recently a program called QuickTrack has been developed to allow such an approach. The development is the consequence of bringing together what were originally two separate developments. Joe Telford published an easy to use, conventional printed circuit board design program in Acorn User\(^8\). This was subsequently enhanced by John Ashurst, with support from Manchester LEA. At about the same time Andy Tubbs and Colin Rainford (Advisory Teachers for Hampshire LEA) were exploring the use of pre-designed sub-systems using ‘Diagram’ software. Following a conference organised by the National Council for Educational Technology (NCET) it was agreed to bring these two developments together and NCET funded this development. ‘QuickTrack’, now with the facility to place pre-designed sub-systems on the screen, is currently being trialled by some 63 schools and institutions and will be available from NCET when published\(^9\).
There are a number of substantial advantages to a computer-based approach. Firstly, there is no need for the school to have a stock of transfers (since all of the pre-designed sub-systems come with the software) and therefore there is no need to produce multi-function sub-systems; each sub-system can correspond precisely to a sub-system in the systems kit. The second advantage is that since QuickTrack is still a printed circuit board design program, it is possible to edit sub-system (perhaps to accommodate components with slightly different dimensions) or indeed to develop new sub-systems if none are available within the pre-designed files provided.

The supporting documentation has now taken into account the need to build one sub-system at a time and includes explicit fault-finding information in case any problems are encountered.

A Preliminary Evaluation

In an extensive postal questionnaire survey of the modular pcb system\textsuperscript{10}, Maro Hadjisophocleous found that out of nine respondents reporting on the original modular pcb system, five encountered some difficulties — identifying the correct components, inserting components in the right hole, recognising the mirror image of the copper side and being unable to test the units.

QuickTrack has only just been distributed to trials schools and institutions. However, Martin Coleman and myself have conducted a short course for teachers and used it as part of the course. We did find one or two minor problems but the teachers found the software easy to use.

One problem that emerged is a consequence of the restrictions of the BBC computer's filing system. File names are limited to ten characters and this meant that abbreviated names had to be used for some of the sub-systems. Occasionally teachers were unsure as to the correct names of corresponding sub-systems. All the sub-systems that were built by teachers worked and 23 of the 28 teachers requested copies of the software.

Conclusions

There is strong evidence for asserting that the ability to transfer from a systems kit prototype to a dedicated circuit is an important and worthwhile aspect of work with electronics in Design and Technology. The conventional path of "manual translation" from a circuit diagram to a printed circuit board is obsolete because of Information Technology. Pre-designed modules can help this process for pupils who are not particularly experienced.

Probably the most important insight is to remember that the "artifact" ie the complete printed circuit board with component mounted etc. is still a "system" ie. it is still important to identify the sub-systems and to be able to test them separately!

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