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Effective teaching: questioning teachers’ interactions with pupils in technology and design

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Abstract
Effective teachers create rich learning opportunities that foster understanding of key subject concepts, and part of their effectiveness is seen in the range and types of questions they ask pupils. While research literature on questioning abounds, little is written about how questioning theory develops capability within individual subjects. This paper examines teachers’ questions from a subject perspective and links them to questioning theory by ranking within a hierarchy. Of 191 higher-order questions asked across 22 hours of Key Stage Three technology and design teaching in Northern Ireland, those questions relating to the key subject skill of analysing are examined.

Data indicate that teachers’ higher-order questions are used both to induce responses and as a model of pupils’ own analyses of design factors. The study highlights the difficulty in maintaining higher-order responses from higher-order questions by showing how teachers further articulated the concept of analysis on the basis of limited pupil responses. We highlight the need for teachers to provide opportunities for pupils to respond in ways that reflect depth of understanding of key technology and design skills. The paper concludes with a brief discussion about how question analysis contributes to a greater understanding of teacher effectiveness in technology and design.

Keywords: case studies, classroom practice, design pedagogy

Introduction
Technology and design (T&D) teachers in Northern Ireland have, through successive policy statements, been encouraged to focus on effective teaching (NIELB, 1994:6; DENI, 1998; DENI, 1999). Effective teaching is summarised by Shulman (1999:67) as:

“... those teacher behaviors and strategies most likely to lead to achievement gains among students”

While Shulman links strategy and behaviour to pupil achievement, Stones (1995:14) suggests that achievement should be understood within the context of the teachers’ curriculum subject and should include:

“... the conceptual structure of the subject under study [and] the most appropriate approach to teaching for meaningful learning.”

While the notion of ‘conceptual structure’ is beyond the scope of this paper we view such a structure as being characterised by knowledge, skills and understanding central to designing and making. Specified in the programme of study for T&D (DENI, 1999), designing and making includes analysing, investigating and evaluating. Effectiveness in T&D should therefore be understood in terms of how teacher knowledge is used to control interactions that lead pupils to learn how to analyse, investigate and evaluate while designing and making.

In this paper the focus of classroom interaction is on teachers’ questions. We acknowledge that while questioning is important when analysing teachers’ classroom interactions (Cohen et al, 1996:231), its influence on pupil learning is less understood (Dillon, 1988:104; Woodward, 1992:147). However, we bring together questioning theory, and technology and design (T&D) subject content by examining how teachers’ questions elicit pupil responses that conform to the conceptual structure of the subject.
Teachers’ Questions

Teachers need to use a wide range of question types, according to the hierarchy outlined by Cohen et al (1996: 231):

“Lower-order cognitive questions embrace chiefly recall, comprehension and application; higher-order questions, by contrast, involve analysis, synthesis and evaluation. Lower-order questions tend to be closed questions ... higher order questions end to be open....”

While lower-order questions are needed in many teaching situations, ‘analysis’ and ‘evaluation’ are directly specified as core T&D activities (DENI,1996; DENI,1999), and synthesis is strongly implied in many of the statements (ibid.). Teachers therefore need to strive towards a high frequency of higher-order questions that induce analysis, synthesis and evaluation within T&D. We believe that higher-order questions are those that are likely to:

“...[provide] rich and varied learning contexts for the development of thinking and reasoning skills....” (ibid.:1)

Literature shows, however, that teachers use mainly lower order in preference to higher-order questions (Dillon, 1988:235; Hargie et al,1994:99; Cohen et al,1999). One possible reason for this under-use of higher-order questions is the lack of subject-specific application of questioning theory. Much of the literature on questioning may be of limited use to teachers unless it can be applied directly to the understandings, skills and knowledge required within that subject. One study where subject-specific analysis of questions was made, illustrates the potential of subject-centred question analysis to influence what teachers do (Newton, 1997: 31).

The research outlined in this paper seeks to demonstrate that the application of questioning theory within T&D can help redress any theory-practice mismatch and illuminate how effectiveness can be better understood.

Technology and Design in Northern Ireland.

Technology and Design, at Key Stage Three (the only phase at which it enjoys mandatory status), was introduced into the Northern Ireland Curriculum in September 1992 (DENI, 1992). Since then, the subject has gone through two major revisions (DENI, 1996; DENI, 1999) in which the elements that make up its single attainment target, “technology and design capability”, have been reduced in content and changed in number. Those elements now consist of four areas:

Designing
Communicating
Manufacturing
Using Energy and control

T&D differs from technology education in other countries and UK regions. The first difference relates to the specification of wood, metal and plastic through which ‘design and manufacturing activity’ should be conducted. The second major difference is the requirement that the central focus of the subject must be:

“...the design and manufacture of products which require the use of energy and control to make them function.” (DENI, 1999:3) (our emphasis)

While the materials and energy and control specification might seem to restrict Northern Ireland pupils’ experiences, compared with their counterparts in, for example, England and Wales, DENI reinforce the need for teachers to develop “thinking and reasoning skills....” (ibid., p.1). In technology and design, these thinking skills are expressed in terms of the subject requirements stating that:

“When designing, pupils should develop the ability to:
...analyse... investigate... evaluate... justify.”

The subject specification also states that teachers should not develop these skills in isolation but in conjunction with other elements of the subject, such as when using materials and components, using energy and control, and when manufacturing.

The conceptual structure of the subject therefore is design-orientated and requires pupils to analyse, investigate, evaluate and
justify as part of technology and design capability. These fundamental activities relate directly to the higher-order activities of analysis, synthesis and evaluation outlined by Cohen et al (1999). In this paper we examine the T&D activity of ‘analysis’ as an example of how linking questioning theory to technology and design can bridge the gap between theory and practice. We believe that examining the T&D element of analysis will illuminate teacher-pupil interactions that can easily be transferred to other T&D activities, including those that involve synthesis and evaluation.

Method
The research was designed around the following questions:

- What higher-order questions do teachers ask of pupils both in a whole-class and individual context?
- What do pupils’ responses tell us about the processes they use and relationship of those responses to the conceptual structure of the subject?
- What can our understanding of this relationship tell us about how questioning theory can be applied to subjects?

Case Selection
The research was conducted in three post-primary schools over three years, each being treated as a separate case study (Yin, 1994). Each participant, an experienced T&D teacher, was selected on the basis of his willingness to participate, his perceived standing as a model of good teaching and the fact that each was working on similar electronic projects with pupils. All studies took place at the end of Key Stage Three (year 10), when it could reasonably be assumed that pupils’ technology and design capability should be nearing its optimum development. Other selection considerations included availability of classes, suitability of teachers’ timetables, the desire to sample schools from differing Education and Library Boards (ELBs) and school management types. The projects consisted of a timing device (teacher 1), a security alarm (teacher 2) and a moisture sensor (teacher 3). Each project used an electronic circuit, housed in a container, two of which were vacuum formed in rigid polystyrene and one fabricated in metal.

In total, 22 lessons were video-recorded and transcribed to facilitate detailed analysis of the questions and the contexts within which they were asked. All observations were undertaken with minimal camera and observer movement so as to avoid any intruding influence on classes. Non-participant observation of this nature is consistent with Woods (1999:4).

Triangulation was provided in the form of teacher interviews, conducted before recording, and through an analysis of pupils’ written work and verbal responses after the observations. The main purpose of triangulation was to enhance validity and reliability as well as illuminate data when viewed from differing research perspectives.

Coding
Once transcribed, all teacher questions were coded on the basis of our understanding of the hierarchy of question types outlined by Hargie et al (1994). For example, questions that required simple yes/no responses were categorised as closed, those that required pupils to repeat previously taught content were coded as recall. Other codes included management and rhetorical questions.

Once identified, higher-order questions were categorised according to the relationship between the activities pupils were required to carry out, and the key curriculum requirement of analysing, as outlined above.

Results and Discussion
In total, 877 questions were recorded of which 191 (21.7%) were categorised as higher-order questions. This proportion of higher-order questions is in line with Hargie et al (1994:99) and suggests a higher frequency of lower-order responses from pupils than could be accounted for by management, organisational and revision factors. Although we show three other T&D skills in Figure 1 below, only the skill of analysing will be discussed.
Developing the process of analysing

Analysing in T&D requires pupils to think about the various design elements of a product or idea in order to determine the parameters within which they need to consider it. It is quite common for teachers to develop a ‘factor analysis’ prior to writing a design specification. We found two ideas embedded in teachers’ questions relating to analysis and we refer to them as process and product. First, the teachers observed taught a process of analysing through a sequence of questions. In the example shown below teacher two seeks to develop the ability to analyse design factors (DENI, 1999:5), leading to a specification for a security device. To develop pupils’ understanding of the concept he uses the example of a hospital bed, asking the whole class;

T “What are the basic things a hospital bed would have to do or would have to have?
P It would have to have wheels.
T It would have to have wheels. Why?
P Because you move the patients and you move the beds round and all and for safety in an emergency you need to move them quick.
T Hospital beds unlike our beds at home have to be movable. You have to move them from ward to ward or up to operating theatres or – or – or places like that. What else must it have?
P It has to take all the weights.
T It has to be pretty strong because people come in all shapes and sizes so you know there are slim people like myself, then there are not so slim people. So it has to hold all sorts of people. So what about size. Then?…”

This interaction shows a typical pattern of pupil-response/teacher-articulation and highlights a major difficulty in using higher-order questions within T&D. The limited pupil responses leave the teacher to further articulate the required depth of analysis. While such teacher articulation is often desirable (Cohen et al., 1996:237), such articulation can defeat the purpose of higher-order questions in developing the skill of analysis. If these responses are to closely reflect the original aims of the question sequence teachers will need to find ways of framing questions to induce analytical responses.

After the questioning sequence from which the above sample was taken had been completed, the teacher expected pupils to apply these steps to their container by replicating, in their own contexts, the types of questions he had asked, as the transcript below illustrates:

“So a specification for a hospital bed includes… I could go on and on and on I’m not going to but every time you set out to design something you draw up a specification OK… So what I want you to do … is to draw up a specification for your burglar alarm.”

The teacher’s expectation of pupils’ ability to apply a similar question sequence may have been high. What is interesting, however, is that the teacher presented a model questioning sequence to pupils and then expected them to replicate it in their own context. Here the teacher is requiring the pupils to ask their own higher-order questions.

While this task exemplifies a potentially rich opportunity for pupils to offer higher-order responses, and thus develop analysis-type skills, we are, notwithstanding, cautious about the learning gains (effective transfer of the process of asking higher-order questions) unless pupils are given specific instructions and opportunities to apply these questions to their own design activities. Given the limited time available for technology and design at Key Stage Three in most schools, and the high demand for other forms of assessment
evidence as a basis for measuring learning, effective embedding of higher-order questions by pupils is, we believe, unlikely.

The second idea that we found related to the response induced by the teacher’s wording of the question. We referred earlier to this as the product and reflects an important opportunity for pupil learning. For example, in the question shown below, teacher one discussed ergonomics with the class and, leading to a discussion on locating the battery within the box, asked:

T “... make it a reasonable size so you can handle it, you may also want to make it such a size that you can get inside it, for what purpose, why would you want inside it?
P Batteries

In this case the pupil response was accurate and reflected the required response. The subsequent ‘teacher articulation’ of the need for access to batteries constructed a definition of ergonomics for this context:

T ... if you want to get inside to change the battery you need to be able to get in with your fingers, right, to remove that battery, so it needs to be large enough to allow your fingers to fit into it, ok?”

This questioning sequence was followed by a pencil and paper designing activity for the container. The success of the designing exercise in terms of the pupils including ergonomic factors in their designs was due to the teacher’s interventions, sometimes at a whole class, but often at an individual level. The mismatch between pupil responses and the subsequent designing activity, we believe, illuminates the potential that lies in higher-order questions to provide pupils with a firmer cognitive basis for subsequent designing activities.

Analysis across a range of activities.
A total of 84 out of 191 higher-order questions (44%) were found to have strong elements of analysis associated with them. Figure 2 shows that these analysis-associated questions were asked frequently when the teacher was developing an understanding of the topic (time, moisture sensing or security) and less frequently when manufacturing or developing subject knowledge (electronics in each case).

This difference can partly be explained in terms of the high knowledge requirement that characterises electronic projects and also the high concentration on practical activity during manufacturing. It is easy to understand that both of these activities would provide fewer opportunities for higher-order questioning. However, allowing for these factors, the apparent reduction in higher-order questions at these stages in the project should alert teachers and others to the possibility of a potential loss of learning opportunity.

Conclusion
We have shown that technology and design provides rich opportunities for higher-order questions that reflect the conceptual structure of the subject.

Teacher-pupil interactions have the greatest potential for effective learning in T&D as it is the place where meanings are negotiated and developed by pupils. We have shown that, in terms of the T&D activity of analysing, the potential for higher-order responses remains high and that such questions need to allow for this in the answers offered by pupils.

In our examples, the teachers required pupils to transfer the process of asking higher-order questions to their own contexts. We recognise this as a valuable skill and one which should be promoted. Pupils need to be shown that the questions they ask themselves require higher-order responses and that these
responses should reflect the key concepts that characterise the subject. While we contend that teachers need to strive to induce analysis-type responses during all T&D activities, we concede that pressure of curriculum time may militate against such advances, particularly when manufacturing. We would encourage teachers, however, to maximise the learning potential for higher-order questions in all areas of the subject.

Finally, the process of examining questioning theory in the context of T&D has, we believe, bridged a gap between theory and practice by linking, in this paper, the activity of analysing within T&D to higher-order questions asked by teachers. This research highlights the importance of maintaining a link between key subject concepts and pupil responses to those higher-order questions. While we focused on the T&D element of analysing, our research continues and will be applied to other areas of the subject. Indeed, we believe that its application to other subjects will more generally enhance our understanding of effective teaching.

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