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# Some Teachers' Views of the Use of Construc–tional Kits in Schools

**Introduction**

The use of constructional kits such as Meccano and Fischertechnik has been advocated in such courses as Control Technology[1] and Modular Courses in Technology[2], and in the materials produced for these courses one may find specific suggestions for mechanisms to be built from them. However, in other syllabuses one may find statements which imply a practical use of such kits. For example in the Oxford G.C.E. Physics syllabus 054 of 1980 is printed:

p.56 'Work and energy. The principles of simple machines, e.g. level, inclined plane, simple pulley systems, screw'.

p.57 'Energy conversions, treated quantitatively'.

In the South Western Examination Board Physics syllabus 1981 one will find:

'Simple machines. Mecahnical advantage, velocity ratio, efficiency. Practical examples including pulley systems, inclined plane, screw thread, simple gears ....... etc.'

The Technology syllabus of the East Anglian Examinations Board for the C.S.E. gives the following in the 1979 issue:

'4. Mechanisms Module

1 General concepts

....... load effort, mechanical advantage, velocity ratio, friction and efficiency in relation to machines.

7 The use of linkages

Sketch examples of linkages used to transmit motion:

(a) in a straight line parallel to the primary motion;

(b) to produce curved motion;

(c) to produce straight line motion at an angle to the primary motion .......

9 The transmission of motion by gears .......

12 The control of motion using rachets .......

13 Control of motion by clutches .......

14 Transmission by couplings .......

This pattern of the syllabus items is repeated in many other papers both past and present in the field of Technology, Engineering Science and the pure Sciences. Thus in the syllabus for the experimental C.E.E. examinations, 1975 of the Welsh Joint Education Committee-one finds on page 4 under 'Mechanics (b) *Forces*'.

'Appreciation of the function of the following machines: wheel and axle, screw jack, worm and wheel, gear and belt drives. An experiment, using a simple machine, to show the effect of increasing load on Mechanical Advantage and efficiency of a machine ........

So although the kits may not be referred to by name in many syllabuses their use is certainly implied by the syllabus contents.

The views expressed in this paper have been assembled from a variety of sources – a report on a Technology course held in Avon[3], a seminar held under the joint auspices of the Science, Mathematics and Technology Centre, University College, Cardiff and the South Wales Association for Design Education[4], a report on the trial use of Fischertechnik kits for the first time in a local Comprehensive school[5], some advice from two experienced Heads of Department and Technical Studies and of Science in Comprehensive schools[6, 7] and some personal experience on a DES course held at Loughborough University.[8]

Three types of constructional kits are considered in this article:

(a) Fischertechnik;

(b) Meccano; and

(c) Proto.

The uses of these kits in schools is described and their relative merits discussed. Some suggestions are finally made regarding the structured use of one of the kits for educational purposes with pupils at various levels of ability and expertise.

**The Contents of the Kits**

*Fischertechnik*

For educational use the firm have produced several kits which are widely used in German schools and are beginning to gain acceptance in Britain. The two basic kits to be considered in detail are the structures kit (u-t S) and the mechanisms kit (u-t 1); both being made of very tough nylon. The structure kit consists of a large variety of somewhat flexible ties, from 30 mm in length upwards, and a number of different sizes of L-section and U-section girders. Some flat plates are available in suitable dimensions and also a number of corner plates and other joining pieces in various shapes and sizes. The parts are joined to make a structure by nylon pegs and shaped washers which can be fixed through holes and slots in the various components and secured by a half-turn. The kit

comes complete, packed in several layers in a nylon box together with a second stackable box for holding part of the kit when in use. Structures such as a suspension bridge model or a pylon can be constructed using this kit on its own, and in conjunction with the mechanisms kit more elaborate moving structures such as cranes and windmills may be built.

The mechanisms kit has, as its basic constructional unit, blocks approximately 15 x 15 x 30 mm which are slotted and fitted with pegs so as to allow them to be fitted together in a number of ways, and with a variable spacing if desired. Two slotted plates, which may be used as base-plates for mechanisms, are also supplied and a variety of axles, wheels pulleys and variously sized gear wheels. With such a kit it is possible to build such models of steerable vehicles containing gearing such as a fork-lift truck, demonstrations models of simple and complex gear trains and a large variety of other mechanisms such as swing- and lift-bridges.

Further kits, which can be used to extend the variety and types of models, are also supplied – a further gears kit (u-t 2) which also contains a battery driven electric motor, an electromechanics kit, and an electronics kit which is designed to give the pupil a working knowledge of techniques used in controlling regulating devices by means of electronics.

*Meccano*

The reader in Great Britain is probably quite familiar with this system of fabricating structures and mechanisms and will have seen them for sale in toy and model shops for many decades. Because the parts-girders, plates, brackets and gears are made from metal (some Meccano kits for very young children are now available in plastics) they can be made rigid with very much thinner dimensions, and there is no analogue of the Fischertechnik standard blocks. All fastenings are made with conventional nuts and screws. Although 'toy' kits are made varying from the very simple to large kits containing a large number of parts and are on sale in retail shops, schools usually purchase by ordering individual parts or a large multi-user kit as specified by the Control Technology course.[1]

*Proto*

Proto, supplied by Model and Prototype Systems Limited, is, as its name suggests, designed for building what might be called engineering prototypes. Its parts are made from metal and engineered to a much higher degree of precision than those of other systems, and nuts and bolts are used to join components. Three kits are supplied, the Basic Construction Unit (PCU 3), the Standard Construction Unit (PCU 2) and the Major Construction Unit (PCU 1). The latter contains, in addition to the basic parts, gears, racks, chains, slotted angle, shafts and bearings and also a geared electric motor and a 4 speed box. Extra components are ordered in packs.

**Discussion of Relative Merits**

One of the main criticisms of the Fischertechnik system offered at a seminar of practising Craft, Technical Studies and Science teachers[4] was that the models finally designed were not realistic representations of the real life article. It was suggested that the pupils' existing experience had, in part, to be discarded when working with this system because the space taken up by the blocks in, say, a fork-lift truck model made the whole model appear to be essential mechanism with no space for the load to be carried nor for an operator. The need to use special design techniques to enable gears to be accurately meshed again created an unreal situation. When several blocks are joined to form a pillar which would support part of the mechanism being designed it is often found that there is a lack of rigidity that would not be found in a similarly functioning mechanism built in Meccano. As a result several extra components have to be added which make the resulting model look crude and cumbersome. It was suggested by several craft teachers, who had only recently been introduced to Fischertechnik, that pupils who were given a sole introduction to engineering mechanisms via this system might build up very biased concepts of the supporting structure needed. They would hence have difficulty when it came to designing and building mechanisms in more conventional media. On the other hand, it was argued, teaching via conventional construction using metal and wood could lead to a blinkered approach to design in new materials. One of the main objectives of the seminar[4] was given by its title and involved the question as to whether the use of these systems can lead to the development of divergent thinking processes and creativity in the pupils who experience them. The participants were, at the outset, given a problem to solve practically: to design a model of a reversible gear train that could be used for demonstration on the overhead projector. It soon became apparent that the precise definition of the problem is no easy affair and that the organiser of such a situation needs to consider defining the spatial relationship of the input and output gears; whether or not the reversibility is to be introduced by inserting an extra gear-wheel manually or by means of an idler to be moved by a lever and saw. Out of the 7 models produced during the session only 2 had a close structural resemblance, and although all satisfied the design brief, none modelled the preconceived structure designed in advance by the author.

As a result of this exercise the discussion ranged over what children at various ages might get out of such a situation in the classroom. It was suggested that before inexperienced people, be they pupils or teachers, are given such problems there is need for some convergent teaching designed to make them familiar with the special techniques involved in this type of kit. Techniques for meshing gear trains accurately have to be shown and constructed, and the many ways of joining the various types of

blocks need to be demonstrated. It was thought that some form of stepwise progression through various types of mechanisms to produce reciprocating motion, unidirectional motion, simple and complex gear trains etc., would be needed before pupils could start to develop problem solving strategies and design creatively. In the school situation, it was suggested, there would ideally be a programme lasting through 2 or 3 consecutive forms whereby the pupils come back to using the kits in a progressively more creative manner.

The reactions of small groups of pupils to using Fischertechnik u-t 1 kits was subsequently investigated by the Head of Craft in a Comprehensive School.[5] He found that in mixed ability groups of boys in forms 1 and 2 who had not already been exposed to the Design-orientated course there was little or no success in designing any form of simple mechanism, and that many pupils found the costruction of fairly simple models for which designs were given, to be rather too difficult.

## COMPARISON OF THE SYSTEMS

| SYSTEM | SHORTCOMINGS | ADVANTAGES |
|---|---|---|
| Fischertechnik | 1. Models made from u-t 1 are unlike the real article except in function. | 1. Speed and ease of assembly and dismantling u-t 1, u-t 2, u-t S. |
| | 2. Expense. | 2. Ease of checking (u-t 1) and (u-t 2) after class use. |
| | 3. Lack of strength and rigidity for operating models, blocks slacken after 18-24 months continual use. | 3. Speed of using the special fastenings in u-t S and the peg-slot system of u-t 1/2. |
| | 4. Low mechanical efficiency of u-t 1 gears under load. | 4. Part-finished models do not need to be stored between lessons. |
| | 5. Difficulty of packing and checking u-t S after use. | 5. A very long life may be anticipated with Fischertechnik parts depending on rate of use – in constant use replacement of blocks in 2-3 years. |
| Meccano | 1. Slow assembly and dismantling owing to nut/bolt fastenings. | 1. Rigidity and strength of individual parts and structures. |
| | 2. Impossible to check parts rapidly after class use. | 2. Mechanical efficiency under load appears greater than with u-t 1. |
| | 3. Part completed models need to be stored between lessons. | 3. The pattern of usage suggests schools need to spend less amount of parts. |
| | 4. Need for large amount of stock. | 4. More realistic models produced. |
| | 5. Teacher may have to dismantle models himself after lesson. | 5. A 10 year life has been suggested. |
| Proto | 1. Expense. | 1. Efficient mechanisms can be made. |
| | 2. Better suited to workshop than classroom. | 2. Very sophisticated, realistic mechanisms can be built. |
| | 3. Structural components not supplied. | |
| | 4. An extensive knowledge of engineering practice needed to make full use of all the parts. | |

A similar group of boys from form 3, who already had some design experience, were mostly able to complete the most difficult models illustrated within 15 minutes, the lesser able taking a little longer.

The reaction in forms 4, 5 and 6 was curiously different. The youngest, form 4, in this group either saw the kits as mere play things and had little patience with the work if they were the least able or, being more able, could design simple forms such as reverse gearing, high and low ratios, and could in some cases test simple theories. The forms 5 and 6 boys and girls were from the Design course and saw the kits as play things which could have some use in testing basic design theories. The criticism was that the kits were limited in their contents and this restricted the experiments they wished to perform. It was suggested that a Geneva wheel could have been included to examine intermittent motion such as found in a production line, and that more pulleys might have been included and a greater number of gears. This point, made by the pupils, indicates the need for the u-t 2 kit to be available alongside the basic u-t 1 kit when in advanced classes design and technology courses.

The experience gained over a period of 3 years in a Technical Studies Department[6] suggests that boys, initially, react towards Fischertechnik better than girls. However, with encouragement and increase of confidence the girls quickly catch up. It is interesting to note that, when dealing with in-service training, teachers seem to have more problems with Fischertechnik than the pupils and require more direction and experience with the kits before they, so to speak, become fluent in using the materials.

The problem of children regarding these constructional kits as something of a toy and therefore beneath them has also been experienced in this school. However, when they get immersed in the problems this viewpoint quite quickly changes as they perceive the difficulty that can arise with even an apparently very simple challenge. The teacher has to be prepared continually to inject new information, and the lesson needs to be kept moving, otherwise the children get bored. A delicate balance needs to be kept between controlled excitement and disciplined working.

The teachers in this department have found that Fischertechnik has enabled them to cover aspects of engineering and design that had hitherto been impossible, and they intend to continue to give all pupils, in this mixed comprehensive school, mechanisms modules as part of their general education in the first and second years. The third year pupils will continue to be given well structured and taught mechanisms modules as part of the preparation provided for upper school technical and design examination courses.

Not only has the use of constructional kits been found essential in technical studies courses, but physics courses can benefit much from their use. It is of interest to give some details of the way in which one school science department[7] structures the relevant parts of its physics course and presents the materials.

In year 3 of the physics course the pupils have 3 periods each of 1 hour 10 minutes. The objectives for this part of the course are:

1. to introduce the material (Fischertechnik u-t 1).
2. to give a basic appreciation of the use and functioning of simple mechanical mechanisms e.g. chains and sprockets, spur gears (meshing and effects of ratios), bevel gears.
3. introduction to the idea of designing within given parameters.

The method of working is to present problems be solved by the design and building of working models:

(a) 'Build a vehicle that can be moved along the bench by turning a handle'.

(b) 'Sketch out a design, and then build a model, the mechanism required to load a stretcher and its patient into an ambulance'.

The teacher[7] reports that the pupils find the work very enjoyable and the components easy to f together and fast to manipulate. At the beginning of year 3 the pupils have virtually no mechanical knowledge and very little idea of spatial relationshi Invariably they over-design at first, and they experience difficulty in focussing on the basic problem. They have difficulty in expressing their initial ideas and, as is to be expected with youngster still mainly in the Concrete Operations Stage of Piaget, they tend to think with the material rather than use it to express ideas. Probably one of the main problems of the teacher is to think of other design problems which will:

1. be within the pupils' capabilities, and
2. involve a more wide-ranging use of the components, and, therefore, ideas.

This school also uses Fischertechnik kits in yea 4 and 5 physics courses to cover the parts of the syllabus referred to in the introduction to this paper. Both the u-t 1 and the u-t 2 kits are used in the teaching of these basic ideas. The concepts of mechanical advantage and velocity ratio are taught using the mechanisms in both kits, e.g. gears, chains and sprockets, etc. These concepts are then applied to the (possibly?) less interesting examples of pulley systems, inclined plane, and so on. An attempt is therefore being made to proceed fro the general to the particular cases rather than by t traditional methods.

Efficiency is, today, a very relevant topic and pupils are asked to measure the efficiency of the motor/gearbox of the kits as a simple hoist. This involves the measurement of electrical and mechanical (gravitational potential) energies and their interconversion. In this connection efficiency is taught as: (see diagram A).

Pupils discover that the efficiency of the motor gearbox is about 10% and this causes some surpris This can then be compared with the 25% or so efficiency of the car engine, and the concept of efficiency now begins to show immediate relevanc

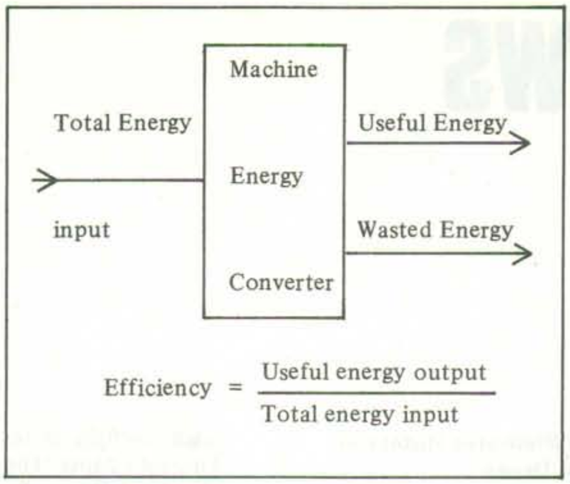


*Diagram A.*

This school also teaches Schools Council Modular Technology[2] and Fischertechnik is used in 2 areas of the course. The writers of the course recommend either Fischertechnik or Meccano in the optional module 'Mechanisms'. Two problems should interest readers for the mini projects of the Problem Solving Module:

(a) 'Design and build the vehicle which will climb the steepest slope'. The problems involved are gearing, traction and stability, and this problem usually develops into a very serious class competition.

(b) 'Design the mechanism of a powered hoist utilising Fischertechnik parts. The hoist must be:

(i) capable of lifting a maximum load of 500g vertically through 1 metre,

(ii) capable of operating repeatedly with a quick return, and

(iii) operated from a battery supply'.

From the above examples one can clearly see that the use of constructional kits under these conditions is not merely an exercise in putting parts together in imitation of a known device, but can and does require some real mental effort on the parts of the pupils, and must form a valuable contribution to their concept formation in various areas of physics.

During the seminar[4] the question was raised of the use of constructional kit models for demonstration by the teacher rather than use by classes, and also as an aid to explanatory work with individual pupils. It would be useful, several members suggested, for the teacher to have a kit or two at his disposal for this kind of work. The speed with which a pre-designed demonstration model can be erected makes Fischertechnik very suitable for demonstrations, but such models are very much clearer if they are constructed from Meccano. However, in the latter case, the time needed to construct the models probably militates against their widespread use. If kits are only to be used occasionally by pupils without any previous structured course in the techniques required, then it would appear that Meccano, because of its greater realism in model form, is the more suitable.

In discussing the use of Proto the Avon report[3] concluded that, educationally, this more expensive kit has no advantage over Meccano, but that where efficiently working models or prototypes were being made as a special project then the greater precision of Proto would be a decided advantage.

Traditionally Meccano appears to have been widely experienced by British teachers and, before other systems are adopted, teachers in the UK will need ample exposure to the techniques and possibilities of these alternatives. The seminar group[4] who had only a very limited exposure to Fischertechnik agreed that perhaps between 6 and 9 hours of private experimentation with the u-t 1 and u-t 2 kits would be needed before they could confidently incorporate the system in their teaching. However, a more experienced view[3] suggests that private experimentation tends to be time consuming, and that, provided teachers are given a structured introduction to the techniques of using Fischertechnik in teaching, this time can be sustantially reduced. The same correspondent emphasises that practical sessions with this brand of constructional kit with children must not be too short, a minimum of about one hour appearing to be necessary for each session.

**Conclusions**

1. The production of a Teachers' Guide and/or work cards giving diagrams and instructions to cover the basic techniques of using Fischertechnik components would be of help to teachers inexperienced with this system.
2. Owing to the initial high cost, assistance might be required from local education authorities for those schools which decide to adopt the use of one or other of these kits.
3. On the whole it would appear that if a school intends to expose every pupil to experience with constructional kits several times during his schooling, the use of a system quick to build up and knock down and presented in easily checkable individual kits such as Fischertechnik u-t 1 would be advisable.
4. If it is wished only to use such a system with a small section of the pupils for specific purposes such as in a Craft, Design and Technology course, then Meccano might cause less of a financial burden to the authority.
5. The use of Proto, except in specific engineering projects and similar applications, might prove unacceptably expensive.
6. The acceptance of the use of such kits on a wide scale might be accelerated if sets of kits were available for loan to teachers in schools for trials, in the first instance personally to the teachers, and later in bigger quantities for class trials.
7. It seems unlikely that the majority of practising teachers of craft would be swayed by any arguments that the use of constructional kits in school is any more than aid to learning, and the use of such kits as an aid to improving creativity in the pupils generally is likely to be rejected.

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