An investigation into the feasibility of introducing computer based control into the early years of secondary education

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Abstract

In our everyday lives we are surrounded by control systems. Computer based control systems are becoming increasingly important. The hardware currently exists in the majority of schools which would enable pupils to participate in computer based control.

Primary schools are beginning to recognise the potential of computer based control. However, control does not generally feature in the first or second year curriculum in secondary schools, which only tend to provide experience of it to fourth and fifth form pupils as part of their examination courses.

This research attempts to establish whether computer based control is a suitable activity for first and second year pupils. It draws from the experience of many curriculum areas and argues that the activities associated with computer based control are consistent with the previous experience of pupils; that pupils would be motivated by the activities and that they would develop procedural understanding.

The thesis describes: a survey into ownership and use of construction kits; a twelve week course in computer based control; the resources which were developed to support the course; and the trials of the course.

The research suggests that computer based control can provide suitable activities for twelve and thirteen year old pupils. It identifies a number of problems which seem to indicate that when modelling pupils tend to operate at an aesthetic rather than functional level, and that the difficulty which pupils encounter with a task is a function of the number of 'steps' involved in the task.

An investigation into the feasibility of introducing computer based control into the early years of secondary education.

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Chapter 1.

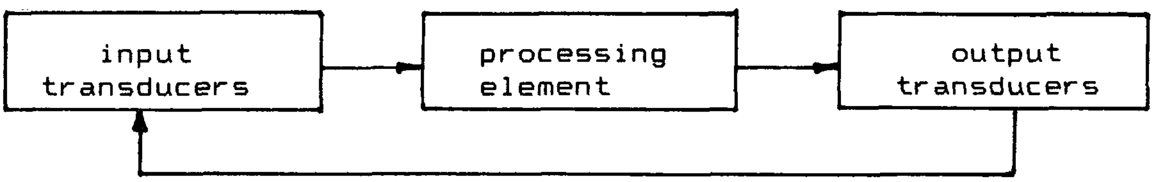
An Introduction to Control Technology

We are surrounded by, and are reliant upon, control systems. They are not recent innovations; they have been used by man since he first began to develop technological devices. Our current life-style and expectations are attributable to our ability to control increasingly complex devices. Control Technology is concerned with the development and operation of control systems.

A control system collects and processes information in order to control a device or process. Systems can be described in terms of the information which is input to and output from them.

Early control systems employed humans to collect information. Someone would 'take the temperature' of a kiln, 'see how fast the windmill was turning' etc. The accuracy and speed of these systems was determined by the human operator. In order to maximise the efficiency of a system and to minimise the running costs technologists have contrived to reduce the 'human element' in control systems and so, as technology has developed, it has become possible for control systems to collect information directly. This data collection is performed by transducers. A transducer is a device which "converts a signal or physical quantity of one kind into a corresponding physical quantity of another kind" (BS1523). This definition, as well as covering sensing devices such as switches, thermisters and potentiometers, also covers actuators such as motors and indicators which cause some change to take place in the outside world. An 'input' transducer is one which provides information to a control system and an 'output' transducer is one which is controlled by a system. A control system can therefore be described in terms of three components; the input transducers, the processing element and the output transducers.

A control system



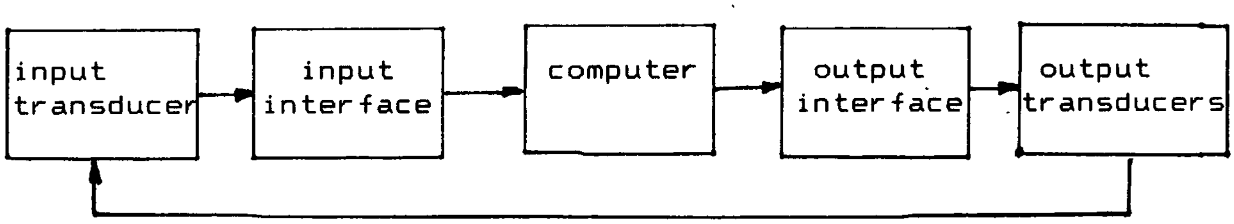
The processing element of a system can take many different forms. It could be a simple mechanism, an analog or digital control circuit or a pneumatic logic system. With any of these systems the required control sequence will have been translated into either a mechanical linkage, an electronic circuit or a pneumatic logic system. The circuit will have been designed for one specific application and without modification could not be used for anything else. Such systems are therefore very limited in their application and are relatively expensive as each one is preprogrammed.

As technology developed it was found that computers could be used instead of these more traditional processing components. The major advantage of using computers is that they can be programmed to perform a specific task. Should the requirements change the computer can simply be reprogrammed. Rising labour costs in the Western economies and the increasing number of manufacturing tasks which need to be carried out in hot, heavy or toxic environments have increased the demand for automated systems.

The advent of the microprocessor meant that a flexible control element could be produced relatively cheaply. This stimulated interest in, and demand for, increasingly sophisticated control systems and has led to the situation in which we find ourselves today - surrounded by control systems. As society and industry comes to terms with each new application of control systems, it discovers many other potential applications and makes demands upon technology for further developments in this area.

The general purpose microcomputer systems which are currently in everyday use cannot be used in control systems without some additional hardware. An input interface and an output interface would be required. These interfaces protect the input and output 'ports' of the computer from damage by incompatible signals or loads, and enable the individual connections in the port to be easily accessed.

A Microcomputer based Control System



The majority of secondary schools and an increasing number of primary schools will have the resources which would enable pupils to assemble and test computer based control systems.

The position of Control Technology in the school Curriculum

In order to present a coherent picture of Control Technology in schools we need to consider its development in recent years.

The Project Technology pilot study, established in 1966, aimed to increase children's technological knowledge and skills and to make them more aware of scientific and technical developments and the importance of these to society. The approach adopted was based on investigation and problem solving.

In 1975 a Control Technology module was developed as part of this Project Technology package. This module relied on relays, transistors, or pneumatics to provide the control element, and on meccano for the structures and mechanisms. It provided pupils with an opportunity to assemble control systems which would "sense, warn, dispense, sort, repeat, display, react, select or in other ways control a machine or system". (Technology in Schools, 1982, p.8)

The most exciting developments were made possible when rather than using the logic based system which was a part of the Project Technology course, models were built and interfaced to a micro computer. By using the computer as the control element, the range of activities was increased while the actual knowledge of electronics required of the pupils was considerably reduced. Rather than being an activity for a minority of pupils who were capable of mastering electronics, it become an activity suitable for pupils of all abilities.

Although microcomputers had begun to find their way into secondary schools in 1978, it was several years before they began to appear in any numbers. In these early days the scarcity of computers precluded the development of pupil-centred activities in computer based control. The situation in terms of computing resources, generally improved after 1983. This improvement can be attributed to the Microelectronics in Schools programme (MEP March 1980) and the TVEI pilot scheme (November 1982), both of which emphasised the importance of information technology, and fuelled the argument for more microelectronic resources to be made available to the schools.

Having identified control technology as one domain of its activity, the MEP was responsible for the development of a number of resources designed to support Control Technology; the MFA Course, Control Basic, the control language BITS, the BBC Buggy, the VELA and the Control

Pathways materials were some of the most notable developments. These resources were designed to promote control technology as a pupil-centred activity. Pupils could become involved rather than simply being spectators.

Control Technology has been introduced into schools in an ad-hoc manner. The emphasis placed upon it, and the manner in which it is presented, is dependent upon the resources available in the school and on the expertise and enthusiasm of individual teachers. The majority of control technology courses and activities have, until very recently, been designed for pupils of above average ability in years four and five of secondary education. A review of the literature, including an on-line bibliographic search of the ERIC and NERIS databases, did not identify any significant research into control technology as a curriculum activity for 11 to 13 year old pupils.

Elements of control technology can be identified in science, technology and IT courses. A survey of the GCSE syllabi offered by the NEA group for examination in 1988 showed that, in addition to being offered as a subject in its own right, control technology also appeared in a number of other subjects. I was able to identify aspects of control technology in the following syllabuses:- Computer Studies, Craft Design: Engineering, CDT:Design and Communications, CDT:Design and Realisation, CDT:Technology syllabus B, CDT:Technology, Information Technology syllabus A, Information Technology syllabus B and Science:Modular. I will need to draw from the literature of these curriculum areas in order to support a number of my arguments

Chapter2

Science and Technology

"Man is a technological creature. In the beginning, he used his natural gifts of intellect and dexterity to raise his standards of life. He fashioned flint axe-heads and raised his capabilities for house building; he made fires to cook his food; he made the plough to provide him with regular supplies of food. His bows and arrows made him a more efficient hunter: words, phrases and language helped him to communicate with his neighbours." (School Technology Forum,1973)

Primitive man used many things before he could understand the general principles upon which they worked. By working with materials "Artists and Artisans developed a pool of knowledge about the ways of things and substances". (Hindle B.,1980,p.14) This knowledge and the associated craft skills were preserved by the practitioners. The craft skills could only be learnt through working with the materials. As man began to control devices and processes, the skills which were required became more technical and required an understanding of the technology which was in use at the time. Technology has been defined as:-

"...extending to all the skills, knowledge and procedures for making, using and doing things". (Tasker M.,1980)

This definition goes some way to illustrate the contemporary view of technology. As well as being concerned with knowledge, it is also concerned with the development of skills and procedures. (Report of Survey of Design and Technological Activities in the School Curriculum, 1983, p.2) Technology is a creative activity which should not be seen simply as applying the knowledge which science has made available. It is an area of experience in its own right. Rather than being dependent upon science, science is often used to "buttress the empirical techniques" which have been developed by technology. (Mathias P., 1972)

Science is often perceived as dealing with facts, or to answer the question 'is it true', whereas technology is more concerned with processes or in answering the question 'how can it be done'. "The scientist is in general a questioner of nature while the technologist manipulates nature." (Hodgson B. and Scanlon E., 1985, p.9)

A technological education

The literature presents differing views on how a technological education should be delivered, and whether courses in technology should be offered, or whether the "main road to technological understanding" should be through science. (Newton P.M., 1987, p.85)

Despite the claims made by Rogers that technology teaching began in 1885 (Rogers R., 1985) only a very limited number of schools included technical subjects as an integral part of the curriculum prior to the 1944 Education Act. (Howard A. E., 1959, p.7) These technical subjects tended to be classed as craft subjects.

"School craft departments developed using the techniques current in skilled trades of the last century and were largely staffed by skilled tradesmen with appropriate educational qualifications. The techniques employed were those current in industry, and the training was oriented towards a 'pre-apprentice' type of pupil." (Mead T.,1983)

An investigation into technical education in Scottish Secondary Schools in 1972 found that craft departments often "reduced the curriculum to a series of practical exercises based on a number of joints". They suggested that the implications of such an approach was that "craftwork then tended to be dull and repetitive, and for the majority of pupils lacked creative interest." (Technical Education in Secondary Schools, 1972, p.9)

A later survey of Technology in schools found that it was common for headteachers to be critical of traditional craft courses. (Technology in Schools, 1982, p.17) These courses were considered to be expensive in capital costs, capitation and staff pupil ratios. Woodwork and Metalwork were not courses which were sought after by parents; they were identified as 'boys interests', they had very little acceptability in employment or in further education and virtually none in higher education. Craft courses were generally aimed at lower ability pupils who were 'good with their hands'.

The relationship between craft and technology has always been fudged and this is one reason why technology is held in the same low esteem as craft. Many advocates of technology in schools were wary of "becoming associated with traditional craft teaching, or with vocational training." (McCulloch G.,Jenkins E. and Layton D., 1985, p.192) In an attempt to promote technology as a legitimate academic activity, teachers and technologists have stressed the intellectual and cultural aspects of technology.

This problem of image was addressed by the former prime minister, J. Callaghan, in the Ruskin College speech in 1976 when he stressed the need to change social and educational attitudes and, in particular, the need to relate education more usefully to society and industry. (Times Educational Supplement, 1976) It was hoped that increased interest in science and technology would result in increased enrolments. Such an increase would in turn produce a larger scientific and technical workforce, and would generally increase technical literacy.

A Scientific Education

We have suggested that the scientist, prompted by the desire for a better understanding of his world, becomes a questioner of nature. A study of science would therefore help pupils to make sense out of their world. The DES Policy Statement, Science 5-16 recommends that "science should have a place in the education of all pupils". (Science 5-16, p.1, 1985) In the past when pupils have been given an option, many have chosen not to take science courses, and much of the blame for this poor take up has been apportioned to the relatively poor image which children have of science.

The Problem of Image

"At a personal level, science is seen as difficult, often dull, and not important in one's own life." (International Encyclopaedia of Education, 1985, p.4451) It is seen as a 'hard' subject at all levels from secondary to higher education, and consequently, a situation seems to exist where science is generally viewed as an "important and critical endeavour, but it is one to be pursued by somebody else." (International Encyclopaedia of Education, 1985, p.4451)

This poor image tends to be self perpetuating. As a result of the failure of science to attract pupils, science graduates have always been in short supply, and therefore in great demand. This shortage has resulted in many science courses in schools being taught by non-scientists and has had serious implications for Science. A 'non-scientist' who is made to teach Science because it 'has to' be included in the curriculum, is not likely either to improve the image of science, or to increase the numbers enrolling on science courses at any level.

Science, a Difficult Subject

Science is "concerned with things in our surroundings that can be investigated with the aid of our senses". This means that the laws and principles of science, i.e. its knowledge base, can be proved or demonstrated by practical experiment. (Hodgson B. and Scanlon E., 1985, p.43) One might expect that this would help pupils to understand the subject matter, yet Dobson cites evidence which suggests that a very large number of school children do not understand physics. (Dobson K., 1985, p.188) It is appropriate at this stage to consider why pupils find science difficult.

An HMI survey found that most science courses concentrated on science concepts and failed to provide either the stimulus or the opportunity for the pupils to observe applications and to become personally involved in applying these concepts. (Aspects of Secondary Education, 1979, p.172) This view is shared by the APU (APU 7., p.3), who consider that "the standpoint adopted in most published science courses is one in which the overall aim of the course is predominantly concerned with the accumulated body of knowledge of science and the explanatory power which derives from an understanding of its key concepts."

Papert argues that there are two ways of knowing: "knowing-that" versus "knowing-how" or "propositional knowledge" versus "procedural knowledge" or "facts" versus "skills". (Papert S., 1982, p.135) Science gives greater emphasis to the acquisition of information rather than to the acquisition of information handling skills.(Stonier T., 1983, p.101) Some people will enjoy 'knowing that'. However, in everyday life, information or knowledge has very little value unless it can be applied to the solution of some problem.

During the past twenty years concern has been growing that the emphasis which science courses have placed on propositional knowledge has not provided pupils with a 'science education'. If this emphasis is considered along with Layton's view that "much of science involves the understanding of concepts which are highly abstract and connected to observations only by complex logical and mathematical relationships", it might be fair to conclude that science is attempting the impossible.(Layton D., 1973, p.19-23)

However there is a view that science is capable of providing activities "in which the knowledge burden is not as great, nor its acquisition seen as being the sole purpose of the lessons" (Dobson K., 1985, p.19).

Improving the Image of Science

A number of attempts have been made at improving the image of science. The late 1950s' marked the end of a long period of stability in the school science curriculum and the beginning of a period of rapid curriculum development. (Hodson D., 1985, p.25) The common aim of these developments was to make science courses more interesting, more relevant and more practical. One significant result of these developments was the Nuffield Science Courses. The Nuffield project concentrated on developing materials which would enable the classroom teacher to present science in a more lively and motivating fashion.

These development were addressed principally towards the more able pupils and were limited in their impact upon the everyday attitudes and practices of the schools. (McCullock G.,Jenkins E. and Layton D., 1985, p.191) The priority appeared to be the training of 'scientists' rather than providing a science education for all pupils.

The Processes of Science

Leek argues that while many pupils are unable to reproduce facts and information, they can learn how to obtain facts through familiarity with basic processes of science. (Leek B., 1987, p.15) For science, as well as being concerned with a body of knowledge, is also concerned with scientific processes. The APU identify the processes of science as:-

"communicating (via prose, graphs, charts and tables), observing, predicting, inferring, hypothesising, interpreting, planning, investigating and problem solving". (APU 9, 1987, p.6)

and the existence and value of these processes has been recognised for some time.

"the value of science in education consists not in the amount of knowledge acquired concerning work done by others, but in training the faculties both of observation and reasoning on facts ascertained by the personal effort and experiment of the pupil" (Board of Education report, 1909)

In recent years there has been a move away from the teaching of science as a body of knowledge towards the "experience of science as a method of generating and validating such knowledge". (Hodson D., 1985, p.34) The goal is that pupils should 'know-how' rather than to 'know-that'. One major advantage of this approach is that more pupils should be able to succeed because the tasks involved will rely less heavily on taught concepts.

Science courses have generally included some form of practical work. One might have expected that the practical work would have been designed to develop the processes of science. However the APU point out that more often than not, the purpose of this practical work has been to illustrate the idea or concept under consideration and not to develop procedural skill.(APU 9, 1987, p.6) Perry recounts a brilliant freshman scientist who was so disgusted with 'cook book' laboratory exercises that he took to playing variations on themes and finally provoked his instructor into blurting: "see here, there'll be no more experimenting in this laboratory". (Perry W.G., 1970)

The DES policy document Science 5 -16(1985, p.13) expects that, in addition to teaching an understanding of scientific knowledge and ideas, pupils should have the opportunity to develop scientific thinking and apply their scientific knowledge to solving social, environmental and technological problems. Many authors have stressed the importance of exposing pupils to practical problem solving activities in order that they might benefit from the process of developing solutions to practical problems. By placing greater emphasis on problem-solving, science would then be able to deliver a science education to more pupils than would be possible by employing the more traditional methods.

Co-operation between Science and Technology

"Science and technology are intimately linked", and yet the relationship between science and technology has always been uneasy. (Science 5 - 16, 1985, p.13) They have tended to develop as separate subjects and in the process have established new curriculum boundaries, rather than having eroded existing ones. And yet there are many advantages to be gained from co-operation between science and technology. One such advantage was identified in a survey into the attitudes of teenage pupils to technology and industry which found that in schools which had strong science and CDT departments, and especially where courses were based on practical experimental work, pupils developed favourable attitudes. (Page R. and Nash M., 1980) This co-operative approach would also mean that a wider range of expertise and resources would be available to pupils. (Technology and School Science, 1986, p.28)

Control is a Component of Information Technology

The Micro-electronics 'revolution' has focused attention on the relationship between science and technology. Technology has acquired a new importance and credibility through micro-electronics. Bevis argues that collaboration between science and technology in schools will be essential as "microelectronics is very different from anything that exists in either department, and because the complementary skills of the two are needed."

(Bevis G., 1985, p.110)

Control is a component of both science and technology, and as both of these curriculum areas search for relevant problem-solving activities it is likely that they will place greater emphasis on control activities. Consequently, a problem which includes some element of computer based control is likely to have greater relevance for the pupil and, in addition to providing pupils with an experience of Information Technology, it will also serve the interests of both science and technology.

Chapter 3

Computer Based Control as a Curriculum Activity

By requiring children to complete a period of formal education, society attempts to deliver what it perceives to be an education. This process, as well as providing children with the knowledge, skills and attitudes which will allow them to survive in society, also ensures that the values of that society are transmitted from one generation to the next. To a large extent the values of society will determine what is taught, and when it is taught.

The Agrarian and the Industrial Revolutions both had profound effects on the societies of their time. Both forced fundamental changes to be made to society and this in turn influenced education. We are currently witnessing an information revolution, and as a society we cannot afford to ignore Information Technology.

"the people and the nations that don't learn to participate in an information based society will be its peasants." (Cleveland H., 1986, p.62)

Schools "have a responsibility to respond to social changes" brought about by this technology. (The Curriculum from 5-16, 1985, p.6) Thus, schools are being urged to make pupils aware of the applications of information technology, and to equip those pupils with the knowledge, skills, and attitudes which will enable them to take advantage of this technology. As control technology is a major component of information technology, schools will need to provide pupils with some experience of control technology.

The place of computer based control in the curriculum

In order to deliver an education, schools provide or encourage a range of activities which comprise the curriculum. The Curriculum from 5-16 identifies a fundamental problem:

"There is so much knowledge which is potentially useful or of intrinsic interest that syllabuses are often overladen with factual content. - schools need to be highly selective when deciding what is to be taught". (The Curriculum from 5-16, 1985, p.37)

This problem of trying to "fit a quart into a pint pot" has become very apparent in recent years as the curriculum has been constantly urged to reflect the advances of technology and the changing face of our society. Coates describes the situation which currently prevails in curriculum development in the area of technology.

"training and curriculum development are proceeding concurrently. Changes are being made to the curriculum before the full consequences can be worked out through trials and careful preparations." (Coates B., 1982)

The current plethora of curriculum initiatives reflects the importance which society gives to developments in science and technology. In the past, "following a technological revolution, a stable period allowed educators to develop their methods ... Today the rapidity of the changes does not permit such a luxury." (Sharon D., 1986, p.21) It is not sufficient to argue that computer based control should be a part of the curriculum without also considering the value of the activities involved.

The worth of an activity can be judged by the effectiveness of the learning experiences which it provides. The effectiveness of these experiences will be assessed in terms of the skills and competences they develop and the awareness or understanding which they promote. For learning to be most effective the learner must participate in, and be personally involved in an activity. However if that activity does not attract or motivate the pupil he will not become involved in it, and the activity is therefore unlikely to promote effective learning. An activity must in some way convince the pupil that they want to participate in it.

Unless the learner can see an "application for learning, or unless he gains improved status or enjoyment from possession of it, he is unlikely to value that knowledge", or appreciate its relevance. (Sparkes R.A., 1986)

"The more that knowledge and skills learned in school can be developed within and applied to activities that have real purpose and place in the wider world, the more clearly their relevance will be perceived by the pupils." (The Curriculum from 5-16, 1985, p.46)

Control Technology can offer a wealth of problems solving activities which the learner perceives to be relevant and which are consistent with their previous learning.

Computer based control builds upon what the child can already do.

Ausubel suggests that the most important single factor in influencing learning is what the learner already knows. He advises us to:- "Ascertain this and teach him accordingly." (Ausubel D.P., 1968, p.31) Any tutoring system, whether human or machine has some model of what the learner already knows. As the interaction between the learner and tutor develops, so the tutor's perception of what the learner knows is refined. Our teaching and in turn the learning environment which we engineer relies on what we think the pupil knows.

It would appear that something is 'learnt' as a result of 'interaction' between the learner and his immediate environment. (Kolb D.A., 1984, p.23) If two people are placed in the same learning environment it would be unlikely that both would 'learn' exactly the same. How the stimuli are interpreted will depend upon what they have learnt previously, which will in turn affect what is learnt in the future.

"every experience both takes up something from those which have gone before and modifies in some way the quality of those which come after " (Dewey J., 1938, p.35)

Children enjoy playing and are motivated to play. They do not need to be taught to play.

"One of the most important motivations of learning is the Exploration or orientative drive - and this activity has an important role in playing" (Grastym E. and Verecki A., 1974)

From a very early age children investigate the environment in which they find themselves and this interest arises from their desire to control or use the things around them. (Crowther Report, 1959). Much of this investigation and experimentation is seen as play by the child with learning taking place when there is a need to learn, and at the child's own pace.

Many of the toys and models which children encounter in their play are becoming increasingly technological. It is through experience with these technical toys that children will get their first hands-on experience of machinery.

" The skills which children learn from these toys lay the foundations of mathematics, scientific and technological learning; they develop elementary problem-solving concepts and introduce the language of science." (Girls and IT., 1985, p.4)

Perhaps the most important skill which is developed is the intuitive approach to problem-solving. Most of the learning which children bring with them to the primary school will have been learnt through play. At the core of most of the activities which they associate with 'play' will be some form of modelling.

"Even at a very early age pupils can begin to gain confidence in their ability to get to grips with the world about them; to be active participants as well as users and spectators. ---- Such modelling can be readily extended to provide some involvement and insight into the process of technology; eg. designing a model crane which will actually lift something." (The Curriculum from 5-16, 1985, p.35)

Computer based control relies heavily upon modelling in one form or another. The child might be required to produce a physical model of a device, or to produce a model of a process in the form of a control program. There would appear to be many similarities between play and the processes of computer based control. I would contend that pupils would show similar levels of motivation towards control activities as they would towards play and hence control can fulfil one of the criteria for meaningful learning, that is motivation.

Computer based control has something to offer pupils of all abilities

That science is perceived as a difficult subject has been attributed to an overemphasis on content and abstract concepts. If, as Cusak suggests, a high percentage of adolescents and young adults operate at the concrete operational level, then many pupils will operate at this level throughout their period of secondary education.(Cusak M., 1986, p.95) Any course which is aimed at pupils of all abilities should therefore not rely heavily on abstract experiences and must take heed of

Ausubel's advice that as teachers we should find out what the pupils know and build upon that knowledge. Children can play, they are motivated by play, and therefore schools should endeavour to build upon the learning which it promotes.

Control is capable of offering both concrete and abstract experiences. The research of Cantu and Heron suggests that even though the performance of formal-operational students is likely to be greater on any concept studied, the performance of concrete-operational students may be quite satisfactory when concrete concepts are studied. (Cantu L.L. and Herron J.D., 1978, p.141) By providing concrete learning experiences, the less-able as well as the more-able pupils would gain something from the learning situation.

This would be consistent with the view of Cantu and Herron who argue that the use of models, illustrations and diagrams, can help all pupils regardless of their intellectual level. (Cantu LL and Herron J.D., 1978, p.142) Layton takes this further and argues that it is through acquaintance with ideas applied in situations which are meaningful and relevant to them that most children can best approach an understanding of abstract ideas. (Layton D., 1973, p.19)

It would appear therefore that modelling, in one form or another, has a useful role to play in concept acquisition regardless of the stage of cognitive development to which the learner has progressed. Computer based control courses would develop procedural skills based on the child's experience of modelling. This approach would ensure that any pupil, regardless of ability, would be able to take an active part in problem-solving activities.

Computer based control in the primary curriculum.

Current primary school practice tends to encourage practical 'pupil centred' activities. With these activities the pupils have a goal, whether it is to do some thing, to make something or to solve a problem. They are not concerned about using some particular knowledge, skills or tools; they have a problem to solve, and they use whatever tool they think appropriate, along with what 'they know' or 'can do' in order to solve it. Here there are no demarcation lines laid down by subject departments, nor is there pressure from external examinations and, as the curriculum is largely child-centered as opposed to subject-centred, the pupils are not blinkered by the subject boundaries.

The HMI recommend that the work of pupils in primary schools should "encourage the development of skills and inventiveness in producing artefacts". They also recommend that more emphasis should be placed on work in three dimensions and suggest that some of this work might be of a "simple technological kind aimed at designing and making things that work." (The School Curriculum, 1981, p.12) With activities in control technology there is a "tangible end product which is personal to the child". (Jones A. and Preece, 1984, p.145) The child can bring the model to life and exercise control over it.

"There can be few activities in the primary school that provide more learning opportunities than building controlled models." (Hardwick S.,1986)

If there is to be continuity within the education system, then secondary schools must build upon the work which pupils do in primary schools. Despite the problem highlighted in Science 5 - 16 (1985, p.5), that development in primary schools tends to be taking place in a piecemeal fashion, an increasing number of pupils will be arriving in the secondary school having developed valuable problem solving skills, only to be fitted into a subject based curriculum which, in many cases, does not accord great value to technological problem solving activities.

If all pupils are to leave school at 16 having some knowledge and experience of technology it needs to be a "compulsory part of the curriculum of all pupils". (Technology in Schools, 1985, p.27) Including a course in computer based control in the first and second year curriculum of secondary schools would go some way to providing this experience. Such a course would also address the problem identified by the HMI who found that "the early years of the secondary school appear to be almost devoid of technological content in CDT courses". (Technology in Schools, 1982, p.15).

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Computer based technology promotes problem-solving skills

In the preceding chapter, problem-solving was identified as an important component in the child-centred curriculum being offered by many primary schools. In the process of solving a novel problem the learner will need to choose a strategy. If (s)he has not encountered this particular problem (s)he will need to search through the strategies which (s)he has used previously and look for similarities between the problem which (s)he is trying to solve and those which (s)he has solved in the past. (S)he will then select a strategy which (s)he thinks will have the most chance of success, and either by reasoning or by experiment, (s)he will test his strategy. As (s)he converges on a solution the success or lack of success which (s)he encounters as a result of using the various strategies will modify the way in which (s)he tackles any novel problems in the future. In the process of problem-solving the learner is exercising control over his thinking. He is developing his problem-solving skills. If a solution works, or is at least partly effective, the child will gain confidence to tackle further problems.

By solving problems the learner has to think about how he has solved previous problems. Through this process he will come to a better understanding as to how he learns and will hopefully become a more efficient learner. In order for the learner to become a better learner, he must be given the opportunity to practise decision making regarding the selection and application of evaluation strategies.(Baird J.R., 1986, p.226)

"If there is a single, central lesson to be derived from years of research on learning sets, it is that animals (including man) learn generalised problem solving skills through repeated experience with different problems of the same type." (Cole M., 1977, p.81)

Computer based control is capable of providing a wealth of problem solving activities which are relevant to the child. By providing pupils with the opportunity to engage in problem solving activities which are likely to motivate them and in which they are likely to experience success they will become more confident and more willing to tackle more complex problems in the future. Through this process they will hopefully develop more efficient strategies along the way.

The way in which pupils approach a problem is important when we consider the range and complexity of the equipment which surrounds them in their everyday lives. A very large proportion of society cannot attempt to understand the workings of the devices which they use. The domestic washing machine is no longer a user repairable device, and the car is rapidly following the same route. These developments are increasing the feeling of helplessness which affects many people, so that fewer people can now pride themselves on being an expert on a particular device, or on having the ability to repair it.

Considering the current pace of development in technology it would be unwise to propose that an education system should aim to educate people so that they can become experts on current technology. Today's technology is already out of date. It could be argued that teaching the majority of pupils about the components which are associated with a particular technology would be of limited value, and that it would be more useful for pupils to develop a systematic approach to problem-solving.

The systems or black-box approach to problem solving assumes that the solution is a system, and that this system can be described in terms of subsystems (black boxes). Each black box will perform a specific function, and it is the function which that black box performs that is the concern of the learner, not the contents of the box. By devising a solution to a particular problem at black box level the learner is in fact producing a model of the problem, and as modelling is a process with which he is likely to be familiar, he is therefore more likely to experience success. By promoting this systems approach to problem solving in a practical context through making use of today's technology (inside the black boxes) pupils will acquire a functional understanding of the devices which surround them in their everyday lives. As well as going someway to demystify, technology this approach would also equip pupils with an approach to problem-solving which would be useful regardless of the technology.

Control as a Cross-Curricular activity

Computer based control is capable of "crossing subject areas with little respect for the subject specialist, and can even extend both the primary and secondary curriculum".(Bostock M., 1986, p.34) Ballerini suggests that computer control presents an opportunity to bring together and develop in a meaningful way a range of skills and experiences which have been acquired in many different areas of the primary curriculum. He considered that:-

"It enshrines the best of Plowden. It is, if you like, the fruit of a co-operative, investigative approach. It promotes learning. It allows the poorest to succeed in the same area as the most able whilst being so open ended as to be only limited by the bounds of the pupils' and teachers imaginations. In a world obsessed with computer promoted unemployment children can learn how it is they, who can be in control." (Ballerini A., 1985, p.10)

It could be argued that as control is a component of a number of different curriculum areas, it is by its very nature a cross-curricular activity. The position of control as such an activity is strengthened when one considers that both Technology and Information Technology are themselves seen to be cross-curricular activities.

The value of cross-curricular activities is acknowledged in the Curriculum from 5 - 16 (1985, p.10). This report argues that unless each subject is taught with close reference to others, there is a risk of "losing that very breadth and 'wholeness' which most schools, in their aims, undertake to provide". Competencies learnt in different curriculum areas can be used in the solution of a problem.

Problem solving activities in computer based control would give application to, and would "enrich and add interest to what is taught in other subjects". (The School Curriculum, 1981, p.17)

It is clear that problem-solving is being given greater emphasis as a curriculum activity, but in many instances the resources available in a school will limit the number of activities in which it would be feasible for pupils to work on their own. This would almost certainly be the case with computer based control. Pupils are becoming increasingly involved in group activities, and although often necessitated by limited resources, "most academic teachers would agree that teaching and learning in small groups has a valuable part to play in the all-round education of a student" (Jacques D., 1984, p.xi) The Schools Council identified "the ability to work in a group" as one of the "handful of fundamental skills" which allow pupils to learn. (The Practical Curriculum, 1981)

The main advantages of a learning environment in which pupils work in groups is that members will have an expanded range of knowledge and abilities to draw on and through interaction within the group they will develop collaborative skills. In a small group environment pupils are less likely to be inhibited by the other members of the group or by the teacher. They are therefore more likely to use tacit knowledge and the intuitive approach to problem-solving which they had developed though their primary school experience. Through this active experimentation all pupils will develop procedural understanding.

Computer based control and the development of Technological Capability

"The area of doing, managing and making is increasingly being referred to as capability". (Toft P., 1985, p.26)

The Assessment of Performance Unit (Understanding Design and Technology, 1982, p.2) define technological capability in terms of twelve competencies, these then being classified as either skills, value judgements or knowledge. They conducted a survey of the teachers of 14-16 years old pupils to determine which subjects aimed to develop technological understanding and competency. The survey also established to what extent each of the subjects aimed to foster each of the twelve competencies. The results of the survey shows that of the five competencies which they classed as skills, implementation was considered to be a substantial aim in only a few curricula areas. This would tend to reflect the low value and status which has traditionally been afforded to procedural knowledge.

This low status has contributed to the poor image of Technology which was discussed in Chapter 2. Page and Nash suggest that one way of improving the attitude of pupils towards Technology would be for them to engage in practically based scientific work and problem-solving activities. (Page R. and Nash M., 1980, p.61)

The Hypothesis

I have argued that computer based control is a worthwhile curriculum activity for twelve and thirteen year old children; that it could be introduced using approaches with which they would be familiar; that they would be motivated by the activities and that they would develop procedural understanding.

Chapter 4.

Towards a course in computer based control

My hypothesis is based upon the premise that twelve and thirteen year old pupils are able to handle the concepts, procedures and apparatus associated with computer based control systems. The absence of documented research into computer based control at this level means that evidence to support this premise would need to be drawn from the experience of other curriculum areas.

The Micro-electronics For All (MFA) Course, although not specifically designed as a control technology course, does provide some experience of the principles of control. This course is aimed at pupils from the complete range of ability and does require pupils to handle relatively complex apparatus. The course is based upon: four input and three output transducers; the AND, OR and NOT logic gates; memory and counter circuits; an interface and a number of plug-in output modules. By using the basic logic boards, pupils can assemble dedicated control circuits. By using the memory and counter modules it is possible to repeat a control sequence. The computer module allows the transducers to be interfaced to either an RML or BBC microcomputer. In this form it becomes a computer based control system. Personal experience of the course and the evidence provided by the schools' trials of the Course would support my premise that pupils would be able to handle relatively complex apparatus. (Microelectronics For All File 4.)

Much of the content of the MFA course is relevant to micro-electronics or information technology courses but is not essential for a course in computer based control.

Introducing logic gates, counters and memory systems to a computer based control course is to introduce unnecessary complications. In order to test my hypothesis I needed to provide pupils with experience of computer based control by means of a course of study, and, as I was unable to identify a suitable course, it became necessary to design one.

The foundations on which to build - A survey of ownership, and attitudes towards, technical construction kits

I have suggested that technological modelling might provide the foundations upon which a computer based control course could build. Children of both sexes and of all abilities can be observed, from the age of 4 to 14+, 'playing' with technical construction kits.

In order to establish what common experience pupils had of technical modelling a survey was conducted of all pupils in the first and second years of an 11 - 18 comprehensive school. A copy of the questionnaire used and the data which it provided is presented in Appendix 1. The table below gives a breakdown of the pupils involved in terms of ability and sex.

Ability Band

	Upper	Middle	Lower	Total
Male	41	73	48	162
Female	62	87	28	177
Total	103	160	76	339

The table below shows the number of pupils who had either owned, or who had used, a construction kit. The kits covered by the survey were LEGO, Meccano, Fisher Technic and LEGO Technic.

Owned or Used a Kit

Ability Band

	Upper		Middle		Lower		Total	
Male	40	97%	71	97%	47	97%	158	97%
Female	56	90%	86	98%	22	78%	164	92%
Total	96	93%	157	98%	69	90%	322	94%

The data suggests that the majority of pupils had some experience of using a construction kit, and that this use did not depend upon sex or ability. Of the kits covered by the survey, LEGO had been owned or used by 292 (86%), Meccano by 126 (37%), LEGO Technic by 51 (15%) and Fisher Technic by 13 (3%). More than half of the pupils (56%) had either owned or used one of the more technical kits (Meccano, Fisher Technic or LEGO Technic).

Pupils were asked to rate the kits in terms of how interesting, or how difficult they were to use. Since LEGO was clearly the most popular medium, the data provided by pupils who had either owned or used LEGO or LEGO Technic has been tabulated below.

Interest (n=339)

	No.	%
Very interesting	52	15
Interesting	121	35
Average	110	32
Boring	29	8
Very Boring	15	4
(Ambiguous)	12	-

Difficulty Level n=339

	No.	%
Far too difficult	1	-
Difficult	13	3
Average	71	20
Easy	134	39
Very easy	106	31
(Ambiguous)	14	-

The majority of pupils (83%) considered that the LEGO and LEGO Technic construction kits to be of average or above average interest, while 91% of pupils considered them to be average or below average in terms of difficulty of use. This first survey established that the majority of 11 - 13 year old pupils had had some experience of using construction kits and that more than half of the pupils had used a technical kit.

A practical assessment of the ability of pupils to use LEGO for technical modelling

In order to determine whether pupils could follow instructions and to test if they could employ the various technical fitting techniques it was necessary to design and administer three short practical tests. The LEGO Technic kit was chosen for use in the tests both because of its similarity with traditional LEGO, which many pupils had experienced, and because of the technical modelling which it allowed.

In order that the pupils involved in the tests should be representative of the ability range, two pupils were chosen at random from an upper, a middle and a lower ability class in both the first and second years. A total of twelve pupils took part in the tests. All three tests were completed in a forty minute lesson. Pupils were allowed a maximum of ten minutes to complete the first test, a further ten minutes for the second and fifteen minutes for the third test.

In the first test each pupil was given a LEGO Technic kit (Technic 1) and a copy of a worksheet on which there were photographs of 5 simple LEGO assemblies (Appendix 2a). They were asked to make all of the assemblies which were shown on the worksheet. In order to do this, pupils would need to use all of the common LEGO Technic fitting techniques. All pupils were able to identify and use the necessary fitting techniques although some pupils took longer to 'work them out'. Ten of the twelve pupils were able to identify the various components shown on the photographs, and were able to relate them to the actual LEGO components. The other two pupils although able to identify components of the correct colour and with the required features, found it difficult to select components having the required dimensions.

In the second test, the same pupils were asked to follow the instructions given on a LEGO Technic worksheet (Appendix 2b). The instructions were in a graphic form and described how a simple pulley system could be assembled. Pupils encountered very little difficulty with this test. They were able to read the instructions (photographs/diagrams) and were able to translate them into LEGO models.

The third test presented pupils with a sketch (Appendix 2c), which showed a box with a line drawn from it, over a wheel and on towards another wheel. They were asked to make a simple crane which would lift a standard LEGO brick. It was suggested that the sketch might help them. Pupils experienced considerable difficulty with this test. It was obvious that they were aware of the function of a crane and that they needed to use a winder and a pulley. However, construction of the framework and the positioning of the main pulley deteriorated into a trial and error exercise.

The data provided by these tests suggested that pupils were able to engage in technical modelling when it was of a prescriptive nature but that they encountered difficulty when the modelling took a more creative or functional guise. It was apparent from listening to the pupils that they had a limited technical vocabulary, and therefore, before proceeding further, it was necessary to establish a vocabulary which could be used in the course.

Establishing a Technical Vocabulary

In order to establish a technical vocabulary, a test was devised in which 64 pupils were asked to describe a number of LEGO Technic components. The components were fixed to boards (See Appendix 11a) and the boards were presented in turn to all of the pupils. They were asked to describe the components. The words which pupils used most frequently in their descriptions have been listed in Appendix 11b.

The data confirmed that pupils did have a very limited technical vocabulary and as a result they tended to describe components in terms of their colour, relative dimensions, shape and features. It was apparent that the majority of pupils were not familiar with terms such as 'gear', 'axle', 'pulley' or 'screw'. Indeed surprisingly few pupils used the term 'brick', so that when describing a standard LEGO brick, the majority of pupils would explain that it was red and large, with very few pupils thinking it necessary to give actual dimensions. A number of pupils did explain that it had two rows of four bumps/humps.

Assessment of pupils' ability to identify common mechanisms

Mechanisms play a major part in most computer based control systems and as such would be part of any control course. Whilst it may not be necessary for pupils to be able to name mechanisms, it was felt important that they have a 'feel' for what they do. Therefore, although a limited vocabulary had not prevented pupils from successfully engaging in modelling activities, it was thought necessary to determine what common experience of mechanisms the pupils had.

Fifty pupils from two second year classes, one a middle and the other a lower ability band class, were shown seven LEGO models (See appendix 12). Each of these seven models was based on a different mechanism which were as follows: a lever, a winder, a belt and pulley, a rack and pinion, a straight gear, a worm gear and a bevel gear. Pupils were asked three questions:-

1) What does it do?
2) Where have you seen it before?
3) What happens when the handle is turned?

Question 1 in retrospect was a very difficult question and produced very little useful data. The results for questions 2 and 3 are tabulated below. In question 2 there was a tendency for pupils to describe the mechanism in a 'it looks like a -- ' style. Answers of this type were not accepted. Answers were only included in the count if it was clear that the pupil had associated the LEGO mechanism with one which they had encountered in real life.

Pupils who recognised the mechanism (n=60)

	No.	%
Lever	41	68
Winder	39	65
Belt + Pulley	31	51
Rack + Pinion	12	20
Straight Gear	8	13
Worm Drive	3	5
Bevel Gear	3	5

What happens when the handle is turned? (n=60)

	No.	%
Lever	32	53
Winder	25	41
Belt + Pulley	19	31
Rack + Pinion	18	30
Straight Gear	15	25
Worm Drive	12	20
Bevel Gear	21	35

The data suggests that pupils were more familiar with some mechanisms than they were with others. They were most familiar with the lever, the winder and the belt and pulley and least familiar with the worm and bevel gear. It was interesting that only 5% were able to recognise the worm drive, yet 20% were able to say what happened when the handle was turned. This trend was also apparent with the bevel gear, the straight gear and the rack and pinion. With these mechanisms pupils appeared to experience less difficulty in understanding what they did at 'the handle was turned which turned a small cog, which moved the comb (rack) along' level, than when asked to relate them to mechanisms which they were familiar with.

It was clear that pupils did not have a common experience of, or interest in mechanisms. Certainly, the majority of pupils did not share Papert's enthusiasm for mechanisms, and it would be safe to assume that most pupils were familiar only with the lever and winder.(Papert S, 1982, p.vii)

A course in computer based control

The data provided by the survey and short trials would suggest that pupils had some common experience of technical modelling and some had favourable attitudes towards such activities. It also identified creative modelling and mechanisms as two areas in which pupils had limited experience. However if a computer based control course was designed carefully, this limited experience should not present major problems, and it would be likely that such a course could provide opportunities for pupils to extend their experience in a meaningful way.

Accepting that pupils should be able to handle the technical modelling element, it was necessary to determine whether they could come to terms with the other major components of a computer based control course. Such a course would require pupils to use transducers, interfaces and control programs in a problem-solving environment. In order to assess how well pupils would perform in such an environment and how well they would come to terms with the concepts and apparatus involved, it was necessary to develop a course and the supporting curriculum materials.

The course aimed:-

1) to stimulate and foster an interest in, and an enjoyment of technology;

2) to develop the skills and competencies which will enable the pupil to engage in practical problem solving activities;

3) to promote an awareness of control technology.

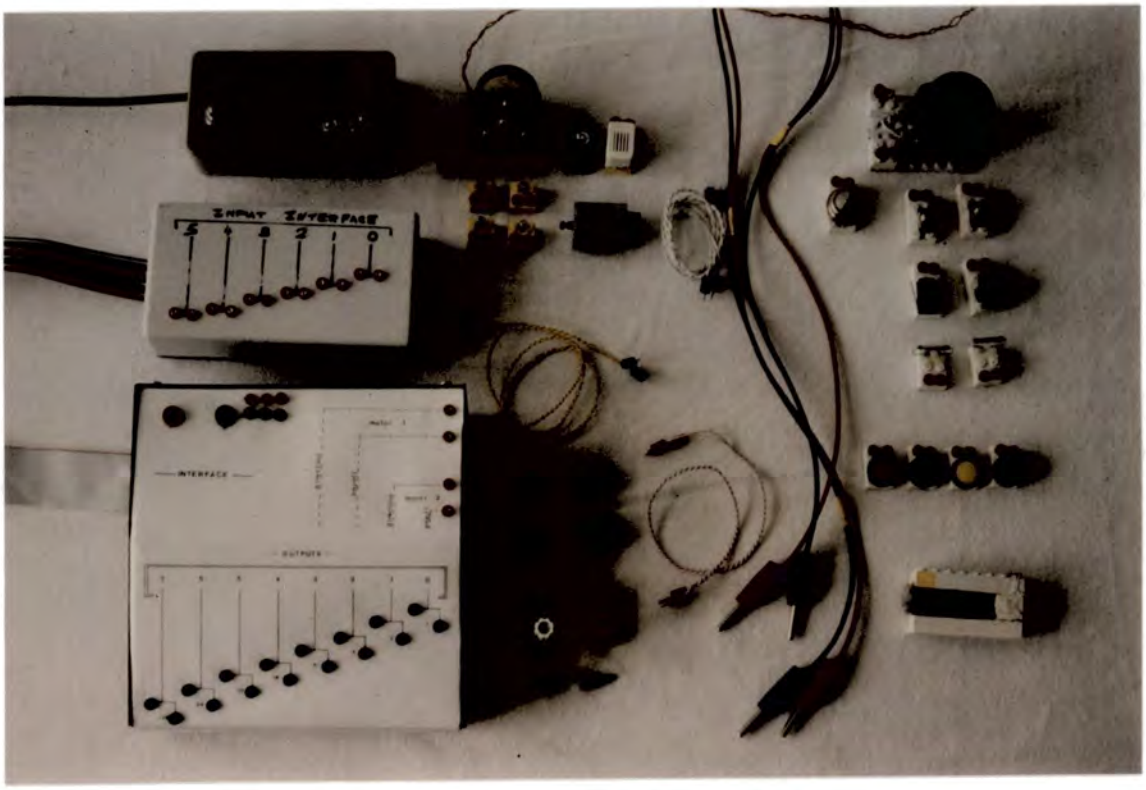
It must be stressed that the course was designed solely to assist with the validation of my hypothesis and as such made a number of assumptions and compromises. The course relied on skills, concepts and knowledge which would be developed in many curriculum areas. It relied on a knowledge of simple electrical circuits, of structures, gears and mechanisms, and on a basic level of competence in programming. A detailed outline of the course is given in Appendix 3.

Supporting Materials

The course required that pupils should have access to: a construction medium which they could use; a range of transducers which were compatible with the construction medium; input and output interfaces which could be interfaced to the available microcomputer systems; and a suitable control language.

As a result of the data provided by the early trials LEGO Technic was adopted as the construction medium. The remaining hardware requirements created a number of problems. I was unable to identify any commercially available transducers which were compatible with LEGO, and so a number of common transducers were fixed on to standard LEGO bricks. The transducers were selected so that pupils could relate them to those which they were likely to encounter in their every day lives. The transducers were wired to 1mm sockets which were also mounted on the bricks. The input transducers used were:- light sensors, toggle switches, push switches, tilt switches, magnetic switches and pressure switches. The output transducers used were:- motors, bulbs and buzzers. By requiring that the transducers could be interconnected (i.e. a light sensor should be able to directly control a motor), the output from the light sensor had to be amplified. This resulted in a rather clumsy unit requiring its own power supply.

Although there were a number of interfaces on the market which could have been used, they tended to be very expensive, often were dual purpose input/output units and did not use 1mm plugs which were required by the transducers.



The BBC microcomputer was adopted for use in the course. Although the choice of computer system was determined by the hardware available in the trial school, it would not be untypical of that available in the average comprehensive.

Eight input, and four output interfaces were designed and constructed specifically for the course. The interfaces each had eight channels. The input interface was connected via the user port, and the output interface to the printer port on the BBC computer.

BITS, a programming language developed by the South Yorkshire and Humberside MEP Resource Centre, was chosen as the control language as it bore a close resemblance to the version of LOGO which pupils had used during their first year Information Technology Course. While BITS is not an ideal control language as it has many weaknesses and limitations, it was considered to be the best language available at the time.

These resources meant that a LEGO model could be built, the transducers mounted onto the model and then connected to the interfaces. A control program could be written to control the model. This approach allowed systems to be rapidly constructed, interfaced and brought to life.

Chapter 5.

The Course Trials

The course was trialled in a seven form entry 11-18 rural Comprehensive school. The school operated a broad ability banding system in which two forms belonged to the upper band, three to the middle and two to the lower band. With the exception of one middle band and one lower band form, all second year pupils were involved in the trials. The course was followed by one hundred and thirty two pupils and it was presented as a module of an Information Technology course.

Assessment Objectives

In order to provide a 'yardstick' with which to judge the relative success of the course, a number of learning outcomes were established and are listed below.

Having completed the course pupils should be able to:

1) Identify, name and classify a given transducer,

2) Select a transducer for a given application,

3) Predict the effect of a given output code,

4) Predict the input code which would be generated under given conditions,

5) Design a control program to solve a given problem,

6) Enter and test a given control program,

7) Design and test a control sequence in order to solve a given problem,

8) Amend a control program,

9) Design appropriate test data for a given control program,

10) Design and assemble structures and mechanisms to solve given or perceived problems,

11) Assemble simple structures and mechanisms from written or graphic instructions,

12) Explain the function which would be performed by the transducers in a given control system,

13) Assemble a control system from written or graphic instructions,

14) Select, position and interface transducers in the solution of a given or perceived control problem,

15) Demonstrate an enjoyment in the use of technology.

Assessment of the Learning Outcomes

In the absence of any established tests, a number of questions/tasks were devised, some of which required written responses while others were of a more practical nature. The questions/tasks were compiled into four written tests, sixteen practical tests and a questionnaire. In order to help with the administration of the tests and the analysis of the results, each test was given a name (e.g. "Transducer", "Washing Machine" etc.) Copies of the written tests are included in Appendix 4, the practical tests in Appendix 5 and the questionnaire in Appendix 6.

In general, the written questions sought to assess how well a pupil had come to terms with the concepts involved, while the practical experiments were more concerned with assessing procedural understanding. Assessment of attitude was based on the results of the information provided by the questionnaire, and on the observations of the course tutor.

Commentary on the course

The course was presented in as practical a manner as possible within the constraints of the timetable and available resources. The style of the course tended to be class based followed by group practicals. When working on practical assignments or exercises pupils worked in groups of 3 or 4, except when the activity involved the use of an output interface when the group size would increase to a maximum of 7.

The course introduced a range of common transducers. Pupils were encouraged to use the transducers to set up simple circuits and to discuss typical applications for each of the transducers. A distinction was made between transducers which provide information (input transducers) and those which cause something to happen(output transducers). The input interface was introduced as a device which allows input transducers to be connected to a computer and as means of protecting the computer. Pupils were given the opportunity to interface a number of input transducers and to enter control programs which would display the status of the input transducers.

Pupils were introduced to an information processing view of a control system, and they discussed the role of the control program, the interfaces and the transducers. They then took part in practical sessions in which they developed and tested programs which produced given output codes. Pupils devised and tested programs which switched on, or switched off specified transducers.

Pupils were shown how it was possible to repeat a sequence of instructions within a program, and how this would allow them to output specified output codes in response to given input conditions.

Pupils investigated a number of applications in which a motor was used to open or close, or raise or lower, something. These applications tended to rely on a motor which could be made to rotate in either a clockwise, or an anti-clockwise direction. Throughout the course pupils were encouraged to perform practical experiments and to relate their activities to everyday computer based control systems.

The course was presented by an experienced teacher who had not encountered computer based control prior to her involvement in the trials. She considered that the majority of pupils had enjoyed the course and that they had been motivated by the activities. Moreover she reported that this interest and enjoyment was common to both girls and boys, and that the less able pupils appeared to enjoy the course as much as the more able.

Early concern that the 1mm plugs which were used might present some mechanical or handling problems proved to be unfounded. On the whole the hardware proved to be very reliable. The light sensor seemed to present pupils with most problems in that they had difficulty accepting that the light sensor should require four connections to be made when all other transducers worked quite happily with two.

The only major problem with the course was that the thirty-five minute lesson severely restricted the activities. Pupils had to be stopped from working!

The Written Tests

Administration of the Tests

The module was completed in 17 weeks. This included 3 weeks taken up by the written tests, 2 weeks by the practical tests and 1 week by the questionnaire. As a result of unforeseen circumstances it was only possible to administer three of the written tests, "Transducer", "Interface" and "Washing Machine". "Transducer" was completed after lesson 2 , "Interface" after lesson 10, and "Washing Machine" at the end of the course.

The tests were conducted under normal examination conditions, each pupils being given a question paper and a sheet of file paper. Each test was completed within a thirty five minute lesson.

Commentary on the Tests

Although 132 pupils took part in the tests, not all pupils were present for all of the tests. "Transducer" was completed by 124 pupils, "Interface" by 100 and "Washing Machine" by 118. The data from the written tests is presented in Appendix 7. In order to assist with the interpretation of the data, Appendix 8 and Appendix 9 shows the same data in a reduced form.

In the discussion which follows the data from the individual questions is considered in the light of the data provided by Appendix 8 and 9, and the discussion is organised around the learning outcomes listed at the beginning of the chapter.

Outcome 1 - Identify and Classify a Transducer

The pupils were shown a slide of all of the transducers which had been introduced during the course. When asked to name nine of the transducers (question 1 "Transducer"), three quarters of the pupils, (73%) were able to correctly name more than 4 of them. Table 1 gives a breakdown of the data in terms of the individual transducers.

Table 1

Identify, and name a transducer from a given photograph.

	No.	n=124
Light sensor	77	62%
Motor	88	70%
Pressure switch	83	66%
Magnetic switch	76	61%
Toggle switch	84	67%
Tilt switch	97	78%
Buzzer	81	65%
Bulb	83	66%
Micro switch	60	48%

In the second part of this question pupils were asked to identify which of the transducers shown on the slide, were used for input and which for output. More than one half of the pupils (59%) were able to correctly classify more than 4 of the transducers.

Pupils demonstrated that, in addition to being able to name the common transducers, they were also able to name the more obscure transducers (i.e. the tilt switch and the micro-switch), which they were less likely to have encountered in their everyday lives. The data suggests that pupils found it more difficult to classify the transducers than to name them.

Table 2 shows the number of pupils who correctly named and classified each of the transducers. From this data it would appear that pupils experienced the most difficulty with the light sensor, the magnetic switch and the micro-switch.

Table 2

Name and Classify a transducer from a photograph

		No.	n=124
Light sensor	input	50	40%
Motor	output	76	62%
Pressure switch	input	63	52%
Magnetic switch	input	46	38%
Toggle switch	input	76	62%
Tilt switch	input	62	51%
Buzzer	output	63	52%
Bulb	output	75	61%
Micro switch	input	45	37%

In question 1 and 2 ("Washing Machine") pupils were given a sketch of a Washing Machine. Included on the sketch were eight transducers. 5 of these transducers, (the level switch, temperature switch, water valves [in and out], and heater), had not been specifically covered in the course. The pupils were asked to classify the transducers as either input or output. The results are tabulated in Table 4.

Table 4

Classify transducers from an application

		No.	n=118
On/off switch	input	81	68%
Level switch	input	97	82%
Door switch	input	98	83%
Temperature switch	input	83	70%
Water valve(in)	output	47	39%
Water valve(out)	output	60	50%
Heater	output	74	62%
Motor	output	81	68%

Two thirds of the pupils (66%) were able to correctly classify more than 4 of the transducers. As all of the input transducers were 'switches', one might expect that pupils could have employed a selection strategy which classified all switches as input, and which did not consider the function of the transducer. This was not the case with the output transducers. The motor, which pupils would have encountered was correctly classified by 68% of pupils. However, as they had not encountered the water heater, pupils would need to think about its function before they could classify it. 62% were able to classify the heater as an output transducer.

Pupils could be expected to have some everyday experience of a heater, but few, if any, would have encountered electric water valves. The problem of classification was further compounded in that one valve was labelled Water (in) and one Water (out). Both valves ought to have been classed as output transducers, and it is clear from the results that some pupils did class the Water(in) valve as input, and the Water (out) as output. However, as more than one third of the pupils (39%) were able to avoid these distractions and correctly classify the Water (in) valve, it would seem to indicate that these pupils had a good understanding of what a transducer 'is' and what it 'does'.

Outcome 2 - Select a Transducer for a given application.

"Transducer" described eight applications in which transducers could be used, and asked pupils to select the transducer which would be most appropriate for each application. Two thirds of the pupils, (67%) were able to select transducers for more than 3 of the given applications. Pupils had to think about the phenomena which would affect the transducer as well as its function before being able to make any selection. The complexity of the phenomena which had to be considered differed in each of the applications.

The roll-over warning question required an understanding of a relatively simple phenomenon and as pupils had already been introduced to a tilt-switch, which they could easily relate to the problem, the majority of pupils encountered very little difficulty with this application.

The applications which appeared to present the most difficulty were those which involved the more complex phenonoma, i.e. the depth-warning, the audible warning and traffic sensing applications. It would appear that there may be some relationship between the difficulty which pupils encountered with an application and the complexity of the phenonoma which had to be considered. It is difficult to explain why pupils had difficulty with the audible warning questions.

It is interesting to note that of the 84 pupils who were present for all tests 24 correctly selected a transducer for the depth warning, 28 for the audible warning and 17 for the traffic sensor. None of these pupils belonged to the lower ability band. This might suggest that the general ability of the pupils might have influenced their performance.

Table 3

Select an appropriate transducer for a given application;

		No.	n=124
Tractor roll-over	(tilt switch)	102	80%
Magnetic	(magnetic switch)	74	59%
Propel a car	(motor)	85	68%
Street light switch	(light sensor)	59	47%
Depth warning	(pressure switch)	39	31%
Audible warning	(buzzer)	40	32%
Traffic sensor	(light sensor) (pressure switch) (micro-switch)	27	21%

That one third of the pupils (31%) were able to see that the pressure switch could be used to provide a depth warning demonstrated that the pupils were prepared to think about the problem and to apply knowledge which they had learnt elsewhere.

Outcome 3 - Predict the effect of a given output code.

When given a sketch of a control system and an output code (question 1a Interface) the majority of pupils (89%) were able to predict the effect of the code in terms of which transducers would be 'switched on' . Question 6 (Washing Machine) presented pupils with a similar problem but was more concerned with the implications of an output code. Nearly three quarters of the pupils (74%) realised that the effect of the code would be that the heater would be switched on, though these pupils also realised that there would be no water in the machine. In general this led pupils to conclude that the heater would " have nothing to heat".

Pupils experienced less success when they were asked to predict the code which would produce a given effect. In question 5 Washing Machine 60% were able to predict the code which would cause the water (in) valve to be switched on.

In their response to these questions pupils demonstrated that they were able to predict the primary effect of an output code and were willing to go on to consider the implications of the effect.

Outcome 4 - Predict the input code which would be generated under given conditions

Question 2 ("Interface") described a control system, gave the status of the input transducers and asked pupils to predict the code which would be generated. Nearly three quarters of the pupils (73%) were able to predict the correct code. It would seem fair to assume that the reasoning required to answer this question would be very similar to that required in question 1a. In both of these questions pupils were either given the state of the input transducers, or an output code, and asked to predict the effect. They appeared to encounter very little difficulty with this type of question.

"Interface" question 1a asked pupils to predict what state the input transducers must be in to cause the given code to be generated. Here pupils were given the effect and were asked to predict the cause. Generally pupils found this much more difficult than when they were given the cause and asked to predict the effect, and only one half of the pupils could relate the code to the state of the input transducers. This is consistent with the results from question 5 ("Washing Machine"). In order to answer this type of question pupils had to work backwards and it would appear that pupils find this type of reasoning quite difficult.

Question 4b ("Washing Machine") added a further dimension to the "what caused this" style of question. It asked pupils to predict the input code which would cause the control program to generate an output code which in turn would switch on the motor. In order to do this pupils would need to have some understanding of the basic 'cycle' through which an automatic washing machine would normally go, and would need to relate this process to the given 'model' of a washing machine.

Pupils needed to realise that before the motor is switched on the machine should be on, the temperature should be at some predetermined level, the door should be closed and the water level correct. This involves some relatively complex abstract reasoning and, not surprisingly, pupils found this very difficult as is illustrated in table 5 .

Table 5

What input code would cause the control program to switch on the motor.

Washing machine 4b

		No.	n=118
On/off switch	ON	27	22%
Temperature	OK	26	21%
Door	Closed	36	30%
Water Level	Correct	26	21%

It is interesting that the input which appeared to be most important to the pupils was that the door should be closed. The implications of the open door must have had more impact on the pupils than washing without sufficient water or at too low a temperature.

Outcome 5 - Design a control program to solve a given problem.

When asked to write instructions which would produce a given output code, the majority of pupils (87%), gave the correct commands (question 1b "Interface"). However, when asked to write a procedure to solve a given problem, only 45 pupils made any attempt at a solution; of these pupils only 17 were considered to have made a reasonable attempt (question 2c "Interface"), while only 2 pupils were able to design a procedure which could have been considered to be complete. However it is interesting to note that 10 of the 17 pupils were also able to select transducers for the more abstract applications.

Pupils appeared to experience the same degree of difficulty with this programming question as they did with the more abstract transducer and code questions.

Analysis of the data provided by the written tests

The written tests provided data on three main aspects of the course: transducers; input/output codes; and programming. To help with the interpretation of this data it has been compressed and is presented in Appendix 9.

As not all pupils were present for all tests, the following analysis relies only on the data which relates to the 84 pupils who were present for all of the tests.

The data suggest that:-

a.) Three quarters of the pupils had formed some conception of a transducer, and, to varying degrees had developed an understanding of the part which they played in control systems.

b.) Four out of five pupils had developed an understanding of input/output codes and of the role which they play in control systems.

c.) Three out of five pupils (64%) had developed an understanding of transducers and of input/output codes.

d.) More than three quarters of the pupils (87%) were able to employ simple commands in order to produce a given output code;

e.) The majority of pupils were UNABLE to design a program which required the use of anything other than simple command sequences;

All of the 17 pupils who were able to make a 'satisfactory' attempt at writing a control program belonged to the upper ability band. These pupils had also mastered both concepts and were able to reproduce the commands which would generate the required output code.

When dealing with conceptual ideas in isolation pupils performed quite well, however when the ideas relied on a number of related concepts pupils encountered greater difficulty. As the reasoning became more complex or more abstract pupils appeared to encounter difficulty.

Chapter 6.

The Practical Tests

Administration of the Tests

The purpose of the practical tests was to assess how well pupils performed in a practical problem-solving environment and to identify any problems which they might encounter with the apparatus required for such activities. The tests presented pupils with a problem which they had to solve using the available apparatus and resources. The tests are included in Appendix 5.

The 16 practical tests were administered to 120 pupils. Each test was designed so that it could be completed in approximately thirty minutes. They involved the use of the resources and the programming language which had been used throughout the module.

Eight of the tests were completed during week 15, and a further eight during week 16, of the module. The first eight tests to be administered were:- "Build", "Reverse", "Drive", "Buzzer", "Daybell", "Lawnmower", "Mechanisms", and "Gate". These were followed by:- "Car", "Burglar Alarm", "Railway Crossing", "Lift", "Traffic Lights", "Bandit", "Automatic Doors", and "Conveyor". These tests were presented to the pupils as practical projects, and not as tests.

Each member of a class was allocated to one of the eight projects, therefore each pupil would complete, in total, two tests. Before attempting these practical tests pupils had previously completed 3 written tests. Appendix 10 groups pupils together according to the practical tests which they attempted and includes details of their performance in the written tests.

The allocation to projects was purely random, and depending upon class size, generally resulted in eight groups of between two and four pupils. On the few occasions that classes had less than sixteen pupils, one test would be omitted in order that individuals did not work on their own. As far as was possible, within the constraints of attendance, pupils would work in the same groups for both of their practical tests.

The tests were conducted in a large computing laboratory which allowed a generous working space for each test. The apparatus which was required for the test was set out prior to the arrival of the pupils. If a computer was required for a particular test, it would be positioned beside the apparatus and would have the control language already loaded. The tests were observed and administered by myself and the subject teacher. Throughout the tests observations were recorded on prepared checklists or in note form.

As each group was allocated to a project they would be given a worksheet, directed to the apparatus, and instructed to read the worksheet and to follow the instructions very carefully. Most of the tests required the pupils to record some information onto their worksheet.

Commentary on the Tests

In the discussion which follows, the performance of pupils in the practical tests has been considered in the light of their performance in the written tests. In order to assist with this analysis the data from the written tests has been grouped by practical test and is presented in Appendix 10.

Outcome 6. - Enter and test a given program.

All of the groups which attempted the tests "Railway Crossing", "Bandit" and "Buzzer" demonstrated that, when given a listing of a control program they were able to enter and test it.

Outcome 7.- Design and Test a control program;

The data provided by the written tests appeared to suggest that pupils would encounter difficulty in writing all but the simplest of control programs. Many of the practical tests presented pupils with a problem in which they had to design and test a control program.

"Burglar Alarm" presented pupils with a model of a house complete with three input transducers and a buzzer. They were asked to design and test a control program for the alarm system. Four of the five groups attempted a control program and three of these groups went on to produce working programs. This conflicts with the data from the written tests which would appear to suggest that only one of the groups should have been able to develop such a relatively complex program.

It is interesting to compare the performance of pupils who tackled "Burglar Alarm" with that of those who tackled "Railway Crossing". Both of these tests could be considered to be equally difficult. However, appendix 10 would seem to indicate that the pupils who attempted these tests were of similar ability, that is, they had performed equally well in the written tests. It would then seem fair to assume that pupils would experience the same level of success with both of these tests.

This was not the case. None of the groups which tackled "Railway Crossing" were able to produce a working program, and, as an activity, this test did not appear to attract, or maintain, the interest of the pupils. The groups had ample time to design the program but they seemed to be disappointed with the relative simplicity of the project compared with some of those which surrounded them.

It would appear that the performance of pupils on these two tests was in some way influenced by the intrinsic interest of the activity. The interest or attraction which pupils had for an activity appeared to affect their motivation which, in turn, influenced their performance.

If the practical tests were to be ranked on their motivational value, I would suspect that "Lift" would be near the top. In this test pupils needed to construct a winding mechanism, position and interface the transducers, and to design and test a control program. In the time available only one group progressed to the stage where they could interface and control the winder.

As an activity "Lift" had something to interest all pupils. Within the groups all pupils found that they had something to contribute whether it was in the construction of the winding mechanism or the design of the program. While thirty five minutes was not long enough to complete this test, I would argue nevertheless that this did not detract from its value as an activity. The group which did develop a program simply produced a test routine which operated the winder and as such did not consider any inputs.

"Drive" appeared to motivate pupils to a similar degree. All five groups made an attempt at a control procedure, however in the time available only one group had progressed to the stage where they tested their procedure. The other four groups were in the process of designing quite sensible procedures when time ran out. Both "Drive" and "Lift" were ambitious tests. However pupils appeared to enjoy them and all indications led me to believe that given time pupils would have solved both problems despite their complexity.

Although "Traffic Lights" asked pupils to write down the codes which would produce the traffic light sequence, all five groups interpreted this as requiring them to write the control program. Contrary to Appendix 10, which suggests that only three of the groups should have been able to write a program, all of the groups demonstrated that they were able to develop a program.

The discrepancy between what pupils might be expected to be able to do, and what they were actually able to do, deserves some investigation. The common factor in the practical tests in which this phenomenon was observed appears to be motivation, so that when motivated by an activity, pupils appeared to perform better in practical tests than their performance in the written tests might suggest.

Despite having tackled a similar problem during the module, pupils were interested in the problem and were motivated to solve it. Under normal circumstances, if pupils were presented with a problem which they had tackled previously one might expect the 'we have done it before' response. This was not the case with this activity. The program to generate the traffic light sequence was relatively simple, it did not need to consider any feedback and was therefore well within the capability of the majority of pupils.

Pupils encountered more difficulty, and experienced less success, as the programming component of a problem became more complex. All of the five groups which tackled "Reverse" encountered problems in the design of the control procedure. One group which could remember the sequence to reverse the motor, could not come to terms with the logic required. Another group was reasonably happy with this logic but could not produce the sequence which would reverse the motor. The group from the lower ability band was given considerable assistance and was the only group to develop a working program.

Pupils encountered similar problems with the test "Car". This test posed a particularly difficult problem, given the limitations of the programming language. The three groups which had been able to interface the model, demonstrated that they could design a simple program which displayed the state of the inputs. Appendix 10 would suggest that two of the groups should have been able to go on to write a control program to solve the problem. However, none of the groups were able to design a control program for this problem. The characteristics of this problem would seem to define the upper 'ceiling' of the range of problems which pupils could be realistically expected to attempt.

Only one of the four groups which tackled "Daybell" were able to design and enter a control procedure. This procedure functioned correctly after early modification. It is interesting that when presented with the same problem in the MFA course the majority of pupils would be able to solve this problem by using logic circuits.

In all of the practical tests very few groups did any preliminary design or planning before entering a program.

Outcome 8. - Amend a control program.

Three of the groups which tackled "Bandit" had to be given considerable assistance in order to incorporate a loop into the procedure. All of these groups realised that a REPEAT instruction was required but were unable to use the CHANGE command. Pupils encountered similar problems in "Buzzer" when asked to modify the control procedure. The commands which positioned the cursor during the editing process were rather difficult to master and provided the majority of the difficulty but, with assistance, three of the groups were able to amend their procedure. What was really a simple editing process proved to be very time consuming. One of the groups introduced a delay of one second (WAIT 10) rather than the required 10 seconds (WAIT 100). They realised their mistake and went on to correct it.

Outcome 9. - Design appropriate test data, and test a control program.

Generally the pupils were very thorough and constructive when testing their programs. In "Burglar Alarm" the tin foil presented an interesting problem as it produced a logical '1' when the foil was intact, and a '0' when broken. This appeared to challenge their popular conception of a transducer which would produce a '0' if everything was 'normal' and a '1' if something had 'happened'. Only one group realised that an alarm bell which could be switched off if the burglar closed the window after breaking in, would be of limited value. This group went on to refine their solution to eliminate this problem, and discussed the possibility of delaying the sounding of the alarm.

Two of the groups which tackled "Bandit" were able to explain that the bandit was not random, another group realised that something was not quite right but were unable to explain what was wrong with the system. The fourth group, which was from the lower ability band, were so pleased with the model which they had brought to life, that they were unable to conceive that there could be anything wrong with it. The procedure which was given had to be executed each time that the bandit was to run and, this was seen as a limitation, as well as a nuisance, by all of the groups. One of the groups, without assistance or prompting, were able to modify the procedure so that it ran continuously.

Outcome 10 - Design and assemble structures and mechanisms to solve given or perceived problems.

In the project "Lift", the design and the construction of the winder took the lion's share of the available time. None of the four groups were able to design and construct a mechanism which functioned at their first attempt. None of the groups made any attempt to design the winder on paper prior to assembling it. Three of the groups were able to produce a functional winder. The fourth group, although they realised that some form of gearing was necessary, were unable to assemble a working arrangement. The most common problem which was encountered was that pupils would tend to increase the gear ratio, rather than decrease it. One group attempted to introduce gearing by increasing the diameter of the motor spindle, and then wrapping the string around it, it didn't work!

Of the three groups which produced a functional winder, only one group went on to consider how the cage could be lowered. This group, although aware that the cage could be lowered by reversing the motor, were unable to test their ideas on how to reverse the motor because as soon as they disconnected the power supply, gravity returned the cage to the ground floor.

Four out of the five groups that tackled "Gate" produced a gate complete with functional hinges. Some of the hinges were very ingenious, while others imitated the actual hinges given to the groups as part of the project. The group from the least able class spent the majority of their time trying to copy the gate which was shown in the photograph. They succeeded in producing the gate but did not have time to design the hinges.

All of the five groups which tackled "Lawnmower" set about constructing something which looked like a lawnmower. None of the groups attempted to design the lawnmower before building it, indeed none of the groups really considered the design requirements. Only one group went on to modify their model so that it might have functioned. Another group designed a cylinder type mower which incorporated a motor and a switch, but which employed a direct chain drive from the motor to the cylinder. One very fast lawnmower! Although this model looked like a lawnmower, the cutting cylinder was simply a number of cogs fitted onto a common shaft.

The groups appeared to pay more attention to aesthetics rather than functional considerations. Two of the groups produced models which neither looked like, nor had any hope of functioning as a lawnmower, and yet both of these groups, when questioned, thought that their models did look like a lawnmower which they had seen. Pupils were modelling a perception which was not the hoped-for conceptualisation.

One group appeared to be very industrious and did build many sub-assemblies, but each time they seemed to be converging on a solution, they would abandon it and start again.

It is important to remember that pupils had not been formally introduced to either structures or mechanisms. Although this omission was necessary for the purposes of these trials, it was apparent that pupils did not have sufficient experience to allow them 'efficiently' to solve problems by modelling. It is interesting to contrast the ability of the pupils to model for enjoyment where they were more concerned with visual similarity, i.e. 'it looks like', and their ability to use modelling in a problem solving environment. Pupils can obviously model at the 'looks like' level but had difficulty at functional modelling.

It appeared that their conceptualisation of a lawnmower did not include many functional concepts. This could have been because the application lacked relevance or because the pupils had not developed the necessary functional/technical concepts.

Outcome 11. - Assemble simple structures and mechanisms from written or graphic instructions.

All of the five groups which tackled Build were able to follow the LEGO assembly diagrams, and to assemble a quite complex model.

"Mechanisms" asked pupils to match LEGO mechanisms with photographs of 'real' mechanisms. Of the two groups from the upper ability band, the first group were able to correctly match seven, and the second group six of the seven mechanisms. Of the middle band groups, one was able to match seven, and the other five of the mechanisms. The group from the lower band was only able to match two of the mechanisms.

The results are tabulated below:-

	LEGO mechanism (n=7)
Screw	4
Rack	3
Bevel gear	3
Lever	5
Straight gear	4
Winder	3
Eccentric	5

The second part of this test presented pupils with seven 'black boxes' each of which contained a different mechanism. The input and output shafts or levers protruded from the boxes and were the only clues to the actual mechanism which was inside the box. The groups were asked to match the hidden mechanisms with photographs of 'real' mechanisms.

Of the two groups from the upper band, both matched five out of the seven. Of the two groups from the middle band, one was able to match four, and the other group all seven of the mechanisms. The group from the lower ability band was able to match four out of the seven mechanisms.

The results are tabulated below:-

	Black Box
	(n=7)
Screw	5
Rack	3
Bevel gear	1
Lever	5
Straight gear	2
Winder	4
Eccentric	5

Pupils demonstrated that they were able to relate a LEGO mechanism to a real mechanism and that they could trace the movement through a black box.

Outcome 12. - Explain the function which would be performed by the transducers in a control system.

The tin foil across the window in the Burglar Alarm problem was new to the pupils, and yet, after an initial investigation and some discussion, all of the groups realised that if the foil was broken, this in turn would break the circuit. Four out of the five groups used the term 'broken circuit', while the fifth group were quite confident that the computer would 'know' when the foil was broken but had to be encouraged to consider how it would know. Once they directed their attention to this 'how' problem, they very soon related the foil to a switch.

When, in the same practical test, pupils were asked to explain how a light sensor could be used as part of an alarm system, three of the groups demonstrated that they had some appreciation of the part which such a sensor could play in an alarm system. This project tended to encourage very lively and detailed discussions, which on two occasions, suggested that some pupils were a little too familiar with the operation of domestic burglar alarms.

On the whole pupils were able to identify a range of transducers and could answer the 'how did the computer know' questions. The practical test 'Car', prompted a number of discussions on existing or potential automobile control systems. The systems discussed ranged from the seat belt warning light on the B.L. Metro to the seat heater on a Volvo. One group engaged in a very lively discussion as to why Volvo should not use a light sensor to switch off the side lights during the hours of daylight.

In Automatic Doors, all five of the groups were able to locate the transducers. Four of these groups were able to explain what information would be provided by each of the transducers. None of the groups realised that the motor connections should be reversed to open or close the door.

All four of the groups which tackled "Lift" realised that the magnet fixed to the cage would operate the magnetic switches, and that if these switches were to provide positional information, one reed switch would need to be positioned on each floor. Only two of the groups correctly positioned both the magnetic and the push switches, and one of these groups went on to connect the push switch on floor 1 to the magnetic switch on floor 2.

"Railway Crossing" presented a similar problem where a reed switch was to provide positional information. Three out of the four groups discovered very rapidly that there was a magnet attached to the underside of the locomotive, and that this would operate the reed switches which were fixed to the track. The other group, while accepting that the computer 'knew' where the locomotive was, showed very little interest in the project and seemed to think that it was not necessary to investigate further.

"Conveyor" showed that all five groups were able to position the motor and to attach the drive belt so that the conveyor belt would operate. They had no difficulty in connecting the motor to the power supply and in demonstrating that the conveyor worked when the power was applied. All groups were able to relate the point of sale terminal shown in the photograph to the model conveyor and to explain that the belt should stop when the groceries had moved along to the till operator. However pupils had difficulty in connecting up the circuit given on the worksheet and it appeared that the circuit was difficult for them to follow and the majority of the groups had difficulty with the four wires required by the light sensor.

Outcome 13 - Assemble a control system from written or graphic instructions

Pupils demonstrated that generally they were able to follow graphic instructions, and to a lesser extent written instructions.

Outcome 14 - Select, position and interface transducers

Pupils encountered very little difficulty when they were given either a diagram or a photograph of a system and asked to interface the transducers.

All five of the groups which tackled "Drive" demonstrated that they could follow written instructions and connect up a fairly complex system. One group made the correct physical connections but when it came to copying it onto paper they showed the switches connected to the output interface, and the motors to the input

Of the five groups which tackled "Automatic Doors", all of them were able to interface the input transducers. However one group did connect a switch to an output interface, but it was obvious that they had made a mistake when connecting up the circuit, as they had intended to connect it to an input interface. Only one group realised that the motor, because it had to reverse, needed to be connected to a 'Motor output' on the interface.

The test "Conveyor" presented problems. Three of the five groups had difficulty in translating the circuit given in the diagram into an actual circuit while only one group progressed onto the question which asked them to show how the light sensor and motor could be interfaced to a computer.

Two of the five groups which tackled the test "Bandit" were able to read the given diagram, and to realise both that the switch should not have been connected to an output interface, and that the motor should not have been connected to the input interface. Another of the groups reported, quite correctly, that there was no power supply.

Outcome 15. - Demonstrate an enjoyment in the use of Technology

The practical tests demonstrated that pupils were able to handle the apparatus confidently and with the necessary care. Rather than being intimidated by the technology pupils appeared to be genuinely interested and eager to participate in the activities. From the observations of the course tutor it was apparent that this level of interest and motivation had been maintained throughout the course.

The activities were such that all pupils had the opportunity to contribute something to the group effort. The pupils worked well in the groups. One pupil would put forward an idea or hypothesis, it would be evaluated by the group and modified in the light of the discussions. Discussions were often heated as pupils argued about the limitations and relative merits of the proposed solutions. The activities certainly encouraged interaction between pupils and I believe that this interaction contributed to the success of the activities.

What the pupils thought about the course.

The questionnaire, (see Appendix 6), was completed by 142 pupils who had completed a two year Information Technology course. 119 of the pupils had followed a course which included the Control Technology module. The remaining 23 pupils had followed the same course but instead of taking the Control Technology module they spent extra time on the File Processing and Word Processing modules. The syllabus of the IT course covered the following topics:- Communications, Programming , File Processing, Word Processing and, for the majority of the pupils, Control Technology.

The data provided by the questionnaire has been grouped by topic (module) and is summarised below:-

"What part of the Information Technology course have you enjoyed the most ?"

	Including Control Tech.		Excluding Control Tech.	
	n = 119		n = 23	
Communications	1	0%	-	-
Programming	14	11%	-	-
File Processing	17	14%	10	43%
Word Processing	13	10%	13	56%
Control Technology	66	55%	-	-
Unable to classify	8			

"What part of the Information Technology have you enjoyed the least" ?

	Including Control Tech.		Excluding Control Tech.	
	n = 119		n = 23	
Communications	4	3%	-	-%
Programming	12	10%	1	4%
File Processing	12	10%	5	21%
Word Processing	17	14%	15	65%
Control Technology	24	20%	-	-
Unable to classify	50	(writing etc.)		

"What part of the Information Technology course did you find the most difficult ?"

	Including Control Tech.		Excluding Control Tech.	
	n = 119		n = 23	
Communications	-	-	-	-
Programming	15	12%	1	4%
File Processing	2	1%	2	8%
Word Processing	14	11%	13	56%
Control Technology	47	39%	-	-%
Unable to classify	41		7	

Findings

More than one third (39%) of the pupils thought that Control was the most difficult part of the IT course. If this is considered along with the 55% who thought that it was the most enjoyable topic, it might be fair to assume that whilst being enjoyable it is also a demanding topic. Pupils appeared to favour the most recent topic which they had studied. In retrospect I believe that this apparent bias was the result of the poorly designed questionnaire. This poor design might also explain why, in response to the question "What topic did you enjoy the least ?", only 57% of the 119 pupils had produced responses which could be classified. The responses which were not classified generally mentioned 'writing' or the 'written tests' (my tests!).

Despite the obvious problems with the questionnaire I believe that it has provided sufficient evidence to suggest that pupils had enjoyed the course. This would certainly be confirmed by observations of the course tutor.

Findings of the Practical Tests

The performance of pupils in the tests would suggest that the majority of pupils were:-

a.) motivated by, enjoyed, and benefited from the investigative problem-solving activities which the course provided;

b.) able to select, position and interface the transducers to which they had been introduced and were able, by following photographs or LEGO style diagrams, to assemble control systems. However pupils encountered difficulty when they were asked to follow written instructions. or when they were asked to design structures or mechanisms which were to perform a specific function or solve a given problem;

c.) able to enter and test a given control program but encountered difficulty when they were asked to design a program to solve a given problem, or when asked to amend a program.

Chapter 7.

Conclusions.

It was clear from the trials that computer based control was capable of providing a range of learning experiences which were consistent with the previous experience of twelve and thirteen year old pupils. I argued earlier that much of the understanding which pupils would have developed from their early experience would be of a procedural nature and this was confirmed by the observations made during the practical tests. It was apparent that pupils did have a working knowledge which, in many cases, they were not able to express. They knew how to make something happen but were unable to explain why it happened or often how they had made it happen. In a traditional curriculum this tacit understanding would be given little value but to ignore this intuitive understanding is to ignore much of the pupil's early learning. The practical problem-solving approach used allowed pupils to capitalise on this understanding, and therefore to take a more active part in the learning situation. As they experienced some degree of success they become more confident, and in turn developed their understanding.

Pupils were motivated by the activities which the course provided. In Chapter 3, I argued that the intrinsic interest which control activities appeared to have could be either a result of pupils associating the activities with 'play', or because they perceived them to be relevant and therefore worthwhile. The models upon which the practical activities were based were quite 'rough and ready'. They were wooden frameworks to which transducers and mechanisms were attached. Pupils were not frightened by overly sophisticated models. They could relate the basic framework to something from their everyday experience and therefore the activity became relevant to them.

Pupils appeared to perform better on the practical tests than they did on the written tests. It was not possible to identify one single factor which would explain this improved performance. However, the two major characteristics of the practical tests were that they presented problems in a practical context, and that pupils worked in groups.

I argued in Chapter 3 that by working in groups pupils would have access to a wider range of abilities and knowledge and could be expected to experience greater success. In the practical activities pupils would put forward a hypothesis, it would be evaluated by the group and then modified in the light of the discussion. Pupils were keen to discuss the limitations and relative merits of the proposed solutions and through this process they would converge on a solution. These activities generated purposeful discussion which in turn led to negotiated decision making, and encouraged pupils to take account of each other's view. In addition to providing many opportunities for language development these activities also encouraged pupils to think about how best to approach a problem.

The trials demonstrated that computer based control was capable of providing practical problem solving activities. The range of possible activities meant that there were appropriate activities for all pupils, regardless of their sex or ability. Pupils were motivated by the activities and the majority of them enjoyed taking part. This enjoyment is often undervalued in schools. I would argue that if a pupil enjoys an activity they will become more confident, more prepared to experiment and therefore take more from the learning situation. "the prime experience we should give pupils must be that of success: confidence first, doubt later!". (Dobson K., 1985, p.190)

The research highlighted a number of problems. The problems could generally be fitted into one of two categories. The first category would embrace the problems which arose as a result of assumptions which had been made about the previous experience or ability of the pupils. The second would embrace problems of a more fundamental nature which related to the understanding which the course aimed to develop.

The course assumed that pupils had some previous experience of programming, structures, and mechanisms. In general, it was found that pupils did not have as much common experience in these areas as had been originally expected. The experience they did have had not been developed in a problem-solving environment and was therefore of limited value in many of the activities. It was clear from the survey that the majority of pupils had used construction kits, but the evidence provided by the practical tests suggested that although they were familiar with, and proficient in the use of these kits, they had difficulty designing structures or mechanisms to solve particular problems.

It would appear that most of their experience would have been gained by following detailed plans or through aesthetic modelling where the model did not have to perform a specific function. With this aesthetic modelling pupils constructed models which matched their perception of the object or device. It was evident from the practical tests that often this was not the hoped-for conceptualisation. Pupils worked at this aesthetic level even though the problem encouraged them to work at the functional level. It appeared that pupils arrived at the learning situation with a preconceived idea that modelling was an aesthetic rather than a functional process. More research is necessary to determine exactly how the preconceptions that pupils possess might influence their ability to engage in technological modelling. This is particularly important if, as Hashweh argues, preconceptions take the form of procedural knowledge, and that procedural knowledge is very difficult to change. (Hashweh, 1986, p.229) It might be that, given more curriculum time, pupils would have been able to confront their preconceptions and then been able to use their preconceptions as "building blocks".(Gilbert J.K. and Watts D.M., 1983, p.61). If this was the case such a course would have much to offer technological education.

A second assumption which had to be made at the time when the course was conceived, was that pupils had a basic knowledge and experience of programming in LOGO. It was thought that the experience which pupils had with LOGO would help when they were introduced to the BITS programming language, and to a limited extent, this was found to be true. However, it was apparent that pupils found programming difficult. Some of the problems which they encountered could be attributed to the language used, while others were related to the demands which programming made on the pupil. In order to write a program the pupil must conceptualise the problem, design a solution and then translate their solution into a program. As the problem becomes more involved so the reasoning becomes more abstract. It was unfortunate that the written test "Dry Run", which would have provided more data on the problems which pupils encountered when programming, was not administered.

There appears to be similarities between the problems which pupils encountered when programming and those they encountered when modelling. In both cases, as the reasoning became more complex or more abstract, more pupils experienced difficulty. This was particularly apparent when pupils attempted anything other than the simplest of programs or when they were asked to build a model which would perform a specific function. In both situations the burden of conceptual understanding could be seen to be greater than in any of the other activities in the course. As might have been expected pupils experienced less success in these situations.

It would appear that there might be some relationship between the number of logical 'steps' involved in a task and the difficulty which pupils encountered with the task. If the task was 'simple' enough for the pupil to be able to see the 'whole picture' they appeared to perform better than if they had to draw the picture together from many concepts/ideas/steps.

I argued earlier that meaningful and relevant situations would help pupils to develop abstract ideas. To a large extent this argument has been supported by this research. Pupils performed better than might have been expected when they were motivated by an activity.

It was not clear whether the difficulties which pupils experienced resulted from problems with the design or presentation of the course material, or whether some of the activities demanded a level of understanding which was beyond that which twelve and thirteen years olds could realistically be expected to have developed having followed a six hour course.

Recommendations

This research would suggest that computer based control is capable of providing worthwhile learning experiences. It would indicate that further research is required in order to clarify a number of issues which have been raised.

It would be important to establish what preconceptions pupils have about modelling, and to identify when, and why they had been formed. It is likely that this would have implications for all stages of technological education. It might be that the experience which pupils have of modelling, inhibits rather than promotes the development of technological capability, and perhaps contributes to the poor image of technology as an activity. It could be that the technological content of the primary curriculum as well as many popular modelling kits needs to be examined.

Further research is required to establish what programming competencies twelve and thirteen year old pupils could reasonably be expected to develop. I would recommend that a more appropriate language needs to be identified or, if necessary, developed before this research is conducted.

Index to Appendices

Appendix 1.

Survey of ownership and attitudes, towards technical construction kits.

THE QUESTIONNAIRE

1. Have you ever owned any of the these construction kits ?
LEGO ., MECCANO , FISHER TECHNIC or LEGO TEChNIC

If you have ,write down the type of kit AND how old you were when you first used it.

2. If you have owned any of these kits do you :-

a) Use it everyday.
b) Once or twice a week.
c) Once or twice a month.
d) Not very often.

3. If you have not owned your own kit have you ever used any of these kits ?

LEGO , MECCANO , FISHER TECHNIC or LEGO TECHNIC

If you have write down the name of the kit and your age when you first used it.

4. If you have used any of these kits , did you find the kit:-

a) Very interesting
b) Interesting
c) of average interest
d) Boring
e) Very boring

5. If you have used any of these kits , did you find the kit:-

a) Far too difficult to use
b) Difficult to use
c) Average
d) Easy to use
e) Very easy to use

6. Draw a sketch of the most interesting mechanism (something mechanical which moves) that you have ever seen.

7. On the back of the answer sheet draw a sketch of the most interesting thing that you have ever made.

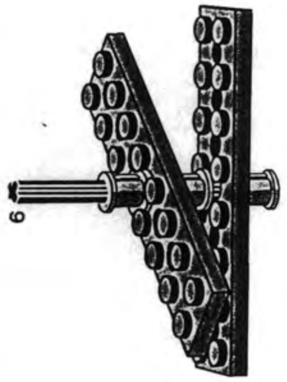
		Year 1						Year 2								
		Upper		Middle		Lower		Upper		Middle		Lower		Male	Female	Total
		M	F	M	F	M	F	M	F	M	F	M	F			
Age (Lego & Lego Technic)	<=4	4	5	5	5	2	1	6	8	12	13	3	2	32	34	66
	5	5	9	11	18	3	–	5	11	6	12	3	4	33	54	77
	6	2	5	8	5	9	5	4	3	3	5	5	3	31	26	57
	7	2	1	6	3	4	1	1	2	5	4	2	–	20	11	31
	8	–	–	1	1	–	1			3	3	2	1	6	6	12
	9	–	–	2	–	1	1		1	–	1	–	3	3	6	9
	>=10	–	1	1	–	1	–		1	2	1	3	–	7	3	10
Construction Kit	Lego	17	23	28	31	15	8	17	27	30	39	16	13	123	141	264
	Meccano	12	5	28	3	11	2	11	6	24	13	9	–	95	29	124
	Fisher Technic	–	–	3	–	3	–	1	–	1	4	–	1	8	5	13
	Lego Technic	10	1	11	1	6	–	6	–	8	1	3	–	44	3	47
	None	1	5	1	9	1	1	–	5	2	5	–	3	5	28	33
Current Use	Everyday	–	–	2	–	2	–	–		–	–	1	1	5	1	6
	Once/Twice Week	1	2	7	9	3	–	2	6	2	2	5	6	20	25	45
	Once/Twice Month	1	2	8	3	–	–	4	1	6	1	1	–	20	7	27
	Not Very Often	13	14	17	16	13	5	10	19	26	37	13	4	92	95	187
Pupils Who Have Used But Not Owned — Age (Lego only)	<=4	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	5	1	–	–	3	–	–	–	3	–	2	–	1	1	9	10
	6	–	–	–	2	–	–	–	–	–	–	–	1	–	3	3
	7	1	1	–	–	–	–	–	–	–	1	–	–	1	2	3
	8	2	–	–	–	–	–	–	–	–	–	1	–	3	–	3
	9	–	–	–	–	–	–	–	1	–	–	1	–	1	1	2
	>=10	1	–	–	2	–	–	–	–	–	–	2	–	3	2	5
Pupils Who Have Used But Not Owned	Lego	3	3	–	7	–	–	–	5	1	3	4	2	8	20	28
	Meccano	–	–	–	1	–	–	–	–	–	–	1	–	1	1	2
	Fisher Technic	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–
	Lego Technic	1	3	–	–	–	–	–	–	–	–	–	–	1	3	4
	None	–	–	–	–	–	–	–	–	–	2	–	1	–	3	3
Interest (Lego + Technic)	Very Interesting	4	3	9	2	6	–	6	6	5	6	5	–	35	17	52
	Interesting	6	5	13	15	14	5	5	11	18	14	8	7	64	57	121
	Average	11	15	7	14	–	2	5	13	11	21	7	4	41	69	110
	Boring	2	4	3	4	1	1	3	3	2	2	3	1	14	15	29
	Very Boring	–	–	–	8	–	1	–	–	2	–	2	2	4	11	15
Difficulty (Lego + Technic)	Far Too Difficult	–	–	–	1	–	–	–	–	–	–	–	–	–	1	1
	Difficult	3		1	1	1	–	–	–	2	3	2	–	9	4	13
	Average	4	6	10	7	6	3	4	4	9	8	5	5	38	33	71
	Easy	8	10	11	13	10	2	11	17	14	20	14	4	68	66	134
	Very Easy	8	10	12	19	4	4	4	12	11	13	4	5	43	63	106
Totals		22	28	35	41	21	12	19	34	38	46	27	16	162	117	330
		50		76		33		53		84		43				

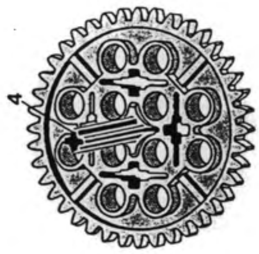
THE DATA PROVIDED BY THE QUESTIONNAIRE

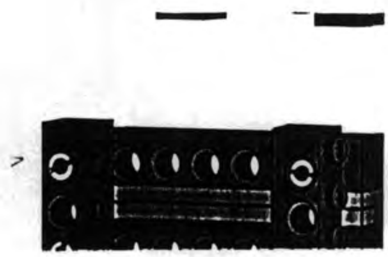
Appendix 2.

Practical assessment of the ability of pupils to use LEGO for technical modelling.

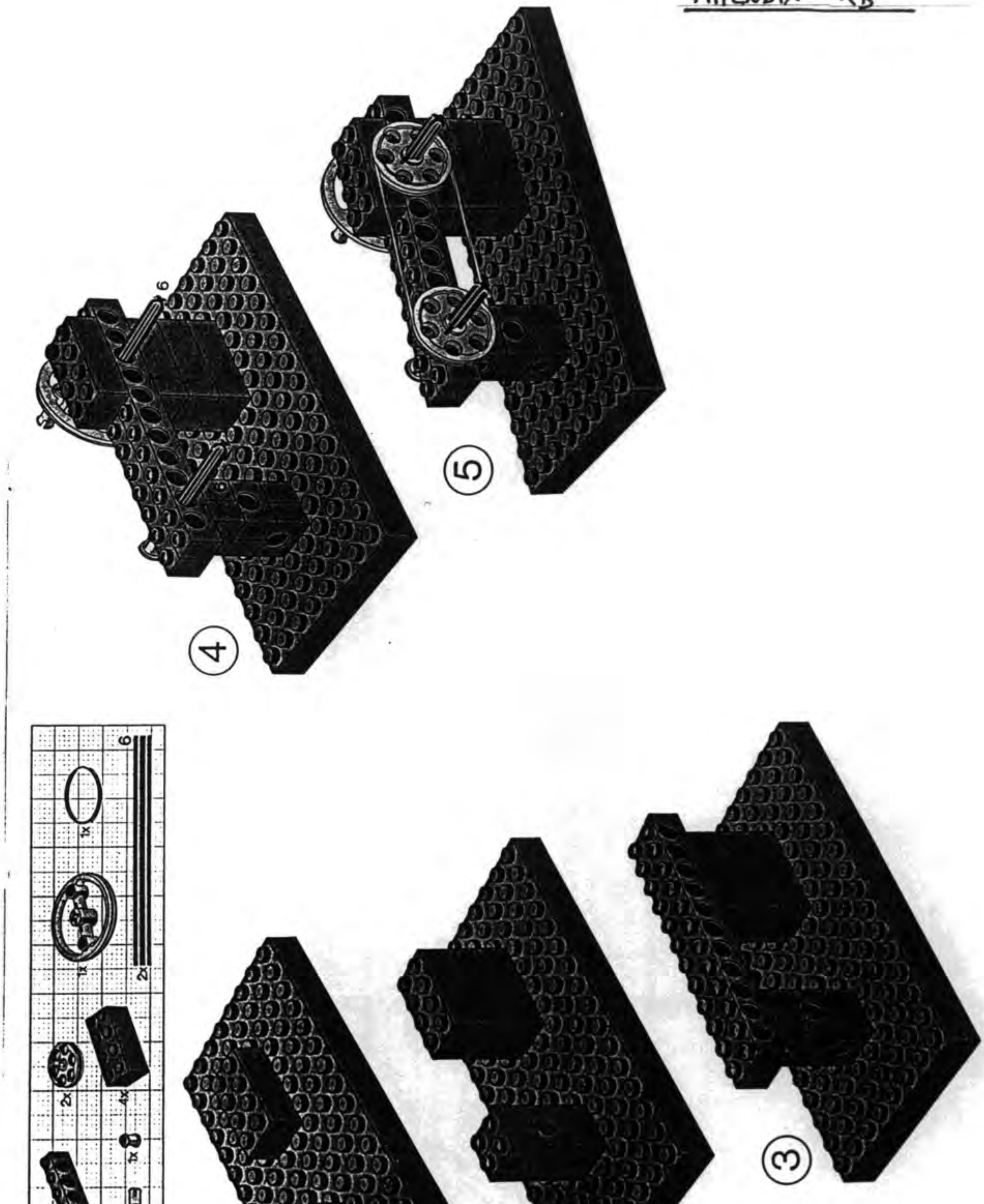
Appendix 2a



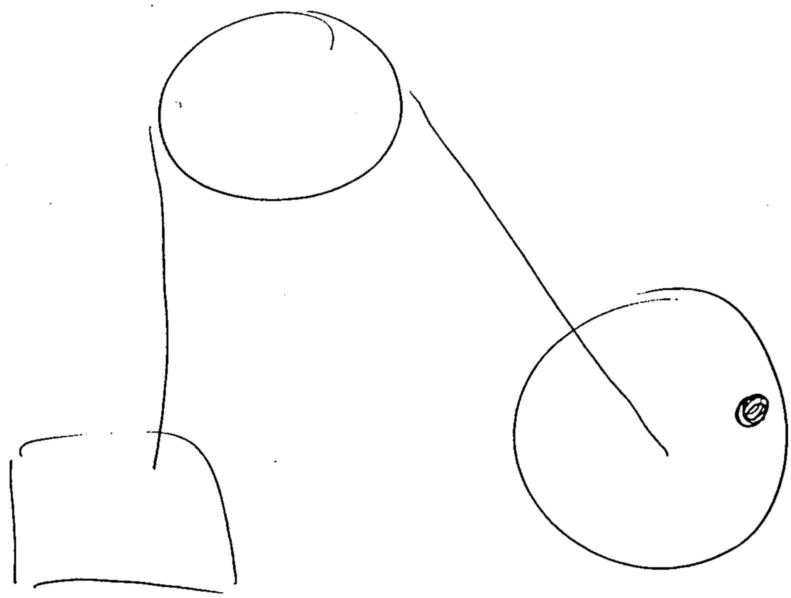




APPENDIX 2b



CRANE



Appendix 3.

A course in computer based control.

Module:- Control Technology

Pre-knowledge This module assumes that pupils have some experience of programming in LOGO and are capable of assembling LEGO structures and mechanisms.

This module aims to:-

1.) stimulate an interest in, and an enjoyment of technology;

2.) provide pupils with a practical introduction to control systems;

3.) provide pupils with an awareness of a range of common applications of control technology;

4.) provide pupils with an opportunity to apply control technology in the solution of real problems;

5.) promote an understanding of the computer as a general purpose problem-solving tool.

Having followed this module pupils could be expected to be able to:-

1.) demonstrate a functional understanding of the component parts of a control system;

2.) demonstrate an awareness of a range of common control applications;

3.) handle relatively sophisticated resources with confidence and respect;

4.) assemble and test simple control systems;

5.) design and implement a solution (including the control program) to a simple control problem.

Content.

Transducers

Introduction to a range of common transducers.(toggle, slide, push, micro, magnetic, tilt and light sensitive switches, bulbs, motors and buzzers)

Classification of transducers. (input or output, sensors or actuators)

Discussion of where, in terms of devices/equipment which the pupils are likely to come into contact with, and why, in terms of what information they provide or what function they perform, transducers are used.

The Input Interface

Discussion of the need for, and the function of input interfaces.

Demonstration of how input transducers are connected to (interfaced to) an input interface.

Demonstration of the operation of a simple control system consisting of:- an input transducer, an input interface, a microcomputer and a control program.

Programming - a simple control procedure

Discussion of the role of the control program in a control system.

Demonstration of the input patterns which can be produced by a range of transducers when they are interfaced to a microcomputer.

Class exercise - prediction of the binary input patterns which would be generated under given conditions for a range of different input configurations.

Introduction to the concept of a channel and a bit.

Programming - how to enter and execute a control program.

Introduction to, and demonstration of the following commands:- Build, Repeat, Input, Again and End.

Preparation for a practical lesson. Classroom procedures, revision of interfacing, the input window and the operation of input transducers.

Practical Session - input patterns

Pupils to enter and execute a given control procedure and to record the input patterns which are produced under given input conditions, or to predict the status of the input transducers for a given input pattern.

A Control System

Introduction to a control system in terms of an input interface, a computer system, an output interface, a control program and transducers.

Discussion of the function of an output interface.

Demonstration of the Set and Reset commands as a means of producing an output pattern.

Class exercise - pupils to use the Set/Reset commands to produce a given output pattern.

The Output Interface

Demonstration of the relationship between the value of a particular bit in the output window to the state of the output transducer which is connected to that 'channel'.

Demonstration of how output transducers can be interfacing and controlled.

Discussion of the Repeat/Again command and introduction to the Wait command as a means of introducing a delay into a sequence.

Practical Session - Traffic Lights

Pupils to interface a set of 'traffic lights', and to design, enter and test a control sequence.

Programming - Making decisions

Discussion of the decisions which have to be made by the programs which control a number of common devices.

Demonstration of the If/Test command.

Class exercise - pupils to design and test a number of control programs based on the If/Test command.

Programming - Loops

Discussion of a control application which operates continuously highlighting the need for a programming language to have a 'loop' facility.

Introduction to a conditional loop (Repeat N/Again command).

Practical sessions based on conditional loops.

Programming - Reversing a Motor

Discussion of applications/devices which rely on a motor being able to rotate in both a clockwise and an anti-clockwise direction.

Demonstrate a control sequence which will reverse a motor.

Practical problem solving exercises

Pupils to work on a number of practical problems which could make use of a control system.

Appendix 4.

The Written Tests.

Project Name TRANSDUCER.

Write your name ,form and the Project Name on the top of your sheet of writing paper.

1.) Copy this table onto your writing paper:

Transducer	Name	Input/Output
A		
B		
C		
D		
E		
F	PUSH SWITCH	INPUT
G		
H		
I		
J		
K		

Look at the slide and find transducer F . You will see that it is a push switch. A push switch is used for input .

You will see that the first line has been done for you.

2.) What does an input transducer do ?

3.) What does an output transducer do ?

4.) Write down the names of any transducers which you have seen, but which are not shown on the slide.

5.) Copy and complete these sentences :

You will see that the first sentence has been done for you.

Transducer _E_ could be used as the switch for a door bell.

Transducer ___ could be used to decide when a tractor is about to roll over.

Transducer ___ can be operated by a magnet.

Transducer ___ could be used to make a model car move forward.

Transducer ___ could be used to decide if the street lights should be switched on.

Transducer ___ could be used in a submarine to decide if it is too deep .

Transducer ___ could be used to warn a workman that a machine is over heating (hint the workman will not always be looking at the machine.

Transducer ___ could be used to find out if a car was waiting at a road junction.

Project Name DRY RUN

Write your name, form and the Project Name on the top of your sheet of writing paper

Answer all of the questions on your sheet of writing paper .

1.) Look at each of the instructions and explain what you think it does.

a) SET 1 b) BUILD RED

c) REPEAT d) RESET 4

e) WAIT 10

f) IF TEST 1=1 THEN SET 2

2.) Explain what you think each of these procedures will do .

```
g) BUILD PINK            h) BUILD BLUE
   SET 4                     REPEAT
   WAIT 5                    SET 2
   RESET 4                   RESET 2
  END                        AGAIN
                            END

i) BUILD RED
    REPEAT
    UNTIL TEST 1=1
    SET 2
   END
```

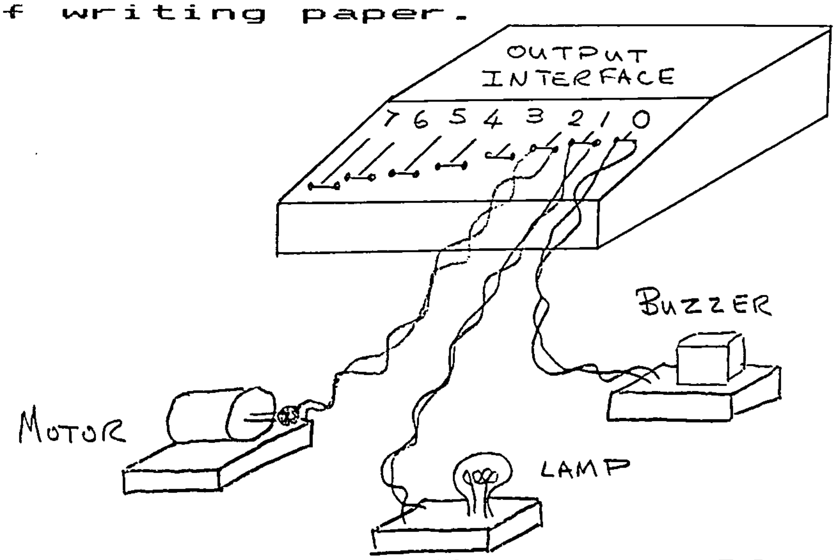
3.) Write a procedure which will set bit 0 to 1, then set bit

6

4.) Write a procedure which will change bit 4 to 0 , then change it back to 1 , then back to 0 .Your procedure should repeat this task until input bit 3 is set to 1.

Project Name INTERFACE TEST.

Write your name, form and the Project Name on the top of your sheet of writing paper.



1.) Look at the diagram. If the interface and transducers were connected up as shown in the diagram:-

a) What would be switched on if this pattern was shown on the screen:-

INPUT

7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0

OUTPUT

7	6	5	4	3	2	1	0
0	0	0	0	0	0	1	0

b) Write the instructions which will produce this output :-

INPUT

7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0

OUTPUT

7	6	5	4	3	2	1	0
0	0	0	0	1	1	0	0

c) What instructions would make the buzzer sound ?

d) What would you write to switch on the lamp ?

e) What would you write to switch on the motor ?

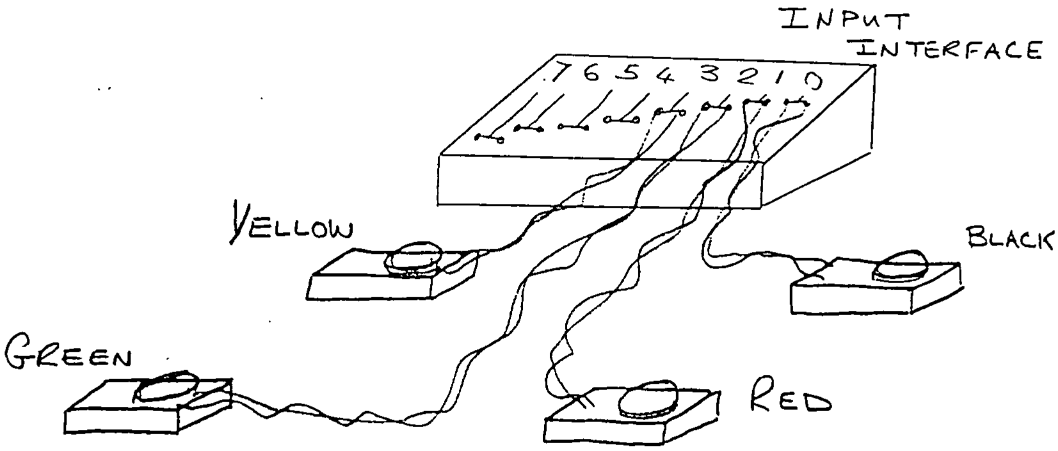
2.) In a different system a toggle switch is connected to bit 2 on the input interface and a motor is connected to bit 3 on the output interface.

a) Draw a diagram which shows this system.

b) Draw a sketch of the screen and show what would happen when the toggle switch is switched on.

c) Write a procedure which will switch on the motor when the toggle switch is switched on.

3.) 4 sensors (push switches) are connected to the interface like this :-



The screen looks like this :-

INPUT

7	6	5	4	3	2	1	0
0	0	0	0	1	0	1	0

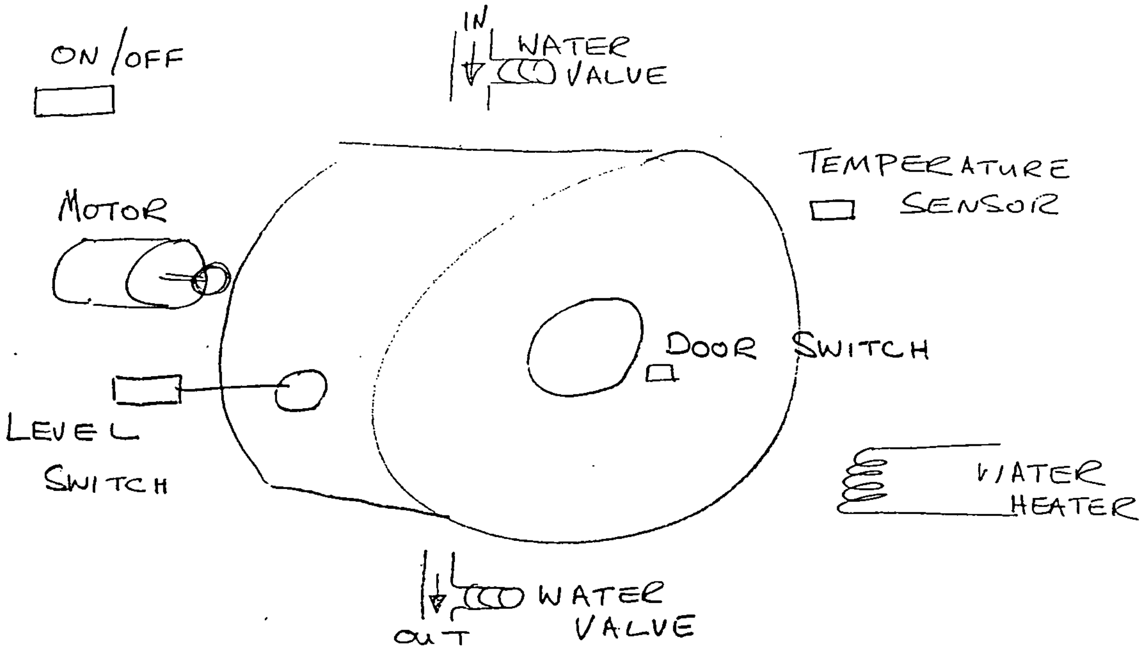
OUTPUT

7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	0

Which of the switches have been pressed ?

Project Name WASHING MACHINE

Write your name, form and the Project Name on the top of your sheet of writing paper



1.) Write down the names of the sensors which are <u>input</u> sensors.

2.) Write down the names of all of the <u>output</u> transducers .

3.) Complete this list of instructions which will wash a load of clothes.

Turn on the input valve (water in)

Wait until the water level is correct

?
?
-
-

4.) Suppose the transducers are connected to the interfaces as shown below

When should the motor be turned on ?

What would the <u>input</u> section of the screen look like then ?

5.) Show what would appear in the output screen when the water in valve is switched on and everything else is switched off.

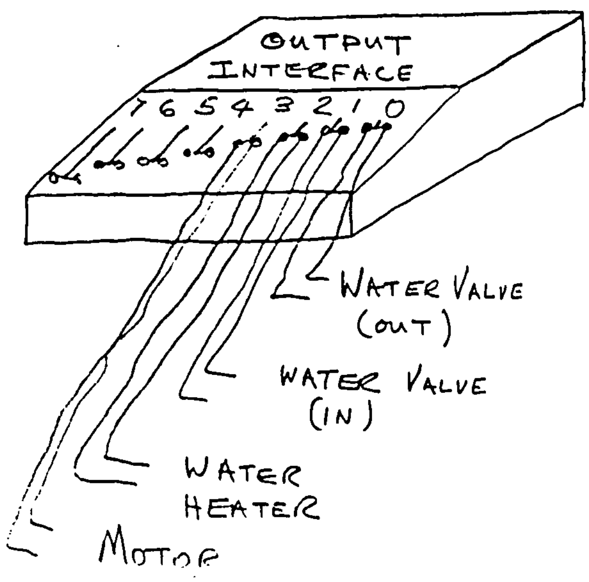
OUTPUT

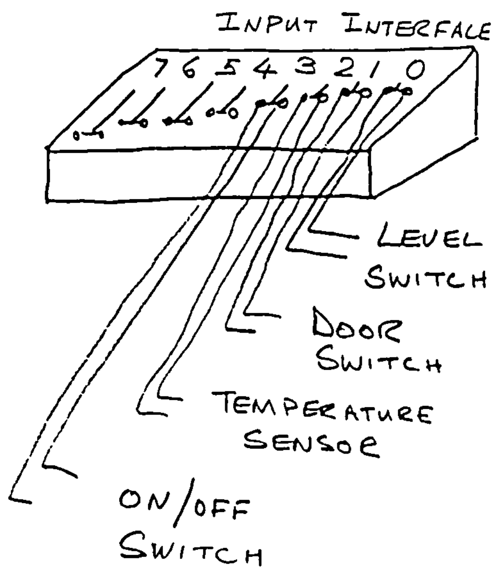
7	6	5	4	3	2	1	0
?	?	?	?	?	?	?	?

6.) What would be wrong if this pattern ever appeared in the output screen.

OUTPUT

7	6	5	4	3	2	1	0
0	0	0	0	0	1	0	1





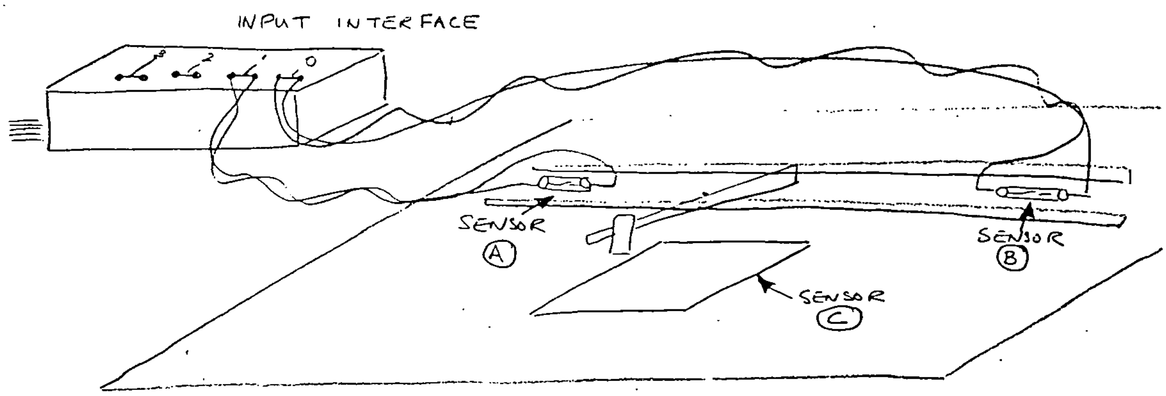
Appendix 5.

The Practical Tests.

Project Name RAILWAY CROSSING

Write your names,form and the Project Name on the top of your sheet of writing paper.

1.) Connect the sensors A and B to the input interface as shown in the diagram.



Ask your teacher to check your circuit.

2.) Type in this procedure:

```
BUILD CROSS
 REPEAT
   INPUT
 AGAIN
END
```

Type CROSS and press the RETURN key.

Move the model engine over the sensor A . Look at the screen. Write down what happens.

Move the model engine over the sensor B. Write down what happens.

3.) What information are sensors A and B giving.

4.) Write the procedure which sets the output bit 4 to 1 when the engine moves past sensor A and sets it back to 0 when the engine passes sensor B . Enter and test your procedure.

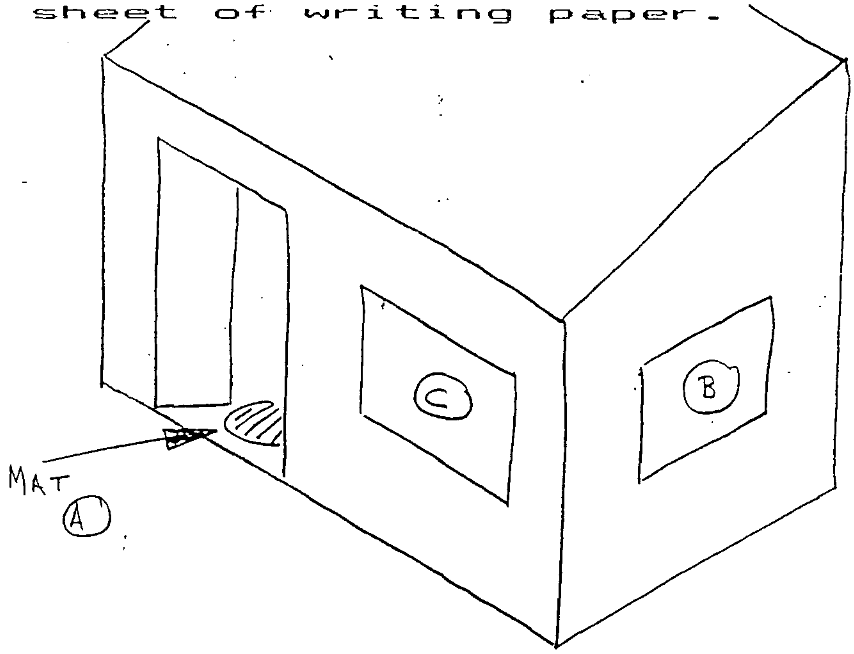
5.) With a real life railway crossing ,the barrier would not be raised or lowered without giving any warning to the motorist.

Explain what you would add to the model to make it more realistic.

6.) Explain the advantages of using automatic barriers of this type.

Project Name BURGLAR ALARMS

Write your names, form and the Project Name on the top of your sheet of writing paper.



1.) Look at the model and answer these questions on your writing paper:

a) How would the alarm system know if window B had been broken ?

b) How would the alarm system know if window C had been forced open ?

c) How would the alarm system know if somebody had walked into the room ?

2.) With this model the sensors A, B and C are connected to channels 0, 1 and 2 on the input interface. The buzzer is connected to channel 3 on the output interface.

Write the procedure (ALARM) which will sound the alarm if, the house is broken into.

3.) Draw a diagram which shows how a light sensor could be used as part of a burglar alarm.

Get the teacher to connect the model to the computer.

4.) Type in and test your procedure.

5.) Write down the advantages of using computer controlled burglar alarms.

Project Name   CAR

Write your names ,form and the Project Name on the top of your sheet of writing paper.

1.) There are three sensors fixed to the model. Each sensor is connected by different coloured wires. Look at each sensor and decide what each sensor does.

Write down White then explain what you think that the sensor with the White wires could be used for.

Write down Pink and explain what that sensor could be used for.

Write down Yellow and explain what that sensor could be used for.

2.) You want to design a control system which will only let the driver start the car engine if he has done everything correctly.

What should he have done before he tries to start the engine ?

Explain how your control system would decide when the driver has done everything correctly.

3.) The diagram on your writing paper shows an input interface and the transducers used on the model. On this diagram show how the transducers could be connected to the input interface.

4.) Write a procedure (DRIVE) which will display this output when it is safe to start the car engine.

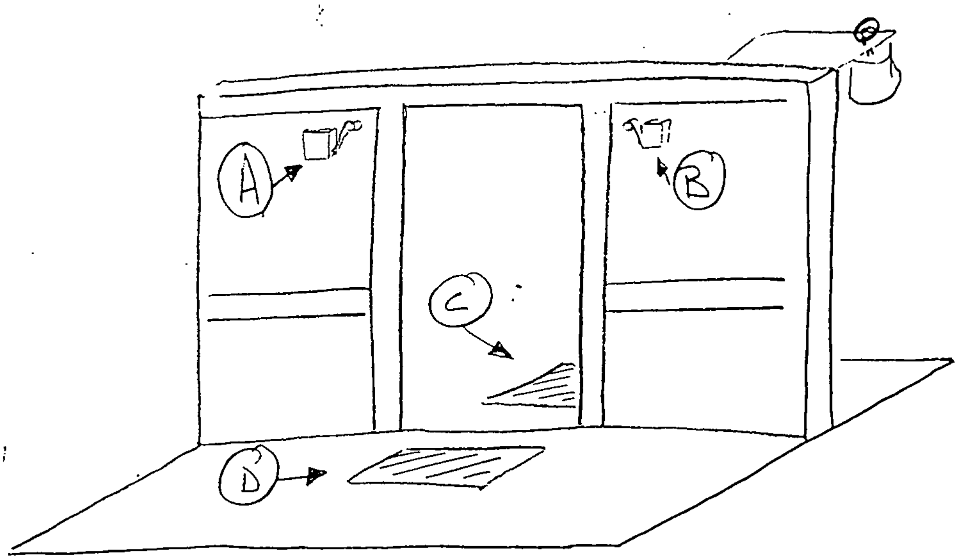
OUTPUT

7	6	5	4	3	2	1	0
0	0	0	0	0	0	0	1

Get the teacher to connect the model to the interface then test your program.

Project Name AUTOMATIC DOORS

Write your names ,form and the Project Name on the top of your sheet of writing paper.



1.) Look at the model and you will find that there are 4 sensors fixed to it. The sketch above shows the position of the sensors A,B,C and D.

a) Write down the letter A and then explain what you think the sensor A is used for. Now write down the letter B and explain what it is used for . Then do the same for sensors C and D

2.) Connect the motor to the power supply and test to see if you can open and close the doors.

3.) Draw a diagram which shows how the model could be connected to the input and output interfaces so that the computer could control the door automatically.

Ask your teacher to check your diagram .

Then connect the model to the interface and get your teacher to check it before you connect the power supply.

4.) Write the procedure (DOOR) which will open the doors when sensor D is switched on and close the door when switch C is switched on.

Test your program

5.) Explain why you think automatic doors are used in large buildings.

Project Name LIFT

Write your names , form and the Project Name on the top of your sheet of writing paper

1.) You will see that there is a magnet fixed to the side of the lift cage.

Write down what you think that it is there for.

2.) Make a winder out of LEGO which will lift the cage. Draw a sketch which shows how your winder works.

Get the teacher to look at the winder before you connect the power supply.

Test your winder and see if it will lift the cage.

3.) Show , by drawing on your diagram ,how you would connect the sensors and motor to the input and output interfaces.

4.) Copy and complete the following sentences

a) If the cage is at the bottom floor and the request button is pressed on the top floor then the cage should - - - - - - - - - - - - - - -

b) If the cage is at the top floor and the request button is pressed on the bottom floor then - - - - - - - - - - - - - - - - - - -

5.) Write a procedure which will move the cage to the right floor when a request button is pressed.

Connect the model to the interfaces.

Ask your teacher to check your wiring before you connect the power supply

6.) Test you program.

Project Name TRAFFIC LIGHTS

Write your names,form and the Project Name onto the top of your sheet of writing paper.

1.) Look at the model .You will see that the red wires are connected to the red bulb. The green wires to the green bulb and the yellow wires to the amber bulb.

Draw a diagram which shows how the model could be connected to an output interface so that the lights could be controlled by a computer.

2.) What channel have you connected the red bulb to .... ?

What channel have you connected the amber bulb to .... ?

What channel have you connected the green bulb to .... ?

3.) The traffic light sequence is :

RED
RED and AMBER
GREEN
AMBER
RED

Write down the 4 patterns which must be given to the output interface to produce this sequence.

4.) Write a procedure (LIGHTS) which will output this sequence.

Connect the model to the output interface

Get your teacher to check before you connect the power supply.

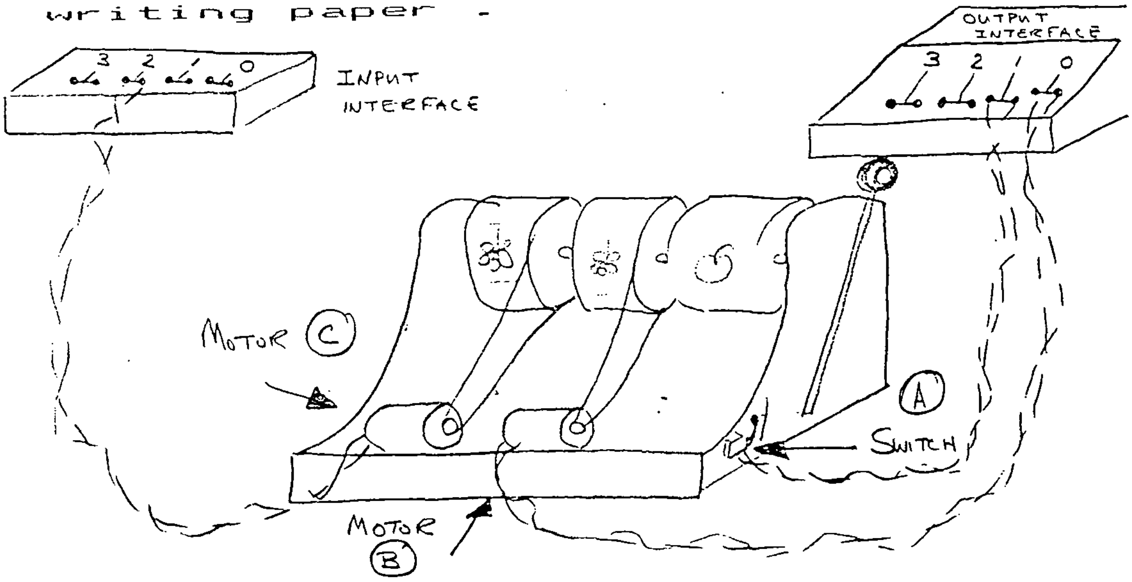
Test your procedure

5.) Write a procedure (LAMPS) which repeats this sequence.(make sure that you give the cars time to stop).

6.) Where would it be useful to use computerised traffic lights.

<u>Project</u> <u>Name</u> <u>BANDIT</u>

Write your names, form and Project Name on the top of your sheet of writing paper .



1.) Look at the diagram .Copy and complete these sentences :

a) The motor C is connected to channel .... on the .... interface.

b) The motor B is connected to channel .... on the ....

c) The transducer ......is connected to channel 1 on the input interface.

2.) Write down what you think is wrong with the circuit shown in the diagram.

Ask your teacher to check your answer and to wire up the circuit.

3.) Type in and test this procedure

```
BUILD BANDIT
 REPEAT
      UNTIL TEST 0 = 1
 SET 0
 SET 1
 WAIT 5
 RESET 0
 RESET 1
END
```

Would you be happy using this one arm bandit if it was controlled by this procedure ? If not explain why not.

4.) Turn over your sheet of writing paper - Show on this diagram how you would connect a sensor to the model to tell the computer when the wheel stops and there is a cherry in the window.

Project Name CONVEYOR

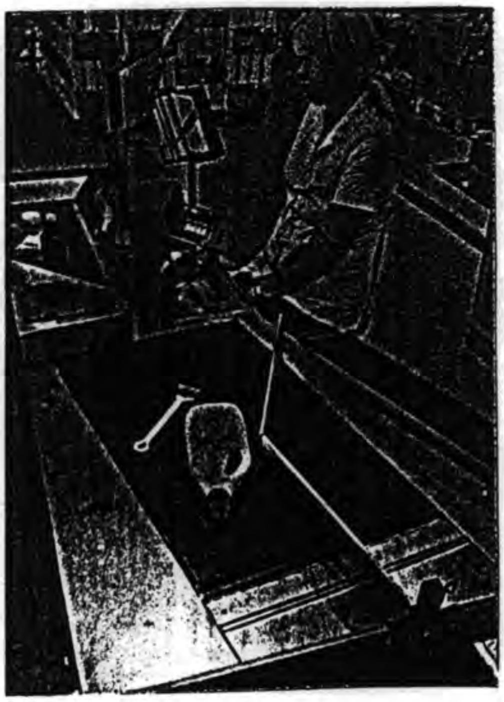
Write your names, form and the Project Name on the top of your sheet of writing paper.

1.) Fit the motor to the conveyor belt so that when the motor turns the belt moves.

Get your teacher to check your model

2.) Connect the motor to the power supply and check to see if the belt moves.

3.) Look at the photograph which shows a conveyor belt.

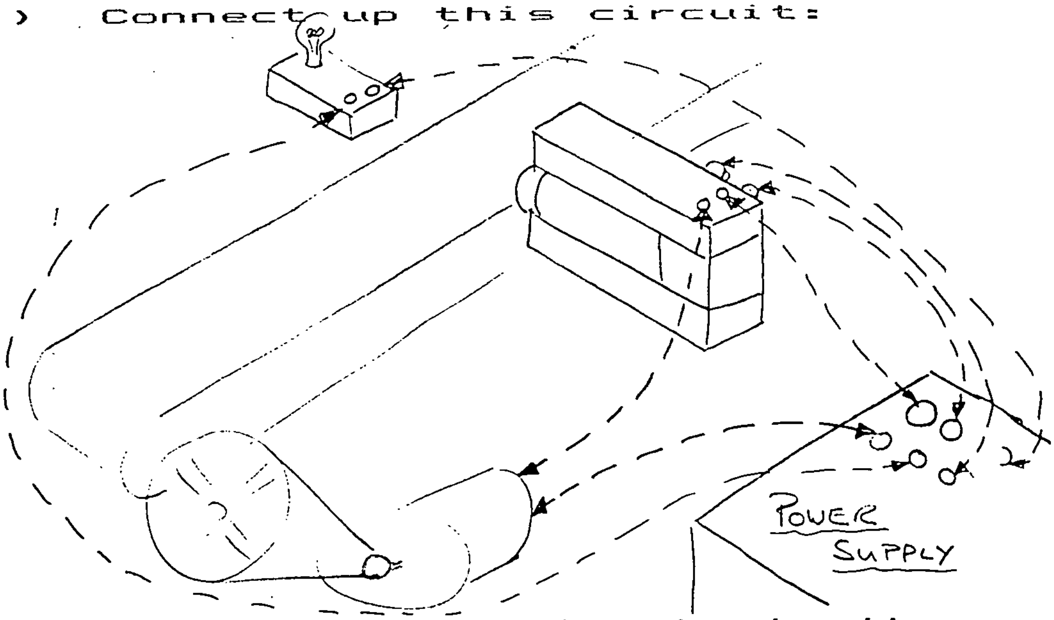


Copy and complete the following sentences:

a) I have seen a conveyor belt like the one shown in the photograph in a ....

b) When groceries are placed on the belt they move along until they reach the .... The belt stops moving when the groceries are between the .... and the ....

4.) Connect up this circuit:



Ask your teacher to check the circuit before you connect the power supply.

5.) The diagram on your writing paper shows an input and an output interface, a power supply, a light sensor, a bulb and a motor.

On the diagram show how the transducers could be connected to the interfaces so that the conveyor belt could be controlled by the computer.

Project Name DRIVE

Write your names, form and the Project Name on the top of your sheet of writing paper

1.) Look at the diagram which has been stuck onto your writing paper.

2.) Put the interfaces, power supply and LEGO buggy on the table ,as shown in the diagram.

Now use the wires to connect up the circuit by following these instructions:—

a) Connect the motors of the LEGO buggy to Channel 1 and channel 2 on the output interface.

b) Connect the yellow push switch to channel 4 on the input interface and the black push switch to channel 1 on the input interface.

c) Make sure that the power supply is NOT PLUGGED IN . Connect a red wire from the large RED socket on the output interface to the large RED socket on the power supply.

d) Connect a black wire from the large BLACK socket on the power supply to the large BLACK socket on the output interface.

Read the instructions again and check your circuit.

3.) Show how you have connected the circuit by drawing the wires onto your diagram .

Ask your teacher to check your circuit and to connect the interfaces to the the computer.

4.) Write the control procedure so that the buggy turns right when the yellow switch is pressed and turns left when the black switch is pressed.

5.) Type in and test the procedure. Demonstrate your procedure to the teacher.

6.) On your writing paper draw a diagram which shows the interfaces and the buggy - Show how you would add a bulb to the buggy (a headlamp really) which could be switched on by a toggle switch.

Project Name GATE

Write your names, form and the Project Name on the top of your sheet of writing paper.

1.) Look at the hinges which you have been given.

Look at the photograph of the gate. (Stuck on to the back of this page)

Look at the hinges on the cupboard doors.

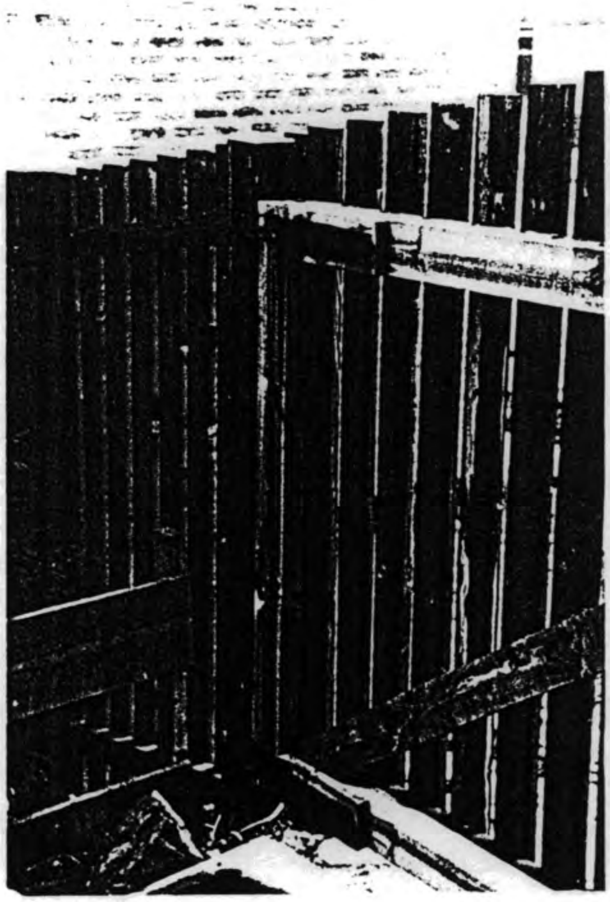
Make a LEGO gate which can be opened and closed.

Ask your teacher to check your model.

2.) Draw a sketch of your gate.

Show on the sketch where you would put a sensor so that a light in the house would come on when the gate was opened.

Write down the name of the sensor you would use.



Project Name LAWNMOWER

Write your names,form and the Project Name on the top of your sheet of writing paper.

1.) Make a model of a lawnmower. The model should have a motor to make it work and a toggle switch to control the motor.

2.) Test your model and show it to the teacher.

3.) Draw a diagram which shows how you built your model and how it works.

Project Name BUZZER

Write your names, form and the Project Name on the top of your sheet of writing paper.

1.) Copy this procedure on to your writing paper and explain what you think each of the instructions will do.

```
BUILD PINK
    REPEAT
     SET 0
     WAIT 5
     RESET 0
     WAIT 5
    AGAIN
END
```

2.) Explain what you think this procedure will do .

3.) Put the output interface and power supply on the table beside the computer .

Connect the buzzer to output channel 0 on the interface.

Ask your teacher to check your circuit, and to connect the interface to the computer and connect the power supply.

Type in the procedure.

Ask your teacher to check your procedure (Before you test it), and to switch on the power supply.

NOW TEST YOUR PROCEDURE.

4.) Switch Off The Power Supply

Disconnect the buzzer.

Connect a bulb to channel 3 on the output interface.

Ask your teacher to check your circuit and to switch on the power supply.

Change your procedure so that your bulb is on for 10 seconds, and off for 10 seconds, on for 10 seconds and off for 10 seconds, e.t.c.

Test your procedure.

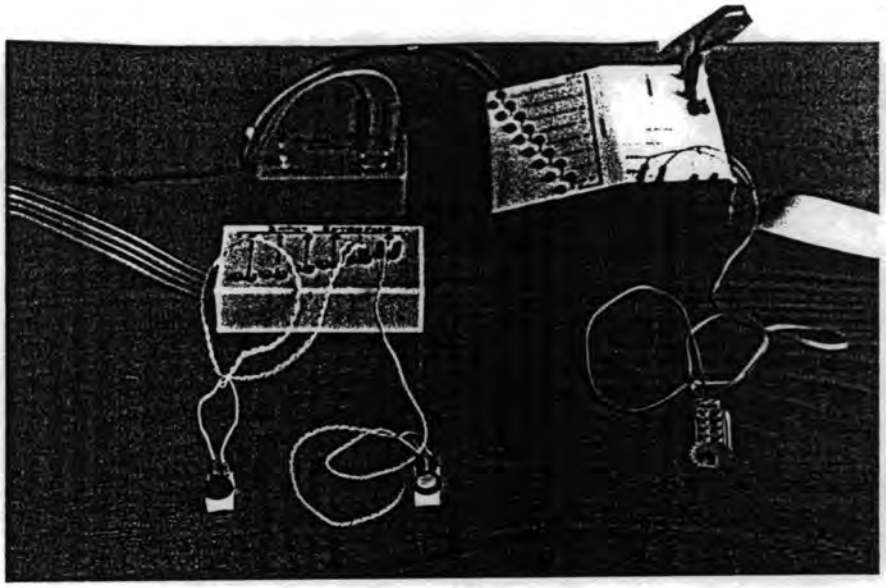
Make a copy of the procedure on your writing paper.

5.) Explain what you found to be difficult with this project.

Project Name REVERSE

Write your names, form and the project name on the top of your sheet of writing paper.

1.) Connect up the equipment as shown in the photograph:



Ask your teacher to check your circuit,and to connect the interface to the computer.

2.) Explain what you can do with a motor when it is connected to a "MOTOR" output which you could not do if it was connected to an ordinary output.

3.) Write the control procedure which drives the motor in one direction when the yellow switch is pressed and in the other direction when the Green switch is pressed.

Type in your procedure and test it.

4.) Do you always need a computer to reverse a motor?

5.) Write the control procedure so that :-

-The motor is switched on when the yellow button is pressed.

AND stays on until the green button is pressed.

-When the green button is pressed the motor stops ,waits for 5 seconds ,and then turns in the opposite direction for 5 seconds.

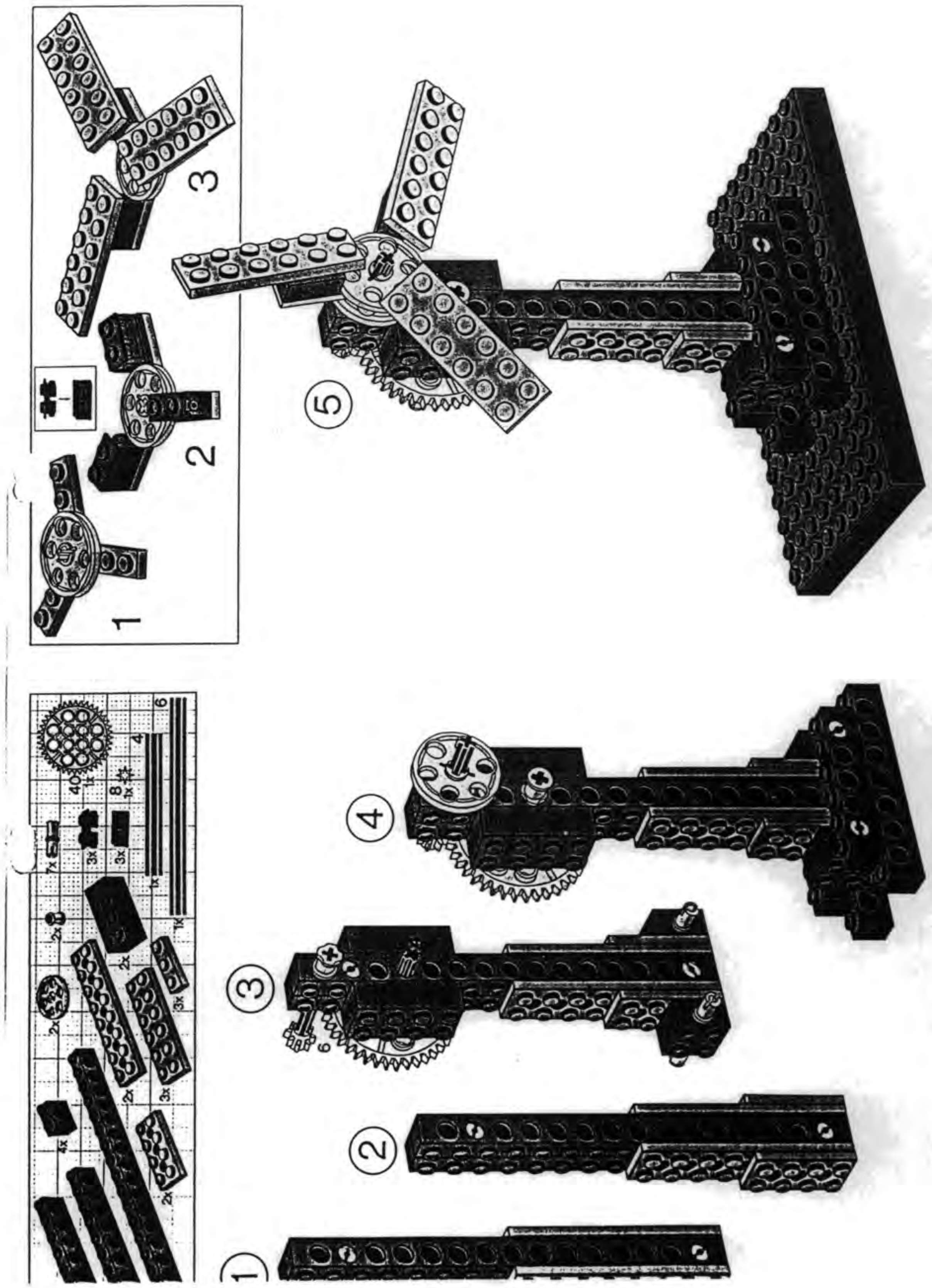
Type in your procedure and test it.

Project Name BUILD

Look at LEGO instructions -

Follow these instructions and build the model windmill.

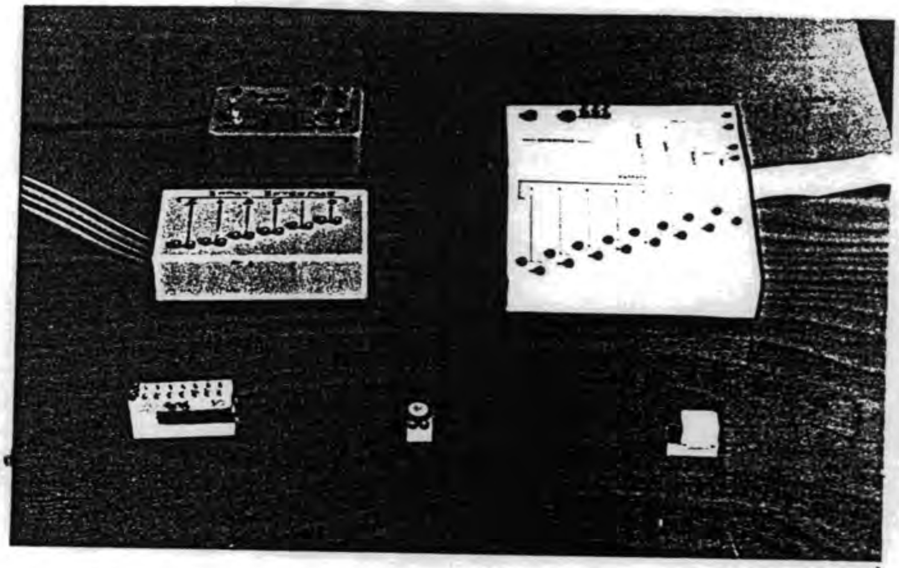
When you have finished ask your teacher to check it.


1
2
3
4
5

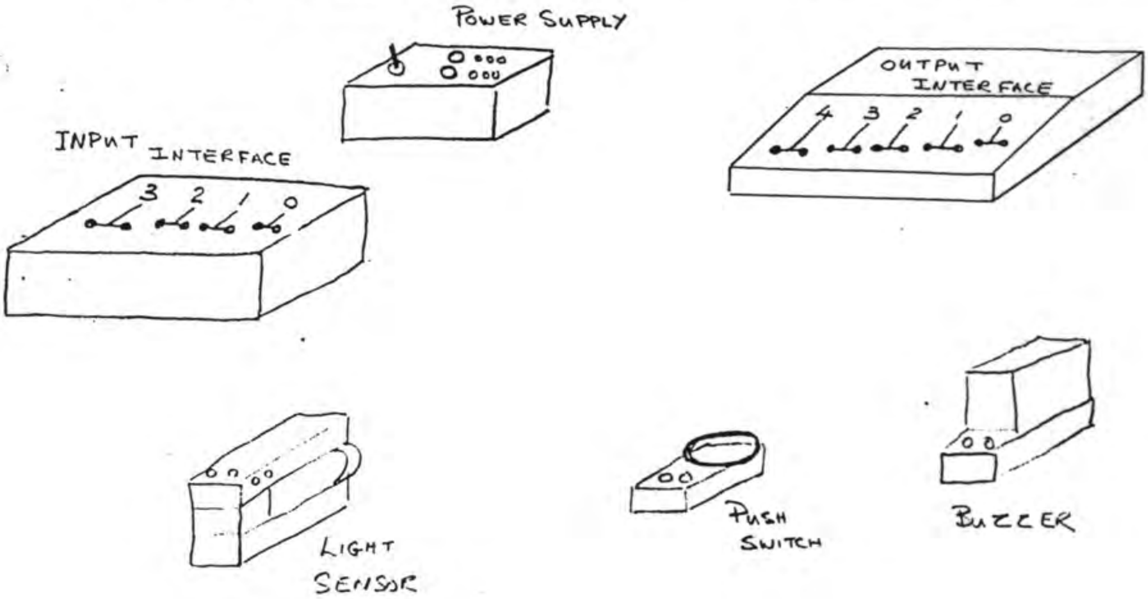
Project Name DAYBELL

Write your names,form and the Project Name on the top of your sheet of writing paper.

1.) Arrange the power supply,the interfaces and the transducers as shown in the photograph.



2.) Copy this diagram onto your writing paper.



3.) You have been asked to design a computer controlled doorbell. The doorbell will only work during the day. If the switch is pressed at night the bell will not ring.

To test your system you have been given a light sensor, a push switch and a buzzer.

Show on your diagram how you would connect the transducers to the interfaces.

Ask your teacher to check your circuit.

4.) Connect up your circuit and ask your teacher to give you a power supply.

5.) Write and test the control procedure.

6.) Copy your procedure onto your writing paper and explain what it does.

Project Name MECHANISMS

Write your names, form and the Project name on the top of your sheet of writing paper.

1.) Copy this table onto your writing paper

Photograph	Model
A	
B	
C	
D	
E	
F	
G	

Look at the photograph A then look at each of the models. Can you find a model which uses the same mechanism. If you can, write down the colour which is printed on the model against the letter A in your table.

Now go on to B etc.

2.) Copy this table onto your writing paper

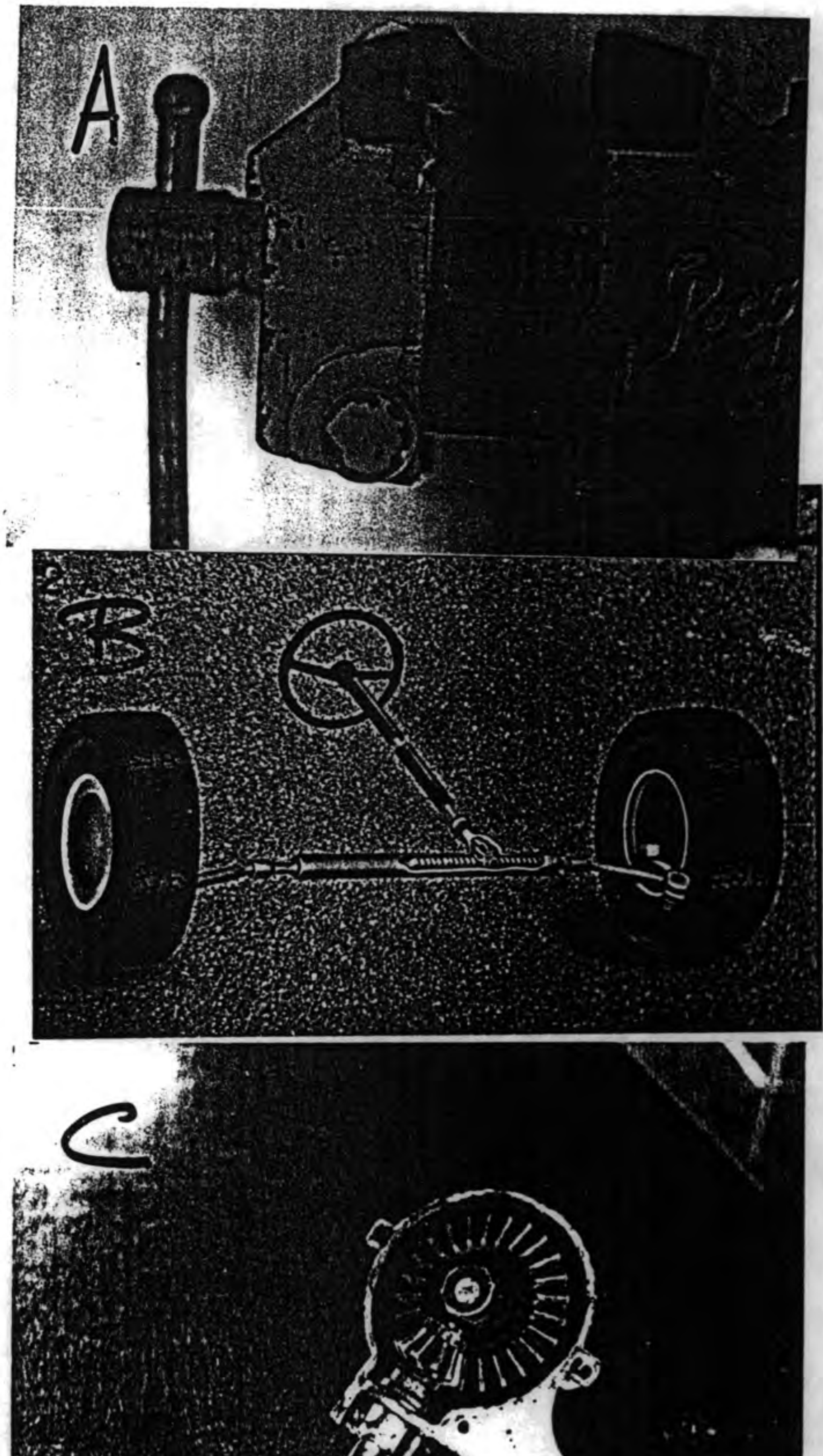
Photograph	Box
A	
B	
C	
D	
E	
F	
G	

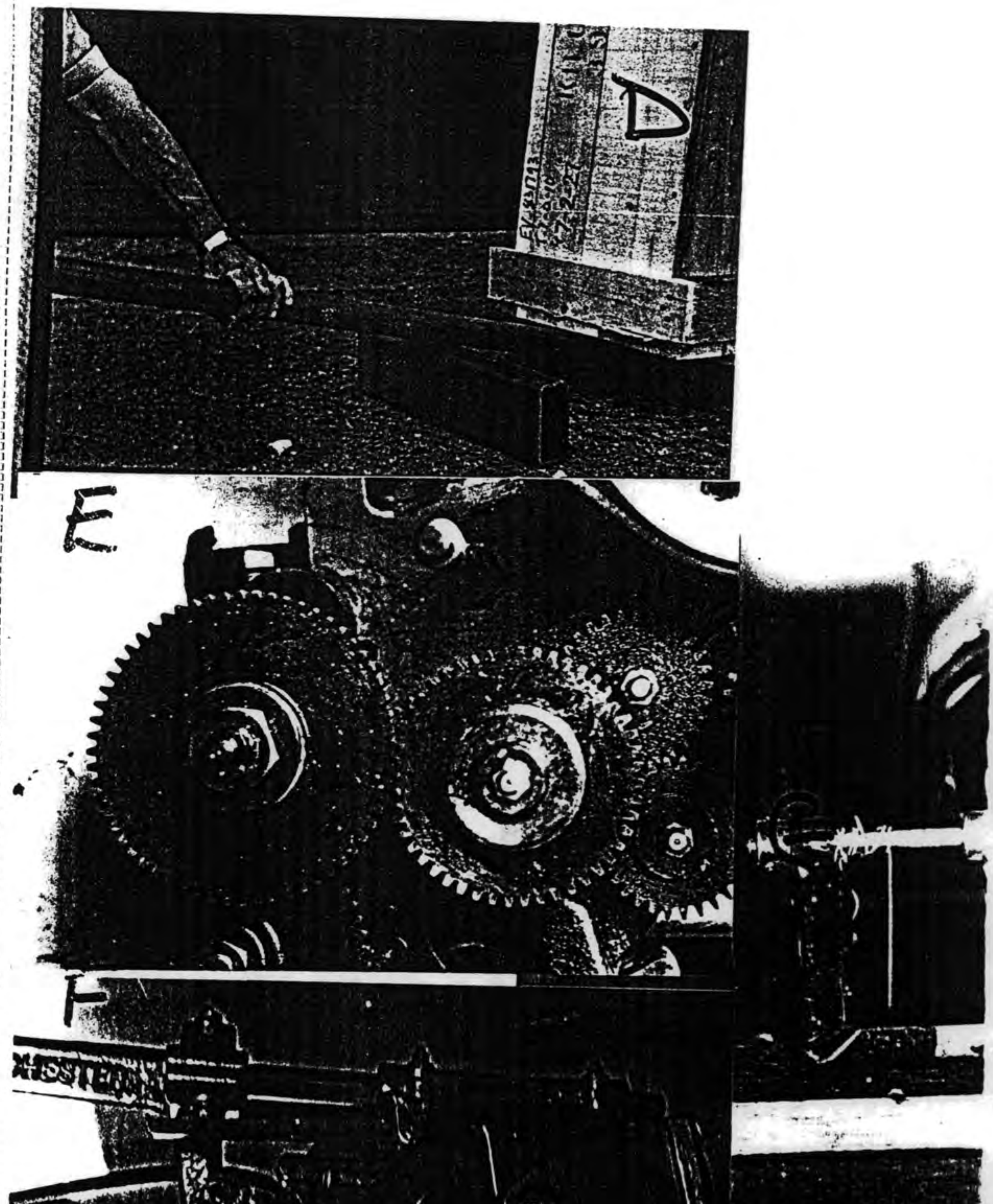
Look at photograph A. Then look at each of the boxes.

Can you find a box which you think hides the same mechanism .

If you can`, write down the name of the tree which is printed on the box against the letter A in your table.

Now look at the other photographs and complete the table.


A
B
C

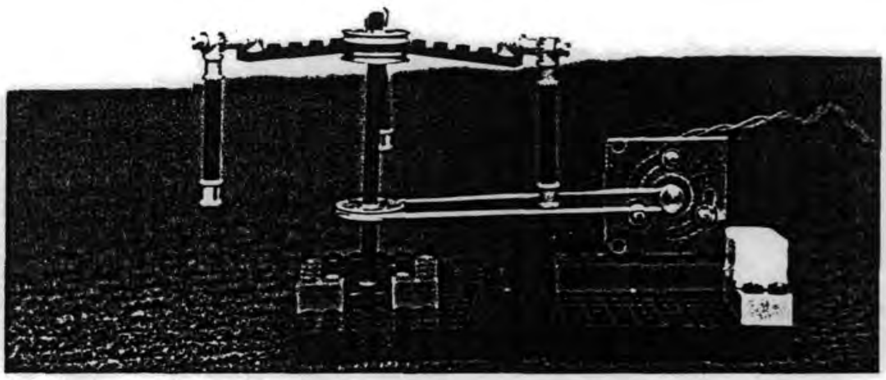


SEE ALSO APPENDIX 12 FOR PHOTOGRAPH OF LEGO MECHANISMS.

Project Name FAIRGROUND

Write your names, form and the Project Name on the top of your writing paper.

Look at the photograph of a LEGO fairground roundabout.



1.) Make this model.

2.) Connect the buzzer to channel 4 on the output interface.

Connect the Roundabout Motor to the Motor 1 output channel on the output interface.

Ask your teacher to check your circuit and to connect the power supply.

3.) Your job now is to write a procedure which will :

- Switch on the warning buzzer
- Turn the roundabout clockwise for 30 seconds.
- Stop the roundabout.
- Turn the roundabout anti-clockwise for 30 seconds.
- Stop the roundabout.

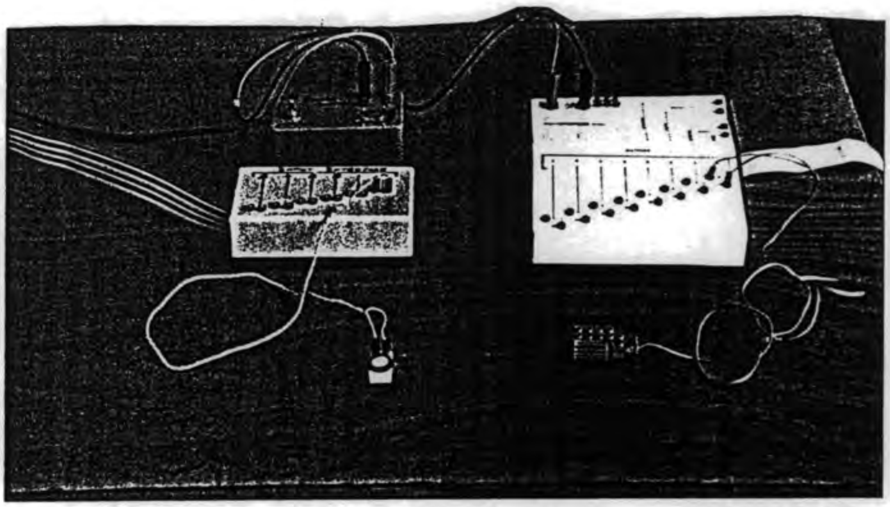
Type in the procedure and test it

Make a copy of your procedure on your writing paper.

Project Name IN/OUT

Write your names form and the Project Name on the top of your sheet of writing paper.

1.) Connect up the circuit shown in the photograph .



Ask your teacher to check the circuit and to connect the interfaces to the computer.

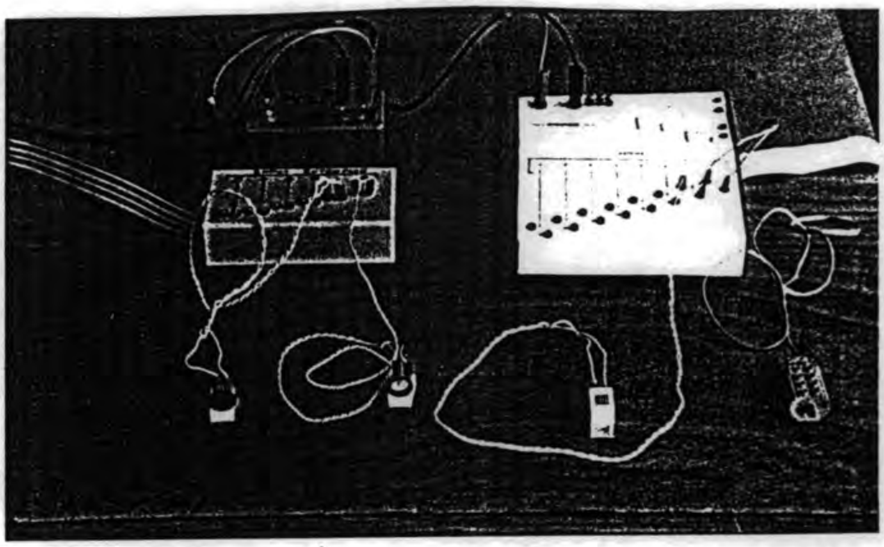
2.) Draw a diagram on your writing paper which shows the circuit .Label your diagram.

3.) Write the procedure which will switch on the motor when the yellow switch is pressed.

Type your procedure into the computer and test it.

DISCONNECT THE POWER SUPPLY

4.) Connect up the equipment as shown in the photograph.



5.) Write the procedure which switches on the motor when the yellow switch is pressed and switches on the buzzer when the green switch is pressed.

Ask your teacher to check your circuit and to connect the power supply.

Now test your procedure.

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Appendix 6.

The Questionnaire.

End of Course Questions

1. What have you learnt in information technology lessons during the last two years.

2. What part of the information technology course have you enjoyed the most.

3. What part of the information technology course have you enjoyed the least.

4. What part of the information technology course did you find the most difficult.

5 Computers do many different jobs. Write down three jobs which are done by a computer.

Appendix 7.

The data from the written tests is presented in the table below. Each row in the table presents the data for one pupil. This data comprises:- a student number, a class code, the sex of the pupil, a code for each of the practical tests as well as presenting the 'score' awarded for their responses to each of the twelve written questions.

Note.

The data which relates to the 84 pupils who were present for all tests is grouped together at the beginning of the table.

Key to Appendix 7

Column Number	Contents or Brief description of question(s)	Name of Written Test	Question Number(s)
#01	Student Number		
#02	Form		
#03	Sex		
#04	First Practical Test		
#05	Second Practical Test		
#06	Name transducers from photographs	Transducer	1 part a
#07	Classify transducers from photograph	Transducer	1 part b
#08	Select transducers for an application	Transducer	5
#09	Classify transducers from application	Washing Machine	1 and 2
#10	Effect of o/p pattern on o/p transducers	Interface	1a
#11	Explain the implications of an o/p pattern	Washing Machine	6
#12	Write instructions to produce given o/p pattern	Interface	1b
#13	Given state of o/p tranducers- predict o/p pattern	Washing Machine	5
#14	Given state of i/p transducers- predict i/p pattern	Interface	2b
#15	Draw circuit from written description	Interface qu.	2a
#16	Given an i/p pattern- predict the state of i/p trans	Interface	3
#17	Write a procedure from written specification	Interface	2c

Appendix

Results of the Written Tests (pupil number order)

TABLE 1 -- Pupils who were present for all tests.

pupil No. *	class *	sex *	practical 1. *	practical 2. *	*06	*07	*08	*09	*10	*11	*12	*13	*14	*15	*16	*17
100	21	m	re	wa	9	9	7	6	1	1	1	1	0	4	2	1
101	21	m	ga	ve	9	9	5	6	1	1	2	1	0	3	0	1
102	21	f	dr	au	4	5	1	7	1	1	2	0	1	4	1	2
103	21	f	bu	di	7	5	5	5	1	1	2	1	1	4	2	0
104	21	f	re	wa	6	4	2	5	1	1	2	0	1	0	1	2
105	21	f	lm	li	3	5	0	5	0	1	0	0	0	0	0	0
106	21	m	bl	ur	9	9	7	6	1	1	2	1	1	4	2	1
107	21	f	ga	ve	9	9	5	3	1	1	2	1	1	3	0	3
108	21	f	re	wa	0	6	0	8	1	1	2	1	1	4	0	0
109	21	f	zz	ca	4	5	4	6	0	1	2	0	1	4	0	0
111	21	f	ga	ve	9	9	5	8	1	1	2	1	1	4	2	1
113	21	f	bu	di	1	2	1	2	0	1	2	0	0	2	2	0
114	21	m	bu	di	7	9	5	3	1	1	2	1	1	2	0	2
115	21	f	me	tr	8	7	3	8	1	1	2	1	0	4	2	0
116	21	m	me		6	5	4	4	0	1	2	1	0	4	1	1
117	21	m	bl	ur	5	3	4	3	1	1	2	1	1	4	2	0
119	21	f	dr	au	3	4	2	8	1	0	2	1	1	4	2	0
120	21	m	zz	ca	5	2	0	4	0	1	2	1	0	2	2	0
121	21	m	lm	li	9	9	7	8	1	1	2	1	1	4	2	4
123	21	m	bu	di	9	6	7	8	1	1	2	1	1	4	2	0
124	21	m	zz	ca	7	1	8	4	1	1	2	1	1	4	1	4
125	21	m	dr	au	9	8	6	6	1	0	2	0	1	4	2	1
127	21	f	ga	ve	3	6	1	6	1	1	2	1	1	4	2	2
128	21	f	zz	ca	7	8	3	5	1	0	2	1	1	2	2	0
129	21	f	lm	li	7	5	2	3	1	1	2	0	1	4	0	2
130	21	m	lm	li	9	4	7	7	1	1	2	1	1	4	2	2
131	28	f	zz	ca	5	4	3	8	1	1	2	0	1	4	0	0
133	28	m	me	ve	1	4	1	5	1	0	0	1	0	0	0	0
134	28	f			5	4	2	8	1	1	2	0	1	4	0	0
135	28	f	ga	ur	5	4	3	7	1	1	2	1	0	3	0	0
136	28	f	re	tr	5	6	3	7	1	1	2	1	1	4	0	0
138	28	m	zz	ca	2	0	2	6	1	1	0	0	0	4	1	0
140	28	m	dr	au	5	0	4	6	1	1	2	1	1	0	1	0
141	28	m			3	3	4	5	1	1	2	0	1	0	1	0
143	28	f	lm	ve	5	4	2	6	1	1	2	1	0	4	0	0

144	28	m	re	tr	5	5	2	4	1	1	0	1	0	2	1	0
145	23	m		ca	6	6	6	5	0	1	2	1	1	0	2	0
148	23	f	bu	wa	4	4	3	3	1	0	0	1	1	0	0	0
151	23	m	re	di	8	8	4	5	1	0	1	0	0	4	0	0
152	23	f	lm	li	3	4	4	3	1	0	0	1	1	0	0	0
153	23	f	zz	ve	8	9	5	7	1	0	2	1	1	4	1	0
154	23	m	zz	ve	8	8	8	5	1	0	2	0	0	0	0	0
155	23	m	me	ur	8	7	5	6	1	0	0	0	0	2	0	0
156	23	f	re	di	1	2	2	2	1	1	1	0	1	0	0	0
157	23	m		wa	7	4	4	5	1	0	0	0	0	0	0	0
158	23	f	bl	tr	5	1	6	7	1	0	0	0	0	0	0	0
159	23	f	zz	ve	0	0	1	4	1	0	2	0	0	0	0	0
160	23	f	bu	wa	9	6	6	4	0	1	2	1	1	0	2	1
161	23	m	bl	tr	4	4	2	2	0	0	2	0	1	0	2	1
162	23	m	bu	wa	9	9	5	5	1	0	2	0	1	4	0	1
163	23	m	dr	ca	7	7	7	5	1	1	2	0	1	0	0	0
164	23	m	re	di	9	9	7	4	1	1	2	0	1	4	0	0
165	23	f	ga		4	1	4	3	1	0	0	1	1	0	0	2
166	23	f	dr	ca	3	0	3	7	1	1	1	0	1	0	0	1
167	23	f	me	ur	4	1	3	8	1	1	1	0	1	0	0	0
168	23	m	me	ur	9	7	8	6	1	1	2	1	1	0	2	1
169	23	m	lm	li	4	1	2	8	1	1	2	1	0	0	0	0
170	23	f	bl	tr	1	1	2	7	1	0	0	0	1	0	0	0
171	23	f		au	1	3	4	6	0	0	1	1	1	0	1	0
172	23	m	ga	au	8	7	5	5	1	0	2	0	0	4	0	0
173	22	m	dr	au	9	8	7	5	1	1	2	0	1	4	2	1
174	22	m	bu	di	5	8	2	8	1	1	2	1	1	4	2	2
175	22	f	ga	ur	5	6	5	8	1	1	2	1	1	4	0	0
176	22	m	ga	ur	6	6	5	6	1	1	2	1	1	4	2	1
177	22	f	me	tr	5	5	4	2	1	1	2	1	1	4	1	0
178	22	m	zz	ca	6	7	6	5	1	1	2	1	1	4	2	2
179	22	m	bl	ve	5	8	4	8	1	1	2	1	1	4	2	2
180	22	m	me	tr	7	0	6	8	1	1	2	1	1	4	2	2
181	22	m	me	tr	3	8	4	7	1	1	2	1	1	4	2	2
182	22	f	dr	au	3	4	1	1	1	1	2	1	1	4	1	1
183	22	m	zz	ca	7	4	6	8	1	1	2	1	1	4	2	2
184	22	m	lm		5	4	7	8	1	1	2	1	1	4	2	1
186	22	f	re	wa	4	7	4	5	1	1	2	1	1	0	2	1
187	22	m	re	wa	9	9	7	5	1	1	2	1	1	4	2	0
188	22	m	bl	ve	9	9	8	8	1	1	2	1	1	4	2	2
192	22	f	bu	di	8	7	7	7	1	1	2	1	1	0	1	0
194	22	f	re	wa	4	3	4	2	1	1	2	1	0	4	2	1
196	22	f		li	4	3	3	7	1	1	1	1	1	2	2	0
198	22	m	ga	ur	8	0	6	5	1	1	2	1	1	4	2	0
199	22	m	lm	li	9	8	7	5	1	1	2	0	1	4	2	1
201	22	f	zz	ca	0	0	8	4	1	1	2	1	1	0	2	1
202	22	f	ga	ur	4	7	5	8	1	1	2	1	1	4	2	3
203	22	f	bl	ve	1	4	3	4	1	0	2	1	1	0	1	1
TOTALS --					461	422	352	462	74	63	137	55	62	207	88	62

Appendix

TABLE 2. -- Pupils who were absent for one or more written tests.

*	*	*	*	*	*06	*07	*08	*09	*10	*11	*12	*13	*14	*15	*16	*17
110	21	f		tr	3	4	4		1		2		1	4	2	1
112	21	f	bl	ur	7	7	3		1		2		1	4	2	1
118	21	f			6	6	2	8		1		1				
122	21	f	me	tr		5			1	1	2	0	1	4	2	0
126	21	m	dr	au	6	5	5		1		2		1	4	0	1
132	28	m	ga	ur	5	4	1		1		2		1	0	1	0
137	28	m	dr	au	6	0	6		1		2		0	0	0	0
139	28	m	re		7	8	4		1		2		0	0	0	0
142	28	m	lm		2	1	2		1		0		0	0	0	0
146	23	f	ga	au	8	8	6	5		1		1				
147	23	f	zz	ve	6	5	7		1		2		0	0	2	1
149	23	m	lm	li	7	8	4		1		2		0	2	0	0
150	23	m	dr	ca	9	7	7		0		0		1	0	0	0
185	22	m			7	9	6	8		1		1				
189	22	f	re	wa			1				2		1	4	2	0
190	22	f	dr	au				7	1	1	2	1	1	4	2	1
191	22	f	bl		6	3	6		1		2		0	4	0	0
193	22	f	lm	li	8	0	6		1		2		1	4	2	0
195	22	f	lm	li	2	6	5	5		0		1				
197	22	f	bu	di				0	1	1	2	1	1	3	2	1
200	22	f	dr	au				7	1	1	2	1	1	0	2	1
204	25	f			4	2	3	4		1		0				
205	25	m	re	tr	7	5	5	4		1		0				
206	25	m	ga	ur	5	6	6	3		0		1				
207	25	f	ga	ur				4		1		0				
208	25	f	zz	ca	6	3	4	5		1		0				
209	25	m	me	wa	9	9	5	2		0		0				
210	25	f			9	9	5	6		1		0				
211	25	f	me	wa	7	7	5	5		0		0				
212	25	m		au	9	9	7	1		1		1				
213	25	m	zz	ca	8	4	3	3		0		0				
214	25	f	re	tr	7	6	4	3		1		0				
215	25	f		di	8	8	4	4		1		0				
216	25	f	lm	li	7	5	5	4		0		0				
217	25	m	bl	ve	5	1	4	4		1		1				
218	25	m	lm	li	9	7	5	4		0		1				
219	25	m		au	6	2	3	5		1		1				
220	25	m		di	8	7	7	5		1		0				
221	25	f		au	5	2	3	3		0		0				
222	25	m	zz	ca	7	3	4	6		1		1				
223	25	f	bl	ve	5	3	4	5		1		0				
224	25	m	re	tr	9	8	8	6		1		1				
225	25	m	lm	li	9	7	6	7		1		1				
226	25	m	zz	ca	9	9	8	6		1		1				
227	25	f	lm	li	5	6	6	4		1		0				
228	25	f		ve	5	5	4	3		1		0				
229	25	f	ga		5	7	3	6		1		0				
230	25	f	me	wa				4		0		0				
231	25	m		au				3		1		0				
TOTALS --					268	226	196	159	15	27	30	16	11	37	19	7
COMBINED TOTALS --					729	648	548	621	89	90	167	71	73	244	107	69

Appendix 8.

The data from the written tests is presented in a coded form in the table below. A binary code was used in which a 1 was recorded if a pupil produced a satisfactory response to a question. In order to determine whether or not a pupil had produced a 'satisfactory' response, each question was considered in terms of the response an 'average pupil' might have given by idrawing on his everyday experience. Anything above this level was considered to be a satisfactory response.

The criteria established by this analysis is given in the table below:-

Column	Question	Response
*06	Qu. 1 (Transducer) part a	score > 4
*07	Qu. 1 (Transducer) part b	score > 4
*08	Qu. 5 (Transducer)	score > 3
*09	Qu. 1 and 2 (Washing Machine)	score > 4.
*10	Qu. 1 (Interface) part a	score > 0
*11	Qu. 6 (Washing Machine)	score > 0
*12	Qu. 1 (Interface) part b	score > 0
*13	Qu. 5 (Washing Machine)	score > 0
*14	Qu. 2 (Interface) part b	score > 0
*15	Qu. 2 (Interface) part a	score > 2
*16	Qu. 3 (Interface)	score > 0
*17	Qu. 2 (Interface) part c	score > 1

Appendix E

Results of the Written Tests (pupil number order)

TABLE 1 -- Pupils who were present for all tests.

pupil No. *	class *	sex *	practical 1. *	practical 2. *	*06	*07	*08	*09	*10	*11	*12	*13	*14	*15	*16	*17
100	21	m	re	wa	1	1	1	1	1	1	1	1	0	1	1	0
101	21	m	ga	ve	1	1	1	1	1	1	1	1	0	1	0	0
102	21	f	dr	au	0	1	0	1	1	1	1	0	1	1	1	1
103	21	f	bu	di	1	1	1	1	1	1	1	1	1	1	1	0
104	21	f	re	wa	1	0	0	1	1	1	1	0	1	0	1	1
105	21	f	lm	li	0	1	0	1	0	1	0	0	0	0	0	0
106	21	m	bl	ur	1	1	1	1	1	1	1	1	1	1	1	0
107	21	f	ga	ve	1	1	1	0	1	1	1	1	1	1	0	1
108	21	f	re	wa	0	1	0	1	1	1	1	1	1	1	0	0
109	21	f	zz	ca	0	1	1	1	0	1	1	0	1	1	0	0
111	21	f	ga	ve	1	1	1	1	1	1	1	1	1	1	1	0
113	21	f	bu	di	0	0	0	0	0	1	1	0	0	0	1	0
114	21	m	bu	di	1	1	1	0	1	1	1	1	1	0	0	1
115	21	f	me	tr	1	1	0	1	1	1	1	1	0	1	1	0
116	21	m	me		1	1	1	0	0	1	1	1	0	1	1	0
117	21	m	bl	ur	1	0	1	0	1	1	1	1	1	1	1	0
119	21	f	dr	au	0	0	0	1	1	0	1	1	1	1	1	0
120	21	m	zz	ca	1	0	0	0	0	1	1	1	0	0	1	0
121	21	m	lm	li	1	1	1	1	1	1	1	1	1	1	1	1
123	21	m	bu	di	1	1	1	1	1	1	1	1	1	1	1	0
124	21	m	zz	ca	1	0	1	0	1	1	1	1	1	1	1	1
125	21	m	dr	au	1	1	1	1	1	0	1	0	1	1	1	0
127	21	f	ga	ve	0	1	0	1	1	1	1	1	1	1	1	1
128	21	f	zz	ca	1	1	0	1	1	0	1	1	1	0	1	0
129	21	f	lm	li	1	1	0	0	1	1	1	0	1	1	0	1
130	21	m	lm	li	1	0	1	1	1	1	1	1	1	1	1	1
131	28	f	zz	ca	1	0	0	1	1	1	1	0	1	1	0	0
133	28	m	me	ve	0	0	0	1	1	0	0	1	0	0	0	0
134	28	f			1	0	0	1	1	1	1	0	1	1	0	0
135	28	f	ga	ur	1	0	0	1	1	1	1	1	0	1	0	0
136	28	f	re	tr	1	1	0	1	1	1	1	1	1	1	0	0
138	28	m	zz	ca	0	0	0	1	1	1	0	0	0	1	1	0
140	28	m	dr	au	1	0	1	1	1	1	1	1	1	0	1	0
141	28	m			0	0	1	1	1	1	1	0	1	0	1	0
143	28	f	lm	ve	1	0	0	1	1	1	1	1	0	1	0	0

145	23	m		ca	1	1	1	1	0	1	1	1	1	0	1	0
148	23	f	bu	wa	0	0	0	0	1	0	0	1	1	0	0	0
151	23	m	re	di	1	1	1	1	1	0	1	0	0	1	0	0
152	23	f	lm	li	0	0	1	0	1	0	0	1	1	0	0	0
153	23	f	zz	ve	1	1	1	1	1	0	1	1	1	1	1	0
154	23	m	zz	ve	1	1	1	1	1	0	1	0	0	0	0	0
155	23	m	me	ur	1	1	1	1	1	0	0	0	0	0	0	0
156	23	f	re	di	0	0	0	0	1	1	1	0	1	0	0	0
157	23	m		wa	1	0	1	1	1	0	0	0	0	0	0	0
158	23	f	bl	tr	1	0	1	1	1	0	0	0	0	0	0	0
159	23	f	zz	ve	0	0	0	0	1	0	1	0	0	0	0	0
160	23	f	bu	wa	1	1	1	0	0	1	1	1	1	0	1	0
161	23	m	bl	tr	0	0	0	0	0	0	1	0	1	0	1	0
162	23	m	bu	wa	1	1	1	1	1	0	1	0	1	1	0	0
163	23	m	dr	ca	1	1	1	1	1	1	1	0	1	0	0	0
164	23	m	re	di	1	1	1	0	1	1	1	0	1	1	0	0
165	23	f	ga		0	0	1	0	1	0	0	1	1	0	0	1
166	23	f	dr	ca	0	0	0	1	1	1	1	0	1	0	0	0
167	23	f	me	ur	0	0	0	1	1	1	1	0	1	0	0	0
168	23	m	me	ur	1	1	1	1	1	1	1	1	1	0	1	0
169	23	m	lm	li	0	0	0	1	1	1	1	1	0	0	0	0
170	23	f	bl	tr	0	0	0	1	1	0	0	0	1	0	0	0
171	23	f		au	0	0	1	1	0	0	1	1	1	0	1	0
172	23	m	ga	au	1	1	1	1	1	0	1	0	0	1	0	0
173	22	m	dr	au	1	1	1	1	1	1	1	0	1	1	1	0
174	22	m	bu	di	1	1	0	1	1	1	1	1	1	1	1	1
175	22	f	ga	ur	1	1	1	1	1	1	1	1	1	1	0	0
176	22	m	ga	ur	1	1	1	1	1	1	1	1	1	1	1	0
177	22	f	me	tr	1	1	1	0	1	1	1	1	1	1	1	0
178	22	m	zz	ca	1	1	1	1	1	1	1	1	1	1	1	1
179	22	m	bl	ve	1	1	1	1	1	1	1	1	1	1	1	1
180	22	m	me	tr	1	0	1	1	1	1	1	1	1	1	1	1
181	22	m	me	tr	0	1	1	1	1	1	1	1	1	1	1	1
182	22	f	dr	au	0	0	0	0	1	1	1	1	1	1	1	0
183	22	m	zz	ca	1	0	1	1	1	1	1	1	1	1	1	1
184	22	m	lm		1	0	1	1	1	1	1	1	1	1	1	0
186	22	f	re	wa	0	1	1	1	1	1	1	1	1	0	1	0
187	22	m	re	wa	1	1	1	1	1	1	1	1	1	1	1	0
188	22	m	bl	ve	1	1	1	1	1	1	1	1	1	1	1	1
192	22	f	bu	di	1	1	1	1	1	1	1	1	1	0	1	0
194	22	f	re	wa	0	0	1	0	1	1	1	1	0	1	1	0
196	22	f		li	0	0	0	1	1	1	1	1	1	0	1	0
198	22	m	ga	ur	1	0	1	1	1	1	1	1	1	1	1	0
199	22	m	lm	li	1	1	1	1	1	1	1	0	1	1	1	0
201	22	f	zz	ca	0	0	1	0	1	1	1	1	1	0	1	0
202	22	f	ga	ur	0	1	1	1	1	1	1	1	1	1	1	1
203	22	f	bl	ve	0	0	0	0	1	0	1	1	1	0	1	0
TOTALS --					54	46	52	61	74	63	72	55	62	49	51	18

TABLE 2. -- Pupils who were absent for one or more written tests.

*	*	*	*	*	*06	*07	*08	*09	*10	*11	*12	*13	*14	*15	*16	*17
110	21	f		tr	0	0	1	0	1	0	1	0	1	1	1	0
112	21	f	bl	ur	1	1	0	0	1	0	1	0	1	1	1	0
118	21	f			1	1	0	1	0	1	0	1	0	0	0	0
122	21	f	me	tr	0	1	0	0	1	1	1	0	1	1	1	0
126	21	m	dr	au	1	1	1	0	1	0	1	0	1	1	0	0
132	28	m	ga	ur	1	0	0	0	1	0	1	0	1	0	1	0
137	28	m	dr	au	1	0	1	0	1	0	1	0	0	0	0	0
139	28	m	re	.	1	1	1	0	1	0	1	0	0	0	0	0
142	28	m	lm		0	0	0	0	1	0	0	0	0	0	0	0
146	23	f	ga	au	1	1	1	1	0	1	0	1	0	0	0	0
147	23	f	zz	ve	1	1	1	0	1	0	1	0	0	0	1	0
149	23	m	lm	li	1	1	1	0	1	0	1	0	0	0	0	0
150	23	m	dr	ca	1	1	1	0	0	0	0	0	1	0	0	0
185	22	m			1	1	1	1	0	1	0	1	0	0	0	0
189	22	f	re	wa	0	0	0	0	0	0	1	0	1	1	1	0
190	22	f	dr	au	0	0	0	1	1	1	1	1	1	1	1	0
191	22	f	bl		1	0	1	0	1	0	1	0	0	1	0	0
193	22	f	lm	li	1	0	1	0	1	0	1	0	1	1	1	0
195	22	f	lm	li	0	1	1	1	0	0	0	1	0	0	0	0
197	22	f	bu	di	0	0	0	0	1	1	1	1	1	1	1	0
200	22	f	dr	au	0	0	0	1	1	1	1	1	1	0	1	0
204	25	f			0	0	0	0	0	1	0	0	0	0	0	0
205	25	m	re	tr	1	1	1	0	0	1	0	0	0	0	0	0
206	25	m	ga	ur	1	1	1	0	0	0	0	1	0	0	0	0
207	25	f	ga	ur	0	0	0	0	0	1	0	0	0	0	0	0
208	25	f	zz	ca	1	0	1	1	0	1	0	0	0	0	0	0
209	25	m	me	wa	1	1	1	0	0	0	0	0	0	0	0	0
210	25	f			1	1	1	1	0	1	0	0	0	0	0	0
211	25	f	me	wa	1	1	1	1	0	0	0	0	0	0	0	0
212	25	m		au	1	1	1	0	0	1	0	1	0	0	0	0
213	25	m	zz	ca	1	0	0	0	0	0	0	0	0	0	0	0
214	25	f	re	tr	1	1	1	0	0	1	0	0	0	0	0	0
215	25	f		di	1	1	1	0	0	1	0	0	0	0	0	0
216	25	f	lm	li	1	1	1	0	0	0	0	0	0	0	0	0
217	25	m	bl	ve	1	0	1	0	0	1	0	1	0	0	0	0
218	25	m	lm	li	1	1	1	0	0	0	0	1	0	0	0	0
219	25	m		au	1	0	0	1	0	1	0	1	0	0	0	0
220	25	m		di	1	1	1	1	0	1	0	0	0	0	0	0
221	25	f		au	1	0	0	0	0	0	0	0	0	0	0	0
222	25	m	zz	ca	1	0	1	1	0	1	0	1	0	0	0	0
223	25	f	bl	ve	1	0	1	1	0	1	0	0	0	0	0	0
224	25	m	re	tr	1	1	1	1	0	1	0	1	0	0	0	0
225	25	m	lm	li	1	1	1	1	0	1	0	1	0	0	0	0
226	25	m	zz	ca	1	1	1	1	0	1	0	1	0	0	0	0
227	25	f	lm	li	1	1	1	0	0	1	0	0	0	0	0	0
228	25	f		ve	1	1	1	0	0	1	0	0	0	0	0	0
229	25	f	ga		1	1	0	1	0	1	0	0	0	0	0	0
230	25	f	me	wa	0	0	0	0	0	0	0	0	0	0	0	0
231	25	m		au	0	0	0	0	0	1	0	0	0	0	0	0
TOTALS --					37	28	32	17	15	27	15	16	11	9	10	0
COMBINED TOTALS --					91	74	84	78	89	90	87	71	73	58	61	18

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Appendix 9.

The written tests provided data on three main aspects of the course, being transducers, input/output codes and programming. To help with the interpretation of this data it has been compressed and is presented in the table below. Details of the method used to compress the data are given below:-

Column A is derived from columns 6 to 9 in appendix 8. If a 1 appears in two or more of these columns, i.e. a pupil has performed satisfactorily in two or more of the questions Qu.1 (part a and b), and Qu.5 [Transducer], and Qu.1 and Qu.2 [Washing Machine], a 1 was entered into this column.

Column B is derived from columns 10,11,13,14,16 in appendix 8. If a 1 appears in three or more of these columns, i.e. the pupil has produced a satisfactory response to three or more of the questions:- Qu. 1a, 2b and 3 [Interface]; and Qu. 5 and 6 [Washing Machine], a 1 would be recorded in column B.

Column C is a copy of column 12 in appendix 8 in which a 1 appears if the pupil has produced a satisfactory response to question 1b (Interface).

Column D is a copy of column 17 in which a 1 appears if the pupil has produced a satisfactory response to question 2c (Interface).

By using this system a 1 in column A would indicate that the pupil had formed an understanding of a transducer, similarly a 1 in column B would indicate that the pupil had formed an understanding of an input/output code.

Compression of data presented in Appendix .

Key.

Column	Contents	Interpretation
*A	1 if there are 2 or more 1's in columns *06, *07, *08 and *09	The concept of a transducer has been formed
*B	1 if there are 3 or more 1's in columns *10, *11, *13 ,*14 and *16	The concept of a I/O code has been formed
*C	Copy of column *12	Pupil capable of recalling the instructions which produce an O/P code
*D	Copy of column *17	Pupil capable of writing a program from a specification
*E	*A AND *B	Concept of an I/O code AND transducer formed
*F	*C AND *D	Pupil able to produce an O/P code AND able to write a program from a specification
*G	*B AND *C	Concept of an I/O code and able produce an O/P code
*H	*D AND *E	Concept of an I/O code AND a transducer AND able to write a program from a specification

Appendix

Results of the Written Tests coded from Appendix .

pupil No. : :	class : : : : :	sex : : : : : : :	practical 1.	practical 2.					*E	*F	*G	*H
*	*	*	*	*	*A	*B	*C	*D	A.B *	C.D *	B.C *	D.E *
100	21	m	re	wa	1	1	1	0	1	0	1	0
101	21	m	ga	ve	1	1	1	0	1	0	1	0
102	21	f	dr	au	1	1	1	1	1	1	1	1
103	21	f	bu	di	1	1	1	0	1	0	1	0
104	21	f	re	wa	1	1	1	1	1	1	1	1
105	21	f	lm	li	1	0	0	0	0	0	0	0
106	21	m	bl	ur	1	1	1	0	1	0	1	0
107	21	f	ga	ve	1	1	1	1	1	1	1	1
108	21	f	re	wa	1	1	1	0	1	0	1	0
109	21	f	zz	ca	1	0	1	0	0	0	0	0
111	21	f	ga	ve	1	1	1	0	1	0	1	0
113	21	f	bu	di	0	0	1	0	0	0	0	0
114	21	m	bu	di	1	1	1	1	1	1	1	1
115	21	f	me	tr	1	1	1	0	1	0	1	0
116	21	m	me		1	1	1	0	1	0	1	0
117	21	m	bl	ur	1	1	1	0	1	0	1	0
119	21	f	dr	au	0	1	1	0	0	0	1	0
120	21	m	zz	ca	0	1	1	0	0	0	1	0
121	21	m	lm	li	1	1	1	1	1	1	1	1
123	21	m	bu	di	1	1	1	0	1	0	1	0
124	21	m	zz	ca	1	1	1	1	1	1	1	1
125	21	m	dr	au	1	1	1	0	1	0	1	0
127	21	f	ga	ve	1	1	1	1	1	1	1	1
128	21	f	zz	ca	1	1	1	0	1	0	1	0
129	21	f	lm	li	1	1	1	1	1	1	1	1
130	21	m	lm	li	1	1	1	1	1	1	1	1
131	28	f	zz	ca	1	1	1	0	1	0	1	0
133	28	m	me	ve	0	0	0	0	0	0	0	0
134	28	f			1	1	1	0	1	0	1	0
135	28	f	ga	ur	1	1	1	0	1	0	1	0

Appendix

					*A	*B	*C	*D	*E	*F	*G	*H
136	28	f	re	tr	1	1	1	0	1	0	1	0
138	28	m	zz	ca	0	1	0	0	0	0	0	0
140	28	m	dr	au	1	1	1	0	1	0	1	0
141	28	m			1	1	1	0	1	0	1	0
143	28	f	lm	ve	1	1	1	0	1	0	1	0
144	28	m	re	tr	1	1	0	0	1	0	0	0
145	23	m		ca	1	1	1	0	1	0	1	0
148	23	f	bu	wa	0	1	0	0	0	0	0	0
151	23	m	re	di	1	0	1	0	0	0	0	0
152	23	f	lm	li	0	1	0	0	0	0	0	0
153	23	f	zz	ve	1	1	1	0	1	0	1	0
154	23	m	zz	ve	1	0	1	0	0	0	0	0
155	23	m	me	ur	1	0	0	0	0	0	0	0
156	23	f	re	di	0	1	1	0	0	0	1	0
157	23	m		wa	1	0	0	0	0	0	0	0
158	23	f	bl	tr	1	0	0	0	0	0	0	0
159	23	f	zz	ve	0	0	1	0	0	0	0	0
160	23	f	bu	wa	1	1	1	0	1	0	1	0
161	23	m	bl	tr	0	0	1	0	0	0	0	0
162	23	m	bu	wa	1	0	1	0	0	0	0	0
163	23	m	dr	ca	1	1	1	0	1	0	1	0
164	23	m	re	di	1	1	1	0	1	0	1	0
165	23	f	ga		0	1	0	1	0	0	0	0
166	23	f	dr	ca	0	1	1	0	0	0	1	0
167	23	f	me	ur	0	1	1	0	0	0	1	0
168	23	m	me	ur	1	1	1	0	1	0	1	0
169	23	m	lm	li	0	1	1	0	0	0	1	0
170	23	f	bl	tr	0	0	0	0	0	0	0	0
171	23	f		au	1	1	1	0	1	0	1	0
172	23	m	ga	au	1	0	1	0	0	0	0	0
173	22	m	dr	au	1	1	1	0	1	0	1	0
174	22	m	bu	di	1	1	1	1	1	1	1	1
175	22	f	ga	ur	1	1	1	0	1	0	1	0
176	22	m	ga	ur	1	1	1	0	1	0	1	0
177	22	f	me	tr	1	1	1	0	1	0	1	0
178	22	m	zz	ca	1	1	1	1	1	1	1	1
179	22	m	bl	ve	1	1	1	1	1	1	1	1
180	22	m	me	tr	1	1	1	1	1	1	1	1
181	22	m	me	tr	1	1	1	1	1	1	1	1
182	22	f	dr	au	0	1	1	0	0	0	1	0
183	22	m	zz	ca	1	1	1	1	1	1	1	1
184	22	m	lm		1	1	1	0	1	0	1	0
186	22	f	re	wa	1	1	1	0	1	0	1	0
187	22	m	re	wa	1	1	1	0	1	0	1	0
188	22	m	bl	ve	1	1	1	1	1	1	1	1
192	22	f	bu	di	1	1	1	0	1	0	1	0
194	22	f	re	wa	0	1	1	0	0	0	1	0
196	22	f		li	0	1	1	0	0	0	1	0
198	22	m	ga	ur	1	1	1	0	1	0	1	0
199	22	m	lm	li	1	1	1	0	1	0	1	0
201	22	f	zz	ca	0	1	1	0	0	0	1	0
202	22	f	ga	ur	1	1	1	1	1	1	1	1
TOTALS. --					63	68	71	18	54	17	63	17

TABLE 2. -- Pupils who were absent for one or more written tests.

*	*	*	*	*	*A	*B	*C	*D	*E A.B *	*F C.D *	*G B.C *	*H D.E *
203	22	f	bl	ve	0	1	1	0	0	0	1	0
110	21	f		tr	0	1	1	0	0	0	1	0
112	21	f	bl	ur	1	1	1	0	1	0	1	0
118	21	f			1	0	0	0	0	0	0	0
122	21	f	me	tr	0	1	1	0	0	0	1	0
126	21	m	dr	au	1	0	1	0	0	0	0	0
132	28	m	ga	ur	0	1	1	0	0	0	1	0
137	28	m	dr	au	1	0	1	0	0	0	0	0
139	28	m	re		1	0	1	0	0	0	0	0
142	28	m	lm		0	0	0	0	0	0	0	0
146	23	f	ga	au	1	0	0	0	0	0	0	0
147	23	f	zz	ve	1	0	1	0	0	0	0	0
149	23	m	lm	li	1	0	1	0	0	0	0	0
150	23	m	dr	ca	1	0	0	0	0	0	0	0
185	22	m			1	0	0	0	0	0	0	0
189	22	f	re	wa	0	0	1	0	0	0	0	0
190	22	f	dr	au	0	1	1	0	0	0	1	0
191	22	f	bl		1	0	1	0	0	0	0	0
193	22	f	lm	li	1	1	1	0	1	0	1	0
195	22	f	lm	li	1	0	0	0	0	0	0	0
197	22	f	bu	di	0	1	1	0	0	0	1	0
200	22	f	dr	au	0	1	1	0	0	0	1	0
204	25	f			0	0	0	0	0	0	0	0
205	25	m	re	tr	1	0	0	0	0	0	0	0
206	25	m	ga	ur	1	0	0	0	0	0	0	0
207	25	f	ga	ur	0	0	0	0	0	0	0	0
208	25	f	zz	ca	1	0	0	0	0	0	0	0
209	25	m	me	wa	1	0	0	0	0	0	0	0
210	25	f			1	0	0	0	0	0	0	0
211	25	f	me	wa	1	0	0	0	0	0	0	0
212	25	m		au	1	0	0	0	0	0	0	0
213	25	m	zz	ca	0	0	0	0	0	0	0	0
214	25	f	re	tr	1	0	0	0	0	0	0	0
215	25	f		di	1	0	0	0	0	0	0	0
216	25	f	lm	li	1	0	0	0	0	0	0	0
217	25	m	bl	ve	1	0	0	0	0	0	0	0
218	25	m	lm	li	1	0	0	0	0	0	0	0
219	25	m		au	1	0	0	0	0	0	0	0
220	25	m		di	1	0	0	0	0	0	0	0
221	25	f		au	0	0	0	0	0	0	0	0
222	25	m	zz	ca	1	0	0	0	0	0	0	0
223	25	f	bl	ve	1	0	0	0	0	0	0	0
224	25	m	re	tr	1	0	0	0	0	0	0	0
225	25	m	lm	li	1	0	0	0	0	0	0	0
226	25	m	zz	ca	1	0	0	0	0	0	0	0
227	25	f	lm	li	1	0	0	0	0	0	0	0
228	25	f		ve	1	0	0	0	0	0	0	0
229	25	f	ga		1	0	0	0	0	0	0	0
230	25	f	me	wa	0	0	0	0	0	0	0	0
231	25	m		au	0	0	0	0	0	0	0	0
TOTALS --					35	9	16	0	2	0	9	0
COMBINED TOTALS. --					98	77	87	18	56	17	72	17

Appendix 10.

Data from the written tests grouped by practical test.

Results of the Written Tests coded from Appendix .
(sorted by practical group)

pupil No.	class	sex	practical 1.	practical 2.	*A	*B	*C	*D	*E A.B	*F C.D	*G B.C	*H D.E
*	*	*	*	*	*A	*B	*C	*D	A.B *	C.D *	B.C *	D.E *

Practical Test:- Automatic Doors.

125	21	m	dr	au	1	1	1	0	1	0	1	0
102	21	f	dr	au	1	1	1	1	1	1	1	1
119	21	f	dr	au	0	1	1	0	0	0	1	0
126	21	m	dr	au	1	0	1	0	0	0	0	0
173	22	m	dr	au	1	1	1	0	1	0	1	0
182	22	f	dr	au	0	1	1	0	0	0	1	0
200	22	f	dr	au	0	1	1	0	0	0	1	0
190	22	f	dr	au	0	1	1	0	0	0	1	0
146	23	f	ga	au	1	0	0	0	0	0	0	0
172	23	m	ga	au	1	0	1	0	0	0	0	0
171	23	f		au	1	1	1	0	1	0	1	0
212	25	m		au	1	0	0	0	0	0	0	0
219	25	m		au	1	0	0	0	0	0	0	0
221	25	f		au	0	0	0	0	0	0	0	0
231	25	m		au	0	0	0	0	0	0	0	0
140	28	m	dr	au	1	1	1	0	1	0	1	0
137	28	m	dr	au	1	0	1	0	0	0	0	0

Appendix

Practical Test:- Car.

128	21 f	zz	ca	1	1	1	0	1	0	1	0
109	21 f	zz	ca	1	0	1	0	0	0	0	0
124	21 m	zz	ca	1	1	1	1	1	1	1	1
120	21 m	zz	ca	0	1	1	0	0	0	1	0
201	22 f	zz	ca	0	1	1	0	0	0	1	0
178	22 m	zz	ca	1	1	1	1	1	1	1	1
183	22 m	zz	ca	1	1	1	1	1	1	1	1
166	23 f	dr	ca	0	1	1	0	0	0	1	0
150	23 m	dr	ca	1	0	0	0	0	0	0	0
163	23 m	dr	ca	1	1	1	0	1	0	1	0
145	23 m		ca	1	1	1	0	1	0	1	0
222	25 m	zz	ca	1	0	0	0	0	0	0	0
213	25 m	zz	ca	0	0	0	0	0	0	0	0
208	25 f	zz	ca	1	0	0	0	0	0	0	0
226	25 m	zz	ca	1	0	0	0	0	0	0	0
138	28 m	zz	ca	0	1	0	0	0	0	0	0
131	28 f	zz	ca	1	1	1	0	1	0	1	0

Practical Test:- Bandit.

114	21 m	bu	di	1	1	1	1	1	1	1	1
113	21 f	bu	di	0	0	1	0	0	0	0	0
103	21 f	bu	di	1	1	1	0	1	0	1	0
123	21 m	bu	di	1	1	1	0	1	0	1	0
197	22 f	bu	di	0	1	1	0	0	0	1	0
174	22 m	bu	di	1	1	1	1	1	1	1	1
192	22 f	bu	di	1	1	1	0	1	0	1	0
151	23 m	re	di	1	0	1	0	0	0	0	0
156	23 f	re	di	0	1	1	0	0	0	1	0
164	23 m	re	di	1	1	1	0	1	0	1	0
215	25 f		di	1	0	0	0	0	0	0	0
220	25 m		di	1	0	0	0	0	0	0	0

Appendix

Practical Test:- Lift.

105	21	f	lm	li	1	0	0	0	0	0	0	0
121	21	m	lm	li	1	1	1	1	1	1	1	1
129	21	f	lm	li	1	1	1	1	1	1	1	1
130	21	m	lm	li	1	1	1	1	1	1	1	1
195	22	f	lm	li	1	0	0	0	0	0	0	0
199	22	m	lm	li	1	1	1	0	1	0	1	0
193	22	f	lm	li	1	1	1	0	1	0	1	0
196	22	f		li	0	1	1	0	0	0	1	0
169	23	m	lm	li	0	1	1	0	0	0	1	0
149	23	m	lm	li	1	0	1	0	0	0	0	0
152	23	f	lm	li	0	1	0	0	0	0	0	0
227	25	f	lm	li	1	0	0	0	0	0	0	0
218	25	m	lm	li	1	0	0	0	0	0	0	0
225	25	m	lm	li	1	0	0	0	0	0	0	0
216	25	f	lm	li	1	0	0	0	0	0	0	0

Practical Test:- Traffic Lights.

122	21	f	me	tr	0	1	1	0	0	0	1	0
115	21	f	me	tr	1	1	1	0	1	0	1	0
110	21	f		tr	0	1	1	0	0	0	1	0
177	22	f	me	tr	1	1	1	0	1	0	1	0
180	22	m	me	tr	1	1	1	1	1	1	1	1
181	22	m	me	tr	1	1	1	1	1	1	1	1
170	23	f	bl	tr	0	0	0	0	0	0	0	0
161	23	m	bl	tr	0	0	1	0	0	0	0	0
158	23	f	bl	tr	1	0	0	0	0	0	0	0
224	25	m	re	tr	1	0	0	0	0	0	0	0
214	25	f	re	tr	1	0	0	0	0	0	0	0
205	25	m	re	tr	1	0	0	0	0	0	0	0
136	28	f	re	tr	1	1	1	0	1	0	1	0
144	28	m	re	tr	1	1	0	0	1	0	0	0

Appendix

Practical Test:- Burglar Alarm.

112	21	f	bl	ur	1	1	1	0	1	0	1	0
117	21	m	bl	ur	1	1	1	0	1	0	1	0
106	21	m	bl	ur	1	1	1	0	1	0	1	0
202	22	f	ga	ur	1	1	1	1	1	1	1	1
175	22	f	ga	ur	1	1	1	0	1	0	1	0
176	22	m	ga	ur	1	1	1	0	1	0	1	0
198	22	m	ga	ur	1	1	1	0	1	0	1	0
167	23	f	me	ur	0	1	1	0	0	0	1	0
168	23	m	me	ur	1	1	1	0	1	0	1	0
155	23	m	me	ur	1	0	0	0	0	0	0	0
207	25	f	ga	ur	0	0	0	0	0	0	0	0
206	25	m	ga	ur	1	0	0	0	0	0	0	0
132	28	m	ga	ur	0	1	1	0	0	0	1	0
135	28	f	ga	ur	1	1	1	0	1	0	1	0

Practical Test:- Conveyor.

127	21	f	ga	ve	1	1	1	1	1	1	1	1
101	21	m	ga	ve	1	1	1	0	1	0	1	0
107	21	f	ga	ve	1	1	1	1	1	1	1	1
111	21	f	ga	ve	1	1	1	0	1	0	1	0
179	22	m	bl	ve	1	1	1	1	1	1	1	1
188	22	m	bl	ve	1	1	1	1	1	1	1	1
203	22	f	bl	ve	0	1	1	0	0	0	1	0
159	23	f	zz	ve	0	0	1	0	0	0	0	0
154	23	m	zz	ve	1	0	1	0	0	0	0	0
153	23	f	zz	ve	1	1	1	0	1	0	1	0
147	23	f	zz	ve	1	0	1	0	0	0	0	0
223	25	f	bl	ve	1	0	0	0	0	0	0	0
217	25	m	bl	ve	1	0	0	0	0	0	0	0
228	25	f		ve	1	0	0	0	0	0	0	0
133	28	m	me	ve	0	0	0	0	0	0	0	0
143	28	f	lm	ve	1	1	1	0	1	0	1	0

Appendix

Results of the Written Tests coded from Appendix
(sorted by practical group)

pupil No.	class	sex	practical 1.	practical 2.	*A	*B	*C	*D	*E A.B	*F C.D	*G B.C	*H D.E
Practical Test:- Daybell												
112	21	f	bl	ur	1	1	1	0	1	0	1	0
117	21	m	bl	ur	1	1	1	0	1	0	1	0
106	21	m	bl	ur	1	1	1	0	1	0	1	0
203	22	f	bl	ve	0	1	1	0	0	0	1	0
188	22	m	bl	ve	1	1	1	1	1	1	1	1
179	22	m	bl	ve	1	1	1	1	1	1	1	1
191	22	f	bl		1	0	1	0	0	0	0	0
170	23	f	bl	tr	0	0	0	0	0	0	0	0
161	23	m	bl	tr	0	0	1	0	0	0	0	0
158	23	f	bl	tr	1	0	0	0	0	0	0	0
217	25	m	bl	ve	1	0	0	0	0	0	0	0
223	25	f	bl	ve	1	0	0	0	0	0	0	0
Practical Test:- Build												
114	21	m	bu	di	1	1	1	1	1	1	1	1
113	21	f	bu	di	0	0	1	0	0	0	0	0
103	21	f	bu	di	1	1	1	0	1	0	1	0
123	21	m	bu	di	1	1	1	0	1	0	1	0
197	22	f	bu	di	0	1	1	0	0	0	1	0
174	22	m	bu	di	1	1	1	1	1	1	1	1
192	22	f	bu	di	1	1	1	0	1	0	1	0
162	23	m	bu	wa	1	0	1	0	0	0	0	0
148	23	f	bu	wa	0	1	0	0	0	0	0	0
160	23	f	bu	wa	1	1	1	0	1	0	1	0

Appendix

Practical Test:- Railway Crossing.

104	21 f	re	wa	1	1	1	1	1	1	1	1
100	21 m	re	wa	1	1	1	0	1	0	1	0
108	21 f	re	wa	1	1	1	0	1	0	1	0
194	22 f	re	wa	0	1	1	0	0	0	1	0
187	22 m	re	wa	1	1	1	0	1	0	1	0
189	22 f	re	wa	0	0	1	0	0	0	0	0
186	22 f	re	wa	1	1	1	0	1	0	1	0
162	23 m	bu	wa	1	0	1	0	0	0	0	0
148	23 f	bu	wa	0	1	0	0	0	0	0	0
160	23 f	bu	wa	1	1	1	0	1	0	1	0
157	23 m		wa	1	0	0	0	0	0	0	0
209	25 m	me	wa	1	0	0	0	0	0	0	0
211	25 f	me	wa	1	0	0	0	0	0	0	0
230	25 f	me	wa	0	0	0	0	0	0	0	0

Absentees.

116	21 m	me	1	1	1	0	1	0	1	0
229	25 f	ga	1	0	0	0	0	0	0	0
191	22 f	bl	1	0	1	0	0	0	0	0
139	28 m	re	1	0	1	0	0	0	0	0
142	28 m	lm	0	0	0	0	0	0	0	0
184	22 m	lm	1	1	1	0	1	0	1	0
118	21 f		1	0	0	0	0	0	0	0
185	22 m		1	0	0	0	0	0	0	0
204	25 f		0	0	0	0	0	0	0	0
210	25 f		1	0	0	0	0	0	0	0
165	23 f	ga	0	1	0	1	0	0	0	0
141	28 m		1	1	1	0	1	0	1	0
134	28 f		1	1	1	0	1	0	1	0
TOTALS --			98	77	87	18	56	17	72	17

Appendix

Practical Test:- Drive

125	21	m	dr	au	1	1	1	0	1	0	1	0
102	21	f	dr	au	1	1	1	1	1	1	1	1
119	21	f	dr	au	0	1	1	0	0	0	1	0
126	21	m	dr	au	1	0	1	0	0	0	0	0
173	22	m	dr	au	1	1	1	0	1	0	1	0
182	22	f	dr	au	0	1	1	0	0	0	1	0
200	22	f	dr	au	0	1	1	0	0	0	1	0
190	22	f	dr	au	0	1	1	0	0	0	1	0
163	23	m	dr	ca	1	1	1	0	1	0	1	0
166	23	f	dr	ca	0	1	1	0	0	0	1	0
150	23	m	dr	ca	1	0	0	0	0	0	0	0
137	28	m	dr	au	1	0	1	0	0	0	0	0
140	28	m	dr	au	1	1	1	0	1	0	1	0

Practical Test:- Gate

127	21	f	ga	ve	1	1	1	1	1	1	1	1
101	21	m	ga	ve	1	1	1	0	1	0	1	0
107	21	f	ga	ve	1	1	1	1	1	1	1	1
111	21	f	ga	ve	1	1	1	0	1	0	1	0
175	22	f	ga	ur	1	1	1	0	1	0	1	0
176	22	m	ga	ur	1	1	1	0	1	0	1	0
198	22	m	ga	ur	1	1	1	0	1	0	1	0
202	22	f	ga	ur	1	1	1	1	1	1	1	1
165	23	f	ga		0	1	0	1	0	0	0	0
146	23	f	ga	au	1	0	0	0	0	0	0	0
172	23	m	ga	au	1	0	1	0	0	0	0	0
229	25	f	ga		1	0	0	0	0	0	0	0
206	25	m	ga	ur	1	0	0	0	0	0	0	0
207	25	f	ga	ur	0	0	0	0	0	0	0	0
132	28	m	ga	ur	0	1	1	0	0	0	1	0
135	28	f	ga	ur	1	1	1	0	1	0	1	0

Appendix

Practical Test:- Lawnmower.

105	21	f	lm	li	1	0	0	0	0	0	0	0
121	21	m	lm	li	1	1	1	1	1	1	1	1
129	21	f	lm	li	1	1	1	1	1	1	1	1
130	21	m	lm	li	1	1	1	1	1	1	1	1
195	22	f	lm	li	1	0	0	0	0	0	0	0
184	22	m	lm		1	1	1	0	1	0	1	0
199	22	m	lm	li	1	1	1	0	1	0	1	0
193	22	f	lm	li	1	1	1	0	1	0	1	0
152	23	f	lm	li	0	1	0	0	0	0	0	0
169	23	m	lm	li	0	1	1	0	0	0	1	0
149	23	m	lm	li	1	0	1	0	0	0	0	0
216	25	f	lm	li	1	0	0	0	0	0	0	0
227	25	f	lm	li	1	0	0	0	0	0	0	0
218	25	m	lm	li	1	0	0	0	0	0	0	0
225	25	m	lm	li	1	0	0	0	0	0	0	0
142	28	m	lm		0	0	0	0	0	0	0	0
143	28	f	lm	ve	1	1	1	0	1	0	1	0

Practical Test:- Mechanisms

122	21	f	me	tr	0	1	1	0	0	0	1	0
116	21	m	me		1	1	1	0	1	0	1	0
115	21	f	me	tr	1	1	1	0	1	0	1	0
181	22	m	me	tr	1	1	1	1	1	1	1	1
177	22	f	me	tr	1	1	1	0	1	0	1	0
180	22	m	me	tr	1	1	1	1	1	1	1	1
167	23	f	me	ur	0	1	1	0	0	0	1	0
168	23	m	me	ur	1	1	1	0	1	0	1	0
155	23	m	me	ur	1	0	0	0	0	0	0	0
211	25	f	me	wa	1	0	0	0	0	0	0	0
230	25	f	me	wa	0	0	0	0	0	0	0	0
209	25	m	me	wa	1	0	0	0	0	0	0	0
133	28	m	me	ve	0	0	0	0	0	0	0	0

Appendix

Practical Test:- Reverse

104	21	f	re	wa	1	1	1	1	1	1	1	1
100	21	m	re	wa	1	1	1	0	1	0	1	0
108	21	f	re	wa	1	1	1	0	1	0	1	0
194	22	f	re	wa	0	1	1	0	0	0	1	0
187	22	m	re	wa	1	1	1	0	1	0	1	0
189	22	f	re	wa	0	0	1	0	0	0	0	0
186	22	f	re	wa	1	1	1	0	1	0	1	0
164	23	m	re	di	1	1	1	0	1	0	1	0
151	23	m	re	di	1	0	1	0	0	0	0	0
156	23	f	re	di	0	1	1	0	0	0	1	0
224	25	m	re	tr	1	0	0	0	0	0	0	0
214	25	f	re	tr	1	0	0	0	0	0	0	0
205	25	m	re	tr	1	0	0	0	0	0	0	0
139	28	m	re		1	0	1	0	0	0	0	0
144	28	m	re	tr	1	1	0	0	1	0	0	0
136	28	f	re	tr	1	1	1	0	1	0	1	0

Practical Test:- Buzzer.

128	21	f	zz	ca	1	1	1	0	1	0	1	0
109	21	f	zz	ca	1	0	1	0	0	0	0	0
124	21	m	zz	ca	1	1	1	1	1	1	1	1
120	21	m	zz	ca	0	1	1	0	0	0	1	0
201	22	f	zz	ca	0	1	1	0	0	0	1	0
178	22	m	zz	ca	1	1	1	1	1	1	1	1
183	22	m	zz	ca	1	1	1	1	1	1	1	1
159	23	f	zz	ve	0	0	1	0	0	0	0	0
154	23	m	zz	ve	1	0	1	0	0	0	0	0
153	23	f	zz	ve	1	1	1	0	1	0	1	0
147	23	f	zz	ve	1	0	1	0	0	0	0	0
226	25	m	zz	ca	1	0	0	0	0	0	0	0
222	25	m	zz	ca	1	0	0	0	0	0	0	0
213	25	m	zz	ca	0	0	0	0	0	0	0	0
208	25	f	zz	ca	1	0	0	0	0	0	0	0
131	28	f	zz	ca	1	1	1	0	1	0	1	0
138	28	m	zz	ca	0	1	0	0	0	0	0	0

Appendix

Absentees.

110	21	f	tr	0	1	1	0	0	0	1	0
118	21	f		1	0	0	0	0	0	0	0
185	22	m		1	0	0	0	0	0	0	0
196	22	f	li	0	1	1	0	0	0	1	0
157	23	m	wa	1	0	0	0	0	0	0	0
171	23	f	au	1	1	1	0	1	0	1	0
145	23	m	ca	1	1	1	0	1	0	1	0
228	25	f	ve	1	0	0	0	0	0	0	0
212	25	m	au	1	0	0	0	0	0	0	0
219	25	m	au	1	0	0	0	0	0	0	0
215	25	f	di	1	0	0	0	0	0	0	0
204	25	f		0	0	0	0	0	0	0	0
210	25	f		1	0	0	0	0	0	0	0
221	25	f	au	0	0	0	0	0	0	0	0
220	25	m	di	1	0	0	0	0	0	0	0
231	25	m	au	0	0	0	0	0	0	0	0
141	28	m		1	1	1	0	1	0	1	0
134	28	f		1	1	1	0	1	0	1	0
TOTALS --				98	77	87	18	56	17	72	17

Appendix 11.

Establish a Technical Vocabulary.

Appendix IIb.

	1 J (9)	1V (27)	2V (28)	Total
Colour				
Black	6	19	27	52
Grey	6	12	19	37
Red	6	22	18	46
Size				
Big	1	6	6	13
C.M.	1	—	10	10
M.M.	2	1	3	6
Fat	1	1	1	3
Height	—	—	4	4
Large	1	1	3	5
Little	3	3	3	9
Long	4	19	24	47
Narrow	1	1	—	2
Short	1	9	9	19
Small	—	10	14	24
Wide	4	—	7	13
Thick	1	3	8	12
Thin	—	13	14	27
Tall	—	—	2	2
Shape				
Circle	2	8	11	21
Corner	—	2	1	3
Cylinder	—	—	2	2
Diameter	—	—	1	1
Oblong	3	6	7	16
Rectangle	—	5	11	16
Round	6	13	16	35
Spiral	1	6	5	12
Square	—	5	1	6
Star	—	—	2	2
Triangle	—	1	—	1

	1J (9)	1V (27)	2V (28)	TOTAL
FEATURES				
BOTTOM		3		3
CENTRE				—
CROSS	3		6	9
DOT		3	2	5
EDGE		2		2
END				
FLAT		6		6
GROOVES		4	11	15
HOLE	9	16	19	44
HUMPS/BUMPS	1	6	16	23
JAGGERD		2	3	5
JOINT			4	4
MIDDLE		9		9
POINTS			3	3
SIDE		11		11
SPIKE	4	2		6
TEETH			2	2
TOP		13		13
IT IS				—
AXEL	1	5	5	11
BRICK	1	1	4	6
CHAIN	1	7	2	10
COG	2	7	11	20
ROD	—	—	3	3
WHEEL	1	14	9	24
POLE	—	5	1	6

A

B

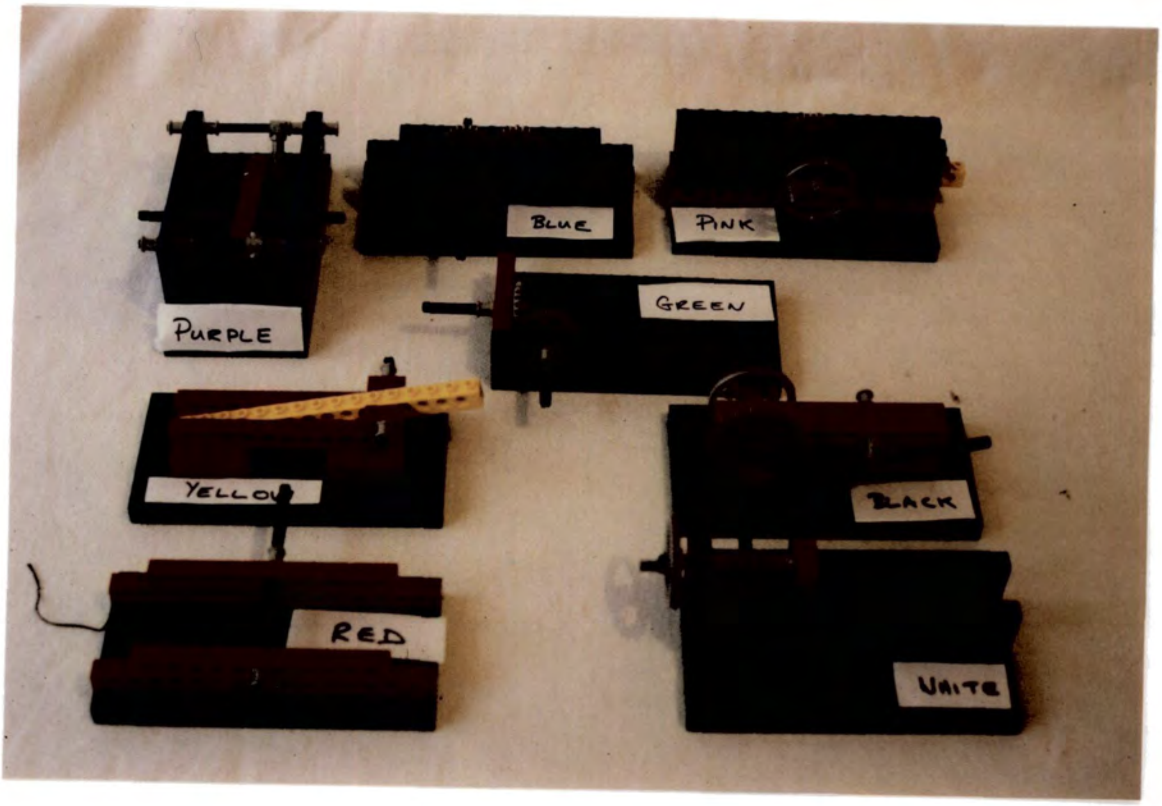
C

D

Appendix 12.

Assessment of the pupils ability to identify mechanisms.

THE MECHANISMS



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