Who’s in control (of the teaching of computer control)?

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Who’s in Control (of the teaching of computer control)?
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Abstract
The UK National Curriculum (NC) review that led to the 2000 NC Orders (DfEE, 2000) had an emphasis on ‘slimming down’ the curriculum and removing areas of overlap between subjects. However, computer control was one of a very few content areas that was left explicit in the National Curricula of two different subjects; Design and Technology (D&T) and Information and Communication Technology (ICT).

Previous research by one of the authors (Steeg, 2003) has noted the different approaches to the teaching of control in the two subjects (led largely by the dissimilar ways that control is described in the Programmes of Study for the two subjects) and highlighted some of the implications that this can have for pupils’ learning.

At a time when the NC is under review and there is renewed interest in the ways that subjects (and D&T in particular) in schools interact with each other (Barlex, 2000, 2005), it is timely to examine in more detail not just the differences in the teaching of control between ICT and D&T departments but also the ways that schools and departments within them deal with these differences.

To this end, the pilot study reported here examines in detail the ways that the teaching of control is conducted in the ICT and D&T departments of six schools, with a focus on two main questions:

- How is control taught and how, if at all, does the teaching differ between D&T and ICT?
- What collaboration exists between D&T and ICT departments in the teaching of control?

The main data collection was through detailed interviews conducted with the heads of department of both ICT and D&T in each school. This was supplemented by classroom observation of ‘control’ lessons and scrutiny of the schemes of work for control in the departments.

The data indicate that there is little collaboration between D&T and ICT departments and that it is common for pupils at Key Stage 3 to be exposed to control ideas in both subjects, but in ways that often have little in common. The implications of this for pupil learning and their attitudes towards D&T are explored.

Key words
control, systems, microcontroller, PIC, ECT, teaching approaches, cross-curricular

Background
In UK schools, at Key Stage 3 (KS3, 11-14 year olds) computer control has an unusual place in the curriculum: it forms an explicit and significant part of the National Curricula for two different subjects (Information and Communication Technology and Design and Technology), despite the rationalisation and ‘slimming down’ that took place during the development of the current incarnation of the UK National Curriculum (DfEE, 2000). This double appearance in the NC could be an opportunity for the ICT and D&T departments in a school to work together to develop and teach an appropriate course, but casual observation suggests that this is relatively rare. It seemed, to the authors, much commoner for computer control, in one guise or another, to be a part of the curriculum at KS3 in both departments. Contemplation of this situation raised various questions in the authors’ minds centred on two main foci; the extent to which the approaches to the teaching of control by the two departments complement each other (or conversely are either at odds or simply repetitive) and the degree to which the two departments might work together in planning and teaching the subject.

A focused study of the approaches to the teaching of control at KS3 seemed to be opportune, particularly in the light of the imminent revision of the KS3 national curriculum. This paper outlines some preliminary findings from this study.
Control and Collaboration

Inspection of the National Curriculum documents for ICT and D&T reveals some interesting similarities and differences. In ICT the focus is on “planning, testing and modifying sequences of instructions” when using ICT to control events, whereas in D&T the focus is “that complex systems can be broken down into sub-systems to make it easier to analyse them, and that each sub-system has its own inputs processes and outputs”. Hence in ICT there is tendency for the curriculum focus to be on control as a context for teaching programming, a key ‘big idea’ in ICT. In D&T the focus is more using systems thinking, a ‘big idea’ in the D&T curriculum, as a tool for teaching control ideas. On the other hand, both curriculum documents emphasise the importance of pupils understanding the importance of feedback in control systems. This suggests that, in the absence of inter-departmental discussions, the approaches to teaching control might be expected to be rather different in the two departments.

Studies on the relationship between ICT and D&T in schools seem to be rare, but there is a stronger literature on the relationship between science and technology that is relevant to this study and this has been summarised recently in Barlex & Pitt (2000) who define collaboration between subjects as involving ‘the teachers in each subject planning their curricula so that some, but not all activities within each subject are designed to establish an effective relationship’.

Owen-Jackson (2002) has summarised the benefits of collaborative work for pupils as:

- enhanced learning through reduced confusion, greater coherence and linking abstract work in one subject with practical activities from another;
- increased motivation through a greater perceived relevance and personal involvement;
- a reduction in the assessment load where shared coursework assignments are used.

Paterna (2001) notes, in the context of assessment, that collaborative work produces ‘better use of students’ time – in terms of assessment as well as enabling pupils to take broader curriculum’.

Owen-Jackson (ibid) also notes that teachers benefit as well from collaborative work through:

- more effective learning for pupils;
- more effective use of teaching time through exploiting the links between subjects rather than duplicating teaching;
- an improved understanding and awareness of other subjects;
- better management of resources and the development of shared resources;
- staff development e.g. through the discussion of teaching and learning approaches.

Paechter (1995) suggests that the most important benefit to be gained from teachers working together across subject boundaries is a fuller realisation of which links can be made without undue strain. Such understanding is critical in underpinning the planning of work which will enable students, in turn, to appreciate such connections as they are unlikely to discover these without guidance.

However, Barlex & Pitt (ibid) note various factors that inhibit collaborative work in schools. These include:

- the tunnel vision induced in teachers by the National Curriculum and the result that teachers know very little about each other’s subject areas;
- uncertainty about the benefits of such collaboration ‘the benefits of collaboration are not immediately obvious’ (39);
- time. There is ‘strong evidence that many wish to [collaborate] but the availability of quality planning time is seen as a major issue for some’ (39). Quality planning requires time to consider the kinds of learning that are desired and the pedagogies appropriate to these learning aims (40). Thus, teachers need to invest time to consider new teaching strategies.

It is, perhaps, significant in this context that the national schemes of work provided by The Qualifications and Curriculum Agency (QCA) for both D&T and ICT contain units covering the area of control:
The message from QCA could certainly be interpreted by schools as being that there is an expectation that work on control should be found in the curricula of both subjects. This interpretation is likely to be compounded by the fact that the units for the two subjects were written by different authors with no collaboration, as this means that there is little in them to encourage collaborative work.

So, while there may be many compelling reasons for school subjects to collaborate, it is not difficult to identify pressures that work against collaboration.

**Constructionism**

Barlex and Steeg have argued (2006) that a powerful reason for including electronics in the curriculum can be found in constructionism, a theory of learning developed from reasoning originally used in relation to encouraging the teaching of programming to children. Constructionism lies in the broad stream of constructivist theories of learning and has been developed by Seymour Papert and others (Papert, 1980, 1994, Kafai & Resnick, 1996). The core argument of constructionism is that people learn best when they are making something (be it a sandcastle on the beach or a theory in physics) because of the powerful interaction between thinking and action during construction. Learning is most powerful when the construction environment is rich and there is ample opportunity to view the success of one’s construction efforts (feedback).

Originally constructionism was an argument for putting children in control of computers through the use of LOGO; a programming language with a ‘low floor and a high ceiling’ (easy to get into but limitless in its applications). This work soon grew to encompass robotics where the programming of the computer controlled not simply what happened on screen but also events in the real world. Here the link to control work becomes clear; work with control systems can, if properly designed, provide a uniquely rich constructionist environment with ample opportunity for feedback on the success of construction efforts.

The pilot study reported here aims to provide some insight into the various approaches to the teaching of control at KS3 and also to investigate the degree to which there is collaboration between D&T and ICT in the teaching of control, with a focus on two main questions:

- How is control taught and how, if at all, does the teaching differ between D&T and ICT?
- What collaboration exists between D&T and ICT departments in the teaching of control?

**Research approach**

To attempt to answer these questions we decided a three-pronged data collection approach would be appropriate.

1. Semi-structured interviews with the teachers of ‘control’ from both the D&T and ICT departments within schools.

   Questions prepared for the interviews covered teachers’ teaching approaches, what they considered to be the key concepts in the teaching of control, the resources used to support the teaching of control and what they felt pupils gain from learning about control technologies.

   Permission was gained in advance of the interviews to record the discussions on audiotape and these were subsequently transcribed and matched against the notes taken during the interviews.

2. Scrutiny of the ‘control’ schemes of work from the two departments.

<table>
<thead>
<tr>
<th>D&amp;T</th>
<th>ICT</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit 07d: Using control to control a display Focus: control and structures</td>
<td>Unit 6: Control – input, process and output</td>
</tr>
<tr>
<td>Unit 08d: Using control for security Focus: control</td>
<td>Unit 13: Control systems</td>
</tr>
<tr>
<td>Unit 09d: Using control for electronic monitoring Focus: control</td>
<td>(QCA, 2000a)</td>
</tr>
</tbody>
</table>

(QCA, 2000b)
Observation of the teaching of control in the pair of departments in each school.

In the event this proved the most problematic data to collect; days when teachers were free enough from teaching duties to participate in the interviews rarely coincided with days when they were teaching control and time precluded multiple visits to schools. Some observations did take place and these have contributed to our understanding of the teaching cultures of the two departments, but there were not sufficient data to contribute to the formal data analysis.

Six schools were involved in the study. Control was not taught in the ICT department in one of the study schools so 11 teachers were interviewed, individually and privately (ten face-to-face and one by email).

Results

Views on Control in D&T

Teachers’ approach to the teaching of control in D&T is mainly focussed on teaching an ‘input, process, output’ approach and linking this to realistic situations to develop an understanding and appreciation of the uses of control technology.

A range of control software was found in the D&T departments:

<table>
<thead>
<tr>
<th>Schools</th>
<th>Software Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>School 1</td>
<td>Flowol and Scantek software</td>
</tr>
<tr>
<td>School 2</td>
<td>LEGO Mindstorms</td>
</tr>
<tr>
<td>School 3</td>
<td>PIC-Logicator</td>
</tr>
<tr>
<td>School 4</td>
<td>Flowol</td>
</tr>
<tr>
<td>School 5</td>
<td>Mechanism software</td>
</tr>
<tr>
<td>School 6</td>
<td>PIC-Logicator</td>
</tr>
</tbody>
</table>

Table 2: Software used to teach Control in D&T

In all but one of the departments this software was linked to hardware through which real control events could be sensed and produced; the hardware included Lego RCX (programmable) bricks, control boxes linked to sensors and output devices and, in two cases, microcontroller (PIC) technology. The department that currently had no hardware saw this as a ‘problem’ that needed to be rectified.

“In Year 7, when they are doing the PICs, like traffic lights in little PIC boxes, they can make like discos effects, little tunes on the box. In Year 8, they can write programs to make the buggies start to move in straight lines, manoeuvring them to turn left and right and finally interacting so we get them to use the inputs so the buggies actually sensing so they can actually write the program to turn left on its own, go round or follow patterns. They can make programs as complex or as simple as they want. It’s a great subject for differentiation because if they can’t manage it, we can give them a lot of help and we can give them focus task. Some of them, you can give them the freedom to write the programs that they want and they can experiment. They can write the program and if it doesn’t work, they can just reprogram it, experiment it and I think that’s the best way for them to learn.”

D&T Teacher school 6

When teachers were asked what they considered to be the key concepts in control, most paused before answering the question. Generally they felt that children should understand how things work, the logic behind technology and an appreciation of technology:

“to innovate with the use of technology to improve one’s lifestyles and other people’s lifestyle through
identifying needs [...] they (pupils) can set up systems and things can happen automatically down to how they put together a program on a logic chip to automatically set things in motion when specific things apply, is all about improving lifestyles.”

D&T Teacher school 4

“(pupils should have a) basic knowledge of technology, like the negative and positive side of batteries, components and LED (light emitting diodes) and an appreciation of electronics like when they watch television, they know what’s going on inside.”

D&T Teacher school 6

When asked what pupils gain from the learning of control, most teachers felt that they would better appreciate modern technology and learn problem solving skills.

“Problem solving, they learn about structured problem solving [...]”

D&T Teacher school 1

“Learning how control fits into technology and things don’t just happen on their own.”

D&T Teacher school 5

Views on Collaboration in D&T

None of the D&T departments reported any formal collaboration with ICT. Nevertheless, most of the teachers claimed that they knew what the ICT department was teaching and that they tried not to duplicate their teaching. Four D&T departments agreed that it would be a good idea to formally collaborate with their ICT department and most teachers gave lack of time as the key reason for lack of collaboration. Other systemic forces were also blamed:

“I think it comes down to why it’s not happening, which is down to the marketing of our subject as an option. You want people to pick this subject, and to see this is what the subject does. They will pick it to do GCSE and that is our bread and butter in terms of keeping our staffing requirements up. [...] So, I think, in a way, apart from a lack of time really, it is a fact that’s why it’s been kept very separately here.”

D&T Teacher school 2

“[D&T and ICT] have separate slots on the timetable, geographically we are about as far away you can get to the school, we are down at this end and they are at the far end therefore is not ideal [...]”

D&T Teacher school 5

Some teachers did not feel the need for collaboration because both departments are teaching different things:

“Why (collaborate)? ICT is teaching programming and D&T is teaching PIC control and programming with robots in Year 10. We do not duplicate work.”

D&T Teacher school 1

Views on Control in ICT

The approach to teaching control in ICT departments is generally focused on the use of flow diagrams allied to the use of ‘mimics’ (on-screen simulations of control situations) that indicate the effectiveness of the control program. It is also clear that teachers felt that ICT is about writing programs or acquiring programming skills and getting things to function in the correct order. It is focused more on logical thinking skills rather than the problem solving skills valued in the D&T department. Teaching control thus supports the ability of children to think in sequence and make sure things happen in the correct order:

“...organizing and order, putting instructions in order, inputs and outputs, learning about loops in the correct order. A bit of programming concepts, which is an important concept to put across.”

ICT Teacher school 4

A slightly different software emphasis was found in the ICT departments:

<table>
<thead>
<tr>
<th>Schools</th>
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<td>Flowol</td>
</tr>
<tr>
<td>School 2</td>
<td>Flowol</td>
</tr>
<tr>
<td>School 3</td>
<td>Flowol, LOGO and Robot Arms¹</td>
</tr>
<tr>
<td>School 4</td>
<td>Flowol</td>
</tr>
<tr>
<td>School 5</td>
<td>Flowol</td>
</tr>
<tr>
<td>School 6</td>
<td>Control is not taught in ICT</td>
</tr>
</tbody>
</table>

¹ This is simulation software, not a physical arm

Table 3. Software used in teaching Control in ICT
Apart from computers, no other control hardware is used in the teaching of control in these schools. It is noteworthy that school 6 does not teach control within ICT; control here is taught exclusively through D&T.

When asked what they considered to be the key concepts in control, ICT teachers generally felt that control in ICT helps pupils to understand the connection with why things happen and the logic behind how things work, which resonates with D&T teachers’ views. At the same time, teachers felt that the development of programming skills is one of the main aims in ICT lesson:

“pupils can start to understand about the connections on why things happened e.g. pressing a button and some logical things happened as well as understanding the processes behind it.”

ICT Teacher school 1

Views on Collaboration in D&T
The ICT teachers concurred with their D&T colleagues that formal collaboration was absent. However most felt that they knew what the D&T department was doing.

“not much (collaboration), no, but I mean I know what they are doing, more or less. They are not doing exactly the same as we are […] not as much as we should be.”

ICT Teacher school 1

On the other hand, one ICT teacher felt no justification for collaboration:

“We don’t do so much control to justify that, it’s only like one unit per year. Last year, we only did it with Year 8.”

Furthermore,

“the other difficulty to add is that, the children coming to this school, quite often realistically they are not at their level, they are only at Level 2. So we have to sort of, get them from Level 2 to Level 5 and we sort of like, have to condense the unit. So, last year, we did a combination unit in control with Year 8.”

ICT Teacher school 2

Conclusions
The data presented here are drawn from a small sample of schools so we have reservations about using our findings as the basis for wide-ranging recommendations. Yet we do believe, based on our extensive experience of other work with ICT and D&T departments, that the situation in these six schools is broadly representative of the situation in the majority of UK schools in at least some respects:

1 Control is commonly taught in both ICT and D&T departments at KS3.
2 It is highly unusual for there to be any formal links between the schemes of work for control in these two departments.
3 Yet there is a presumption within both departments that they ‘know’ what is happening in the teaching of control in the other department.
4 The teachers’ aims for their control curricula in ICT and D&T diverge in fundamental ways – and yet the teaching approach will look very similar to pupils (using computers to create control programs – possibly using the same software).
5 A key difference in the approaches between the two departments is the requirement to interact with real control situations in D&T as opposed to simulated settings in ICT.
6 There is limited, at best, collaboration on curriculum matters between ICT and D&T departments.
Even where there is a strong desire for such collaboration, a range of powerful systemic factors makes it very difficult for collaboration to be successful and sustained. This mirrors findings in the cross-subject collaboration literature cited earlier. This adds up to a rather unhappy situation in which it seems likely that KS3 pupils are often exposed to uncoordinated experiences called 'control' which may well look similar enough to induce ennui while at the same time having aims that are divergent enough to provoke unhelpful dissonances. Neither the D&T nor ICT curricula are to blame for this; both have sound enough aims for this aspect of their curriculum, both face the same systemic barriers to proper collaboration.

It seems at least plausible that the best pragmatic solution to the dilemma is that chosen by school 6 in our sample; to give the teaching of control to a single department. If this route is chosen, there are compelling arguments to follow the example of school 6 and make the chosen department D&T. The first reason for selecting D&T is that the commitment that D&T has to engagement with real-world control provides a richer and more authentic experience for pupils. ICT departments, in general, do not have the resources required to engage with practical control work. Secondly it is much more likely that a D&T department will engage effectively with the 'learning to program' requirement of the ICT curriculum (as it is already a part of what they are teaching), than that an ICT department will add to its teaching commitments the problem solving and systems thinking requirements of D&T.

The third reason for giving the responsibility for the teaching of control to D&T departments relates to constructionism. The nature of D&T is that it is much more likely to have the curriculum flexibility to allow pupils to engage in constructionist activity than ICT (as currently defined in the National Curriculum) because there is a curriculum expectation that pupils will work with either traditional control boxes or modern microcontroller (PIC) systems to control a real system. This forces a deep interaction with the effectiveness of a designed system, supporting a rich constructionist environment with ample opportunity for feedback on the success of construction efforts. Facing up to the effectiveness of design effort in a simulated system is much less compelling.

Pursuing this argument more broadly, perhaps the current review of the KS3 NC should remove all responsibility for the teaching of control from ICT and place it firmly in the hands of D&T.

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