
'Systems' in Design Technology

A Paper contributed to the Loughborough Summer School 1989

WHAT ARE 'SYSTEMS'?

Pupils are used to listening to and engaging in discussion on a variety of topics associated with systems — whether they realise it or not. Either they actually use the word 'systems' or the topics are closely associated with it. A *system is a collection of parts or entities which are joined, or in some way interconnected, to form a complex whole.* The term system can be a way of considering solar, weather, communication, transportation, health care, banking, heating, lighting, air traffic control, brewing, musical notation and economic systems. This is obviously by no means a definitive list but does serve to illustrate that the topic is vast and that there are some systems that are of devised by people and some that are not. It also indicates that there is no one subject interest in the curriculum has a monopoly of any aspect of technology but that CDT teachers have a major role to play in pupils understanding and using the concept of 'systems'.

Various classifications are possible. There are mechanical systems, for example engines and generators; there are biological systems — plants, human beings and other animals; there are social systems — factories, political parties, families. Where a mechanical and biological system combine, as when a person drives a car or pilots an airplane, these may be known as human-machine systems. Then there are natural systems which can work away on their own without human intervention, for example, forest systems, weather systems and river systems. Some of these natural systems which relate particularly to our environment and form a basis of our food and support systems, are called ecological systems, or ecosystems for short.

There are common features of all systems although these are not always obvious, especially when considering non-technological systems. For example system 'boundaries' are decided which isolate parts of a complex system and focus on that part to the (possibly temporary) exclusion of other parts. The

smaller the boundaries the clearer the issues become. Deciding on the boundary means making quite explicit the range of considerations to be taken into account in any analysis.

Each sub-system reacts with other sub-systems, thus the health system of a nation cannot be dissociated from the nation's economy and the transistor may be seen to influence the working of a larger amplifying circuit, the amplifier itself being part of a larger control system.

During the course of their everyday lives, people make use of systems around them. For example, in the case of organising and managing personal finances there exist a number of systems, some of very specific and particular use, others with functions that are broader and serve more numerous purposes. In common with many systems, the example given below, is the result of human ingenuity. It is developed to serve human goals, and in this example, also to satisfy a human convenience.

A bank service till or 'cash dispenser' is a system. It comprises a number of functions, for example, to identify correctly from a code number typed onto its keypad, the account and credit worthiness of a particular customer. When cash is withdrawn, it must count and deliver the notes without error and retain against the possibility of attempted theft, a sizeable reserve of cash in a safe, secure structure behind the wall of the bank.

It would be possible to examine a cash dispenser in minute detail, studying in turn the mechanical system that issues the notes, the different effects of pressing the buttons at different times in the cash withdrawal sequence, the IT system that recognises the account-holder and so on.

Equally, it would be possible to consider larger monetary systems. For example, whenever cash is dispensed, there must be a record of this transaction on the customer's account. On this account however, there may well exist many other functions including, for instance, the overdraft credit-worthiness, standing

orders for direct-payment of bills and means of adding salary payments.

Above the system that exists for a single account, there are systems for managing all the accounts in the branch of the bank. These must include credits and debits from wherever in the country they occur and means of clearing cheques. At a more general level again, there may be a regional or national structure that enables credit transfer in pursuit of business, transactions that earn interest and the payment of this down to individual accounts.

Yet again, inter.nationally, monetary flows can be managed, with exchanges between the currencies of different nations and allowance for the day-by-day exchange rates. Each of the additional, different functions, contributes to an overall system that is reasonably described as a hierarchy.

The 'international flows', are at one level, a complex and diverse system within which many 'sub-systems' exist. Beneath these there occur another whole series of sub-systems, each with increasingly particular purpose, interrelated to the higher level, and to a level beneath itself...down to the level of the specific, cash dispenser in the wall of the local branch.

Therefore, dealing with systems enables pupils to recognise in the services, machines and devices around them, a set of structural relationships that will serve them well when they come to design systems of their own.

SYSTEMS IN DESIGN AND TECHNOLOGY

In the area of Design and Technology the word takes on a more explicit meaning and is often considered as a 'systems approach to solving problems'. Certainly it is a strategy that can be very helpful at certain stages of designing. *A system approach is a strategy for understanding complex situations, and for arriving at solutions to problems which these complex situations reveal.*

The approach is essentially a way of breaking down complexity into a number of manageable parts, making clear their inter-relationships and revealing inadequacies in the system which may be leading to unsatisfactory overall behaviour. Using such an approach involves two distinct activities, analysis and then design or intervention. The results of the analysis are used to help with the design and creation of an improved system, or part of a system, with the intention of obtaining a closer match to what is needed (or wanted).

Schools use the system approach, both analysis as well as intervention, in many aspects of their management. Examples might include:

- The timetable;
- The arrangements for delivering and collection pupils to and from school;
- Movement around the school and in particular places like the canteen;
- Indicating the menu for the day; The collection and return of library books, including their classification on the shelves;
- setting up, selling and all relevant money controls for a tuck shop;
- Designing, making and selling items to raise money for school funds;
- Marketing strategies for a school function;
- Long and short term storage for items like books, materials and equipment.

CONTROL SYSTEMS

A study of such a list as above leads to the conclusion that human intention is an integral part of many systems and that 'control' is a factor implicit, and often explicit, in all such systems. If a system is a result of human intention, then it can be controlled to some extent, but possibly not completely. In recent years there has been more and more interference with ecosystems to meet the growing needs for food, water and commodities but unfortunately the nature, context and extent of the systems has not always been appreciated. The results, or outputs, have sometimes been disastrous and totally unexpected; it is possible, that unless we quickly understand the nature of ecosystems and take some preventive

action, we shall starve or pollute ourselves out of existence.

'Black box' techniques may be used whereby the internal workings of that part of the system are ignored and the emphasis is upon the inputs, the outputs and their inter-relationships. The main concern is aimed at understanding how that part of the system behaves. This approach releases us to concentrate our efforts on describing, and understanding, the relationships of this sub-system to an overall, larger system and then intervening, often incorporating other 'black-boxes' to achieve desired aims.

SOME TERMINOLOGY

Some of the other terms used in a systems approach are self-evident. For example 'input' and 'output'. As previously described there are often unintended inputs and outputs to any system, noise and other pollution for example.

Most familiar control activities involve people — driving a car, writing, playing a game. In this case the person involved is considered to be part of the system and they decided on the goal to be achieved. If, in the process of achieving this goal, it is not possible to make any corrections on the way to the goal, this is considered as 'open loop' control. Thus a golfer driving a ball hopes to direct the ball within acceptable limits but has no control over the path of the ball once it has left the club head. Trying to guide a car by setting a steering wheel and a pattern of subsequent changes of direction, at the beginning of a journey, and making no alterations on the way would be open loop control — and obviously unsatisfactory! In 'closed loop' control there can be continued guidance towards an outcome; thus a car driver responds to initial reactions by careful observation and correction of any deviation regarded as undesirable. The driver is responding to 'feedback' and making alterations that influence output. This implies some relation to intention. Where a human being is not directly involved as part of the feedback loop the system may be said to have automatic control. The presence of feedback is what converts an open loop control system into a closed loop one.

One of the main purposes of using feedback in a control system is to ensure that, despite external influences of various kinds, and despite variations in the performance of the system being controlled, the required output is obtained from the system.

To understand some other concepts of control it is often helpful, again, to consider manual control systems, ie where a human being is involved. For example, a much used example is that of a shower. The inputs are hot and cold water; the black box is the simple mixer unit which regulates the flow of each input to produce an output from the nozzle; the person under the nozzle provides feedback by responding to the temperature sensed on the skin and making a manual adjustment accordingly. In such a system the time 'lag' between making an adjustment and feeling the effects can be so great that the operator runs the risk of being alternatively frozen or scalded. The problem is compounded when the temperature and/or pressure of the hot or cold water supplies is varied. Time delays or 'lag' are thus very important when trying to achieve stable control.

Another kind of delay or lag is very common in mechanical and electrical systems. It can be considered as 'sluggishness' and arises from 'inertia' in the system.

In a system of any sort, for example an economic or a mechanical system, the combination of excessive lag and inertia can lead to oscillation (as in our shower example above) and instability. Whatever your view of economics you are likely to be able to think of current examples! In the mechanical realm the automatic speed control of a petrol powered lawn mower can be considered. When running at slow speeds, and without a load, the engine speed is frequently heard to rise and fall at a regular rate — it is oscillating or hunting. The automatic governor used to control the engine speed is alternately increasing and decreasing the throttle setting — never quite getting it right. Sometimes these oscillations can become unstable and the 'hunting' can build up, the engine either stopping or racing at full throttle — even to destruction.

PROGRESSION

Presenting pupils with experiences that make increasing demands upon their increased competence is as important in learning about systems as in any other aspect of designing and making. Some concepts, crucial to systems, drop neatly into a progressively demanding hierarchy — dealing with concepts like input, output, feedback, lag and inertia, or in devising control methods which are 'open' and unpredictable or 'closed' and adjustable. However, more sophisticated elements will also need to be introduced in the experience of children from aged 5

to 16 years and are likely to involve pupils in tasks that move from understanding the system set up by another person, to improving a system designed by someone else, finally designing a satisfactory system. Even in this last challenge increased complexity is possible since systems can be simple and discrete or complex and inter-related — as when any alteration to one system repercussions through a whole sensitive cluster of systems. The efficacy of a course on systems is likely to be judged by pupils confidence in building a system by available materials and components that answers a stated need. It is unlikely that such a course should culminate in pupils making slight alterations to an establishes system.

Computer control, or some other form of microprocessor control is becoming increasingly important. Here it is often relatively easy to alter some of the characteristics of the control system and gain greater understanding of it and therefore better control. In CDT pupils often use control systems, in particular human-machine systems such as hand and powered tools. However it is in the *developing* of automatic control systems that the highest level of activity occurs. CDT activity frequently involves pupils in developing control systems, especially IT-related ones, at all ages from infants onwards. As indicated above, a system approach to analysing and understanding situations can improve the quality of designing.

The mathematics associated with controlling inter-related systems is often very demanding but it is important that opportunities to model solutions and qualify outcomes should not be ignored, particularly by very able pupils.

The Report of the Design and Technology Working Group includes 'systems' as one of the headings for the programmes of study for each of the 10 levels. They are noted below together with their associated keystages.

Systems 1 START OF KEY STAGE 1

- that a system or an environment is made from a number of related parts which combine to achieve a particular purpose, *for example observing clocks, bicycles, or play shops, play houses.*

(Also applying aspects of Science ATs 10, 12 and 13.)

Systems 2 START OF KEY STAGE 2

- that a system or an environment is made from a number of related parts which combine to achieve a particular purpose;
- that control is making things do what they want them to do, *for example steering, lighting, switching.*

(Also applying aspects of science ATs 10, 12 and 13.)

System 3 START OF KEY STAGE 3

- to identify the function performed by a system and/or sub-system within a product, *for example torch, clockwork or electrical toy;*
- to consider what is the input and output of a system, *for example a hand whisk, hand drill;*
- to consider how effective a simple system is and whether modifications could be made, *for example showing visitors around a school;*
- to give a sequence of instructions to control outcomes, including movement, *for example control a robot device or arrowhead on the screen.*

(Also applying aspects of Science ATs 10, 11, 12 and 13.)

Systems 4 END OF KEY STAGE 1
START OF KEY STAGE 4

- to use their knowledge and understanding of systems and sub-systems to inform their designing and making activities;
- to consider the efficiency of a designed system in terms of inputs and outputs;
- to consider the efficiency of a system and whether design modifications should be made, in order to improve it;
- to discuss the different methods of controlling movement and effects,

including the use of IT, *such as on the screen and through programmable robots*, and to use some of these different methods when designing.

(Also applying aspects of Science ATs 10, 11, 12 and 13.)

Systems 5

- to identify systems, sub-systems, components and their functions and relationships, and use this knowledge to inform their designing and making activities;
- that all systems are subject to control in ways which involve inputs, outputs, feedback and stability.

(Also applying aspects of Science ATs 10, 11, 12 and 13.)

Systems 6 END OF KEY STAGE 2

- to analyse a system to determine its effectiveness, so as to suggest improvements or alternatives;
- to identify the aspects of control in a system, including IT and use some of these aspects to design and make a viable outcome;
- to produce valid representations and simplify existing systems.

(Also applying aspects of Science ATs 10, 11, 12 and 13.)

System 7

- that systems are designed within specific boundaries, *for example transport and distribution systems within a retailing organisation;*
- how feedback from outputs can be used to control sub-systems, recognising the presence and effect of lag;

- to use IT and, where appropriate, sensors to monitor and control a system, *for example security system or temperature control system;*

- to design and make systems, including open loops and closed loop systems.

(Also applying aspects of Science ATs 10, 11, 12 and 13.)

System 8 END OF KEY STAGE 3

- that systems are designed within boundaries and judged against

criteria related to the context for use;

- to recognise that feedback is required by people to make a system operate and function effectively;
- that social and business organisations may be described in terms of systems with boundaries, inputs and outputs;
- to recognise and apply a range of IT systems used in areas, *such as business, industry, education, leisure and communications*;
- to estimate the operating costs of a system and evaluate its efficiency.

(Also applying aspects of Science ATs 10, 11, 12 and 13.)

Systems 9

- to design and implement systems, within specified boundaries, in which control is maintained without the need for human interventions;
- to recognise that people require feedback to make a system operate and function effectively and efficiently;
- that when designing systems in which people operate, sensitivity is required at all times;
- that the aspects of technological design which considers the user as an element within the control system is important for the success of that product.

(Also applying aspects of Science ATs 10, 11, 12 and 13.)

Systems 10

- that an IT-related system can be formulated, constructed and operated to process and transmit information and to establish control over another system;
- to estimate the operating costs of a system and evaluate its efficiency in order to design for improvement;
- to analyse business systems and organisational models.

(Also applying aspects of Science ATs 10, 11, 12 and 13.)

END OF KEY STAGE 4

To: Mrs B Wiggins,
Trentham Books Limited,
151 Etruria Road, Hanley,
Stoke-on-Trent ST1 5NS

Please enter my subscription to Design Technology Teaching

* I enclose payment/official Order for £13.50 (\$30 or £16.00 overseas for a one year subscription commencing with Volume 22 Number 2 Summer 1990) and continuing in subsequent years until cancelled.

Name _____

Address _____

Postal Code _____

I am a new subscriber/existing subscriber.

*delete as appropriate.

Please make cheques payable to Trentham Books. Receipts are not issued unless requested, in which case please enclose S.A.E.

Banker's Order

The Manager

Please pay immediately and, commencing in 1990, on 1st May each year, the sum of £13.00 to Trentham Books Ltd., Lloyds Bank, 30-95-21, Loughborough, Leics, England. Account No.0168192

Please cancel any previous order.

**Insert name of your bankers.*

*Please send to: Trentham Books Limited,
151 Etruria Road, Hanley,
Stoke-on-Trent ST11 5NS
and **not** to your bankers.*

Name _____

Address _____

Signed _____

I am a new subscriber/existing subscriber.