

Computer Control in Key Stage 2 Design and Technology: Massed or Spaced, which is best?

Abstract

Control is an integral element of the programme of study for Key Stage 2 in the National Curriculum for England and Wales. It seems that developing work with control is the least well undertaken aspect of design and technology in primary schools, and the least well covered element of work in information and communications technology. Two organisational approaches to this work are outlined: a reasonably long period of time devoted just to developing work in control, perhaps as a 'one off' experience relying upon support from outside of the school, contrasted with a series of shorter sessions spread over a term or perhaps half of a term. The relative merits of each are discussed, and a mini case study for the first approach is presented. Concluding, it is seen that there are certainly merits to be found with both approaches, and the least effective in the long term may be the one-off approach. This is not discounted however since the constraints placed on teachers mean that in many cases to carry out control work as an integrated element of the curriculum is impossible; the one off approach, with support from outside has much to commend itself.

Introduction

Computer control is an element of the National Curriculum for England and Wales (DfEE/QCA, 2000), and as such it is a legal requirement that this work is undertaken in accordance with the programmes of study which are set out. Casually, and anecdotally it is easy to see that there is actually very little work on control, beyond some excellent introductory level work, being undertaken in schools. That is not to deny that there is some work of very high quality taking place, but in very general terms, control is not well covered.

There are some obvious reasons for this situation. Teachers are not confident in this area of the curriculum, resources are not cheap, the school week is congested enough with the statutory requirements for such important lessons as numeracy and literacy, despite the relaxation of other curriculum requirements in recent years.

We will see later that control work does take time and requires resources and a certain level of competence and, more importantly, confidence on the part of teachers. The whole area of pre and in-service training will not be considered here, but training certainly is a hot issue if work on control is to be developed in schools.

Control?

The National Curriculum (DfEE/QCA 2000) examples given for Key Stage 1 are: controlling the movement of a floor turtle; the use of an on/off switch in a model; designing a route for a turtle to go shopping; or controlling the light in a lighthouse. At Key Stage 2 the National Curriculum (DfEE/QCA, 2000) examples are: designing and making an animated scene which receives information from switches; the use of a control interface to design and control a sequence of events: e.g. a setting for a ghost train, or a treasure island which lights up different areas; or models of other fairground rides.

It is possible to use a simple interface to connect a computer to items, such as lights, motors, and buzzers, which can be switched on and off in order to create a situation in which the results of children's designing and making can be made active, and actually work in the way that they might in the real world. When combined with sensors, the same interface equipment can also deal with sensing. For example, it is possible for children to design, build and then operate such things as a security light which switches on when either a pressure switch is depressed, or a light sensor detects that there is a presence (actually, a decrease in the amount of light detected) or a barrier for a car park which will rise when a proximity switch detects the presence of a car which wishes to leave the car park.

A simple introductory activity which is well within both the capability and range of experience of children in the lower part of Key Stage 2, would be to write a short piece of control language which when operated will make a light flash. The context which this could be put into might be an orange flashing for a zebra crossing, or the warning lights at a level crossing. The design and making of the light fitting itself, including the colours, the post and the rest of the setting, combined with the design and implementation of the instructions in the control language, combine well to make up a suitable activity.

Monitoring?

Monitoring is often seen as a natural progression from control. Also known as datalogging (generally in the context of science), sensing, or monitoring, it means that information from the environment can be detected by means of a sensor of some kind and depending on the signal received, certain actions may result.

For example, in our every day lives we are constantly being sensed and we constantly see the effect of this sensing. The most obvious case would be the door which opens

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automatically as someone approaches. Similarly a car park barrier will lift in order to let a car enter. In this case the barrier will only lift if there is enough space in the car park for another car. A less obvious use of sensing, but to be found in many greenhouses across the country, is a device which will open or close windows according to the internal temperature. Burglar alarms, which work in a variety of different ways, all depending on sensing of some description, are another obvious application of the technology.

In schools many of these 'grown up' systems can be emulated with the use of relatively unsophisticated software, simple model building materials and rudimentary, even home made, switches. Sensing temperature change, or light intensity, requires commercial products. Similarly, very large sized pressure pads are available commercially and can be used to devise and build a burglar alarm, for example, and when a child stands on the pad, an internal contact is made, a simple circuit is completed and a signal sent to the computer via the interface. The result of this signal being received could be the sounding of a buzzer, or the switching on of a light, or perhaps both. Children, and also many teachers, take great delight in making various things happen. In particular, when a system of monitoring and control finally works as it was designed a good deal of excitement and satisfaction can be generated.

One view of the use of control technology would be that the control product should be an integral and essential part of any final design and technology solution to an identified problem. That is to say that the control work would be integrated into some other design and technology project which involves the use of many other skills apart from those involved in the planning and implementing of a control system. For example, in the context of a history topic, design and technology work could be planned in which children are asked to consider how the draw bridge mechanisms of a medieval castle might work. The scope for extending designing and making work into computer control and all that is this would entail could be fairly extensive. Children can be encouraged and enabled to develop the skills involved in both 'motorising' the bridge, and then controlling the motor with a computer and control software. There is scope for developing this further still, if monitoring work is also included. The bridge could, for example, open only when there is a presence on a pressure pad which is placed strategically on the outside of the castle gates. (Naturally a leap, in technological terms, needs to be made here.)

A more common, and perhaps more manageable, approach to using control in the primary school takes the form of a short 'module' which introduces control and gives time to practice and to develop both skills and understanding. The style of this work resembles a focussed practical task (FPT), a concept which was introduced into design and technology as a part of the National Curriculum some years ago. A focused practical task is a short activity which allows skills to be developed which can be used later in the context of a specific design and making project. In a simple form, the FPT could be practice in joining materials together, or a task which introduces the use of gears with a motor. In practice FPTs allow for the basic skills which will be required in some approaching work to be practised and improved. Sometimes the FPT can be used as a form of experimenting or prototyping where children try out different ideas, the best of which is then developed and used in the final product.

In the form of an extended FPT control work can be introduced and great strides forward both in skills and understanding can be made. If simple tasks such as 'Can you make the light come on and stay on for five seconds?' are accomplished and then developed into a more complex task – perhaps the sequences involved in traffic lights, pelican crossings (including sounds) or railway crossings, then there will not only be measurable learning taking place, but there will be obvious enthusiasm and enjoyment. Using new tools to produce predetermined effects can lead to a great sense of pride and achievement. When this is the case the level of engagement with the task and the new skills and ideas is high and even greater things can be considered.

Another way of developing control work, but without the added interest (or perhaps complication) of creating models which are to be controlled, is to use 'ready made' models. Schools often have a selection of motorised models as a part of their control kit which can be used to introduce and develop control and monitoring work. The most common model to have ready for use is a motorised buggy of some kind. It is possible to acquire these buggies from a number of sources. Most construction kit suppliers can provide, in kit form, a simple vehicle which can be built up and used time and again. (Some teachers, realising that these models are likely to come apart with extensive use, have been known to use super glue to keep them together permanently.) Keeping a supply of different models – buggies, opening barriers, fairground rides, sets of traffic lights, is a way

of using design and technology time economically and allowing children to focus on the development of control skills rather than being constrained in their work by not having a model which is suitable for controlling.

Possible forms of organisation

Let us now consider two different models for the completion of work with computer control. It is possible to describe these two models in terms of a skills training analogy. The literature concerning skill, and more latterly, other types of learning, sometimes based on the use of educational technology, goes back a long way. Thorndike as early as 1913, and later in 1932, and Donovan and Radosevich in 1999 describe two approaches to the notion of 'practice' in learning. Massed practice implies that the equivalent of a series of short periods of practice are joined together to add up to one longer period, and spaced or distributed practice is the case when shorter periods of practice are spread over a longer time scale. It is true that most of the literature considers these two approaches in terms of the learning of physical skills, in many cases it relates to sporting contexts, but there is some work carried out in the realm of what might be considered as learning as opposed to training. Thorndike's Law of Exercise, though based on the unfashionable behaviourist tradition does relate to learning generally and deals with the massing or spacing or rewards and the effect that this may have on the associations which are the foundations of learning in the behaviourist view.

Clearly the split between massed or spaced practice is not a simple one. Many other variables come into play. In particular the nature of the spacing and the total time which is massed can make important differences to the learning outcomes (see Adams and Reynolds, 1954; Lee and Genovese, 1988). The intervals between spaced practice sessions, the duration of these sessions need to be measured, calibrated and taken into account statistically if definitive statements can be devised which adequately inform those who plan for learning. The nature of the learning activity itself is also an important consideration. Activities which are made up from a balance of intellectual activity and physical dexterity will respond differently in learning situations to activities which have a very different balance between these two simply defined elements of a learning task.

This paper is not an appropriate setting to delve deeper into the subtleties of this area of learning theory. It is enough to be aware that there is a theoretical underpinning to approaches to practice and reinforcement of

the ideas and skills involved in much of the learning which is planned for in schools and elsewhere, it is also sufficient to recognise that it is not always the case that this, or even any element of learning theory, is given the priority which it could be argued that it deserves in the planning and implementation of programmes of learning.

So, we have massed arrangements with long or extended periods of intensive work; and we have spaced or distributed arrangements which are characterised by shorter 'bursts' of work spread over a longer period of time.

What does this translate to in practice, in the context of computer control in design and technology in Key Stage 2? Put in simple terms it could look something like:

Spaced: One session per week to 1 to 1½ hours over a period of seven weeks (half a school term).

Massed: An entire school day, or perhaps longer, devoted to working on control.

Clearly there could be a great many variations on these two themes.

There actually appears to be a third model, which is more of a minimalist approach. It involves certain avoidance tactics, or the paying of lip-service to the area of the curriculum by using Logo, or work controlling a floor robot. This approach is wholly understandable (and easily justifiable in terms of its educational value and its place in the appropriate programmes of study) given the pressures and constraints placed upon teachers and schools. These constraints include pressures on the timetable, resource implications of any control work, let alone whole classes working together in the massed model, and teacher confidence and expertise.

The massed model for certain activities in primary schools is not a new phenomenon. Though perhaps less common now, there was a time, in their recent past, when extended experiences were commonly used as a way of developing children's work in say art, or maths or almost any subject which a creative staff team chose to consider (for an example in the context of design and technology and children's literature, see Pritchard, 1993.) The advantages of this approach are almost certainly not couched in terms of learning theory, but in terms of children's enjoyment and engagement, and the possibilities for inviting outside help to take a role in the work, such as a visiting writer, or an advisory teacher for the subject in question. The precept of giving children the time to develop work of depth and quality has also been a driving force behind this organisational

approach to the curriculum. With the requirement to meet the regulations set out for the literacy and numeracy strategies schools have had to rethink approaches to this type of extended work, but creative teachers who believe in this occasional way of working find creative ways of solving the problems which they are faced with.

Mini case study: introducing computer control

Context

This case study is of a group of 29 children in Year 6 of a rural primary school. The school does not have the facilities to work with computer control and so has made visits to a very well equipped Business Education Partnership Centre not too far from the school.

The children have no formal experience of programming of any kind, though, as we will see, it is clear that the concepts involved in programming and control are beginning to become established without this formal input. The children do make use of other elements of ICT in their routine school work and many of them have access to computers at home.

The class spend a day at the centre. The aims of the day included introducing computer control to the whole group and, through a series of guided activities and problem solving, giving the children experience of as many of the elements of control which are set out in the National Curriculum as possible. We will see that all of the children were able to demonstrate work at a very high level and with more reinforcement would clearly match the level descriptors for computer control at a level beyond that expected for children at the end of Key Stage 2.

The teaching strategy was centred around whole class work interspersed with exposition of new information, carefully targeted questions and a series of opportunities for children to work at solving staged problems. In most cases the children worked in pairs, with one or two children choosing to work alone. At every stage, appropriate intervention was made and the motivational power of public praise was used to very good advantage. As well as the leader of the session, who was a permanent member of the centre's staff, there were other adults involved, most of whom had little or no prior experience of this type of work.

The progress of the session

On arrival at the centre the day was explained to the children in terms of them becoming skilled as computer programmers, able to 'instruct' a computer and solve problems concerning the work which was to be

undertaken. A very clear approach was taken and the computer described in terms of a 'stupid machine' which would only 'do as it was told' – nothing more, nothing less. Various examples of this stupidity were given and also extracted from the children. The notion of programming was explored and most children were able to describe computer controlled devices around the home which were frequently programmed – video recorders, washing machines and so on. One particular demonstration caught the imaginations of the children. It was established that the main purpose of the facility where the centre is based was to test each and every component and system of a car. One child was enlisted to act as a computer controlling the process of testing a suspension spring. It was drawn out from the children that this would involve a great many repetitive movements and that a computer could easily be 'asked' to repeat a control movement designed to depress and release a spring. A notional program was evolved which would carry out this job, it included the use of 'repeat'; most of the ideas involved were skilfully elicited from the group by the use of suggestion and questioning.

A description of digital data transfer was given in terms of a common language being needed for all computers, and the idea of digital signals explored. The analogy of a conversation between a Japanese speaker and an English speaker was made to illustrate the need for an interpreter. At this stage the computers in the room and the associated control interface boxes were introduced.

Definitions of inputs and outputs were arrived at; the appropriate sockets on the boxes pointed out.

The control software – Logicator – was also introduced and very quickly the children were able to string together a simple set of instructions to switch on a lamp and let it stay alight for a short period. Plenty of opportunity to consolidate this new information was given, and soon all of the children had successfully completed a short control program which switched on lights in different combinations and sounded two different notes at different times. The use of WAIT and REPEAT was also introduced and established as a part of the new repertoire of commands which the class was assembling.

The software really did seem straightforward and easy to use. Particular functions and commands were only introduced on a need to know basis and in this way a steady increase in understanding was achieved without the children attempting to learn a list of commands out of context.

An interesting feature of the organisation of this session was the prominent position given to the levels of attainment which were being pursued. At any particular stage an individual child would have one of the levels of attainment ticked off on a record sheet and initialled by the teacher if it was considered that evidence of achieving the level in question had been shown – by the answering of a question for example. This served as a powerful incentive to engage with the teacher and to answer questions. The level of motivation was very high throughout the session, as was the level of achievement.

Before long the children were able to meet the challenge of producing and amending short programs to answer specific problems. The introduction of a decision feature to the program, allowing for a set number of repeats to be completed, was introduced with a whiteboard, and copious questions. This was readily accepted by the group. When the children returned to the computers there were certain difficulties with the precise procedure for implementing this new feature. These difficulties were quickly overcome by incisive intervention or, in some cases, by the children working as trouble-shooters to find a solution. At every stage it was made clear that mistakes do not matter. If something is tried out and it doesn't work, then the programmer should take this as a learning opportunity and build on the new knowledge which the previous attempt provides. This process was referred to as trial and refinement.

By the end of the session all of the children had written, trialled and refined a program which controlled lights, made sounds as required, made use of the WAIT and REPEAT commands, incorporated a decision, and moved a motorised buggy to order.

An enormous amount of work had been covered by lunchtime, and an enormous amount of confidence had been built. The children displayed great enthusiasm and a great potential for internalising the new information that was presented to them. The children printed out their programs, set off to eat their food and were very soon itching to get back to new challenges awaiting them in the afternoon session.

Commentary

Clearly this is an ideal setting for the introduction of work of this type which many schools find difficult to incorporate into their termly and yearly routines. The resources of this, and many other centres, far outstrips anything which a primary school could realistically expect to match. It would, in an ideal world, not have to wait until children reached the end of Key Stage 2 before

computer control was introduced. Much of the introductory work which the children completed in one session would have been spread over a much longer period if the school had been able to offer control, and by the time the children reached their last year at primary school it is very likely that they would be ready to meet similar challenges, having arrived via a different route. It could be argued here, in terms of critical period theory, that the children in the case study were 'ready' to learn, and that introducing this work earlier might have been less effective; this is material for further detailed investigation, and another paper.

The new and important environment was a very strong motivational factor, as was the use of new and exciting machines and software. The inspiration of the teacher was also an important factor in the success of the session. The class teacher was clearly equally excited, both by the simplicity of the software, and by the fact that without an enormous effort the children in her class had demonstrated very high attainment in a relatively short time. It must be remembered that during this session children were exhibiting evidence of meeting levels of attainment set out in the level descriptions for design and technology, and were told that they had reached particular levels. Strictly speaking this was accurate, but it is important that for a sound and lasting assessment to be made the children should exhibit the same evidence on different occasions. Certainly the approach taken worked as a very important motivator during the work which was undertaken.

This model of delivery for computer control is clearly very effective in terms of the impact which it made on the children, both in the realm of interest, excitement and motivation and more importantly in the very positive development of knowledge, skills, concepts and attitudes. In other circumstances, in school with the same control equipment, the same work could be undertaken. However, it would rely on a level of confidence which most teachers do not have. If teachers were able to spend time, with guidance, working with the hardware and software, there seems to be little doubt that work of equal quality could be achieved.

Conclusion

Something is certainly better than nothing. Developing the use of computer control adds more to a child's education than knowledge of how to do control. Children enjoy this type of work in most cases, though it is always a little rash to generalise in this way. Children develop a problem solving approach to their work which can be encouraged and fostered.

Children can develop the skills required to work in collaboration with others. Related work, in other curriculum areas can also benefit from the engagement that enjoyment may engender. For example, creative writing based on the designed, made and controlled model can become something of far more importance to the individual than might otherwise have been the case; using mathematical knowledge in an applied situation (perhaps looking at the ratios of different gear wheels to one another and attempting to calibrate fine controlled movements) can bring a subject which is for some just a little uninteresting, or even foreboding, to life. A deeper understanding of the effects and ramifications of the computer age in our everyday lives can be engendered too. For these reasons there is a good case for attempting to fulfil the requirements of the National Curriculum, apart from the fact that it is the National Curriculum.

Probably in ideal circumstances there would be possibilities in school (time, equipment, staff confidence and expertise) to allow for control to take its place alongside other elements of design and technology in the curriculum. In an even more ideal situation it might be possible to import additional expert help too. In cases where ideal resources were available, choices could be made concerning the massing or spacing of the experiences. Since this isn't the case, the use of massed work with outside help and facilities is a very good alternative. Since most schools clearly do not have the capabilities to undertake control work of any type, except the most basic, the use of partnership and technology centres should be applauded and encouraged. The whole experience is also, of course a learning and developmental experience for teachers too. It has been seen that having seen first hand precisely how control work can be organised and how straightforward the apparent technicalities are, teachers have returned to school and made resource demands on the school itself which in some cases has led to a level of self-sufficiency in the teaching of control. On the contrary, other teachers have been known to abdicate any responsibility for planning and teaching control and they are happy to make annual visits to the centres which provide them with the wherewithal to tick off, either mentally or in fact, the space on their curriculum chart reserved for control.

There is little doubt that by working for a day, or even half of a day in a local centre, and massing the time allowed for control that enjoyable learning takes place. It may not be ideal, and it may be the case that well planned space activities would lead to a better quality

of learning, but it is enjoyable, it is learning, and it is most certainly better than not covering the topic at all.

Teachers are not able easily to experiment with modes of curriculum organisation. Features of organisation are often fixed and beyond the control of individual teachers owing to the many different variables and constraints described above. Teachers and other planners, should however be aware of the benefits of the different modes of organisation, and work towards optimising the learning opportunities afforded by one or another methods of presenting the curriculum.

Note: For a more detailed consideration of the use of ICT to support learning in primary school design and technology see Pritchard (2001).

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