A pilot study of children's problem-solving processes

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Abstract

This paper reports the preliminary results of an investigation into the nature of 'problem-solving' activity in technology education. The research focuses on the relationship and potential mismatch between teachers' and children's agendas, aims, and perceptions concerning design and technology activities in the context of the National Curriculum. A case study approach involving in-depth classroom observation is used to chart pupils' and teachers' interactions during design and technology activities at key stage 3. Our analysis focused on the influence of teachers' task structuring and interventions on children's problem-solving behaviour. The results so far show that the design process underlying the curriculum is highly complex and not easily communicated. Children encounter different problems, requiring different approaches, according to the kind of task and the stage reached in its solution. The results indicate that 'problem solving' in technology may proceed in a very different way to that characterised by a holistic 'design-and-make' process.

Introduction

Problem-solving processes have long been seen as important in education. They continue to be advocated, by some as essential core skills that will improve industrial performance, and by others as a means of motivating pupils through encouraging active and meaningful learning. In Design and Technology (D&T), problem solving is manifested in the 'design process' underpinning the National Curriculum in England and Wales.[1] This process comprises: recognising a problem, generating and implementing a resolution, and evaluating the results (although it is now proposed to compress these into 'designing' and 'making'.[2] It is used to forge a link between otherwise separate curriculum areas. The intention is that children develop general practical capability, which is expected to enable them to handle complex problems in their personal and working lives. Similarly, many technology educators make claims about the variety of potential outcomes of D&T activities, including, critical assessment, decision making, planning, evaluating, reflecting, and collaboration.[3] Like the design process, such outcomes are believed to have the appealing potential to transfer across subject boundaries as well as to activity outside school and in adult life.[4, 5]

We have reviewed some of the evidence for transfer elsewhere[6] and found little empirical justification for the idea of a general transferable problem-solving process. Research shows that problem solving in a range of areas is highly context-dependent. The knowledge and skills developed by experts and lay people alike are drawn upon according to their appropriateness and usefulness in a specific practical context. Therefore, existing demands upon pupils to transfer across contexts appear over-ambitious. Further, there is no support for the claims concerning the link between problem solving in and out of school. Research on situated learning (reviewed by Hennessy[7]), characterises the successful development and use of informal and intuitive problem-solving strategies in everyday situations. Everyday 'problems' are seen to arise from genuine dilemmas presenting a personal challenge.[8] These problems are authentic and relevant to the learner, rather than artificially constructed, like typical 'design-and-make tasks'. The rhetoric of design and technology education assumes that pupil motivation is provided by the posing of 'real' problems; previous research indicates that such aspects of the everyday culture cannot be so readily transposed to the artificial and constrained environment of the classroom.

In addition, there is an evident lack of analysis of the knowledge required in technology tasks. The National Curriculum presumes that conceptual knowledge is acquired by pupils during their work in other parts of the curriculum and then transferred, or developed during the task. (See McCormick for a discussion of the use of scientific knowledge in design activities.[9]) However, research on 'knowledge in action' indicates that formal scientific and mathematical knowledge, for example, cannot simply be 'applied' in problem-solving situations, but need to be reworked, integrated and contextualised for practical action.[10, 11] It is thus unreasonable to expect pupils to transfer knowledge of concepts across subject areas.

Collectively, the research on problem solving has important implications for technological problem solving particularly of the kind found in design-and-make activities. Such activities now form a central part of the D&T curriculum, yet we know very little about them. HMI found that teachers commonly interpreted the design process narrowly as sequential steps.[12] This was evident in their assessment procedures and in pupils' practice. For example, research shows that pupils tend to omit unsuccessful designs from their project folders,[13] and often describe their activities as a logical, systematic procedure rather than describing the actual way their design ideas developed.[14] Thus they exhibit what is referred to as a 'veneer of accomplishment'.[15]

Issues for research

There is a marked absence of empirical research on what pupils actually do while undertaking technology tasks. It is information of this kind that teachers need to support their pupils' learning. To understand more about what happens in design-and-make activities, we are investigating the kinds of 'problem solving' occuring in technology classrooms.[*] We are conducting a number of detailed case studies over the next three years.

The central issues we are exploring are whether teachers' aims reflect an understanding of, and a commitment to, the design process, and whether children are truly assimilating the design process; or do they merely try to accommodate teachers' aims through superficially following prescriptive procedures? A second focus for research is how teachers assist pupils in acquiring general skills and in making a convincing link between diverse contexts. We examine how pupils perceive and use the design process, and relate this to what teachers believe and communicate to pupils. This includes analysis of the way they represent the process through explicit teaching and through the task structure, the kinds of interventions made, and the effects of these on children's problem-solving behaviour.

A pilot case study: method

We observed and video-taped four girls (referred to as J, K, M and S) aged 13, over two related D&T activities with the same teacher. The first was a 3-week skills module which focused on making patterns using various techniques, and constructing objects affected by wind (e.g. a mobile). The second project, which lasted 8 weeks, was to design and make a kite for a special occasion.

The teacher and pupils were interviewed at various stages throughout. The interviews considered the teacher's and pupils' views of the design process, views of the project, and their reflections on what was, and (in the teacher's case), should have been learnt. Analysis of the video data focused upon identifying the tasks presented by the teacher, pupil behaviour in relation to the task (e.g. drawing), and 'critical incidents' initiated by the teacher or pupils (e.g. a pupil seeking or a teacher giving help). We have selected some issues that emerged and that accord with the literature; their status is, nevertheless, tentative.

Some emerging issues - conceptions of design processes

The design process is seen as a means of linking the separate curriculum areas such as Art and Design, CDT and Home Economics. To achieve this link a theme is selected which can apply across the subjects, in this case 'energy', and a project is identified which relates to the theme but will also involve pupils in using skills developed in the skills module from each curriculum area. Our case study teacher, from the Art area, therefore looked at techniques for making patterns that would be applied to the kite. Hence she was dealing with subject-specific issues, the design process, as well as the application of knowledge and understanding from curriculum areas outside of the technology domain. Our pilot work suggests that this expectation of the technology curriculum, and teachers', fails to take account of potential conflicts between these separate elements and teachers' understanding of, and commitment to, them.

The teacher we studied was aware of the need to keep in mind all of the processes required by the National Curriculum.[1] She had decided for the kite-making project to emphasise the processes concerned with 'generating ideas' and 'evaluation', and the practical activity of using materials. She stated that she did not want the overall process to be seen as a rigid linear sequence (hence pupils were to "evaluate throughout"), but was concerned in addition to emphasise creativity. By this she meant encouraging the children to experiment with materials and to try out ideas without any preconceived notions of a final product. However, in pupils' minds the over-riding impression of the project, and of technology generally (both in and out of school), was essentially of 'making', and learning outcomes in D&T were described as skills related to making. The children appeared to be largely unaware of the design process. In an interview six months after the project the teacher expressed concern about the National Curriculum processes and felt some conflict between teaching the design process and encouraging learning in Art that she valued, i.e. creativity. It is therefore unsurprising that pupils' perceptions would not include these processes.

This conflict in aims led to a lack of explicit treatment of the processes. The lessons over the eight weeks of the project followed the usual sequence of processes:

- defining a reason for a kite (a need)
- generating four designs
- modelling in 2-D and 3-D
- evaluating these models and modifying
- planning the making (using a full-scale 2-D drawing)
- making the kite
- evaluating and modifying the kite
- carrying out final evaluation

Despite this there was little reflection on them and no explicit discussion of the overall process. This was in part a deliberate pedagogic strategy on the teacher's part. In order to prevent the pupils becoming focused upon a final product prior to being creative with their initial ideas, she tended to 'reveal' the process implicitly as the class went through the various stages of the project. This reflected the belief that this stage of exploration was critical if pupils were to apply understanding of the materials to the product from an informed and experienced position. Hence creative experience of the materials was seen as pre-requisite to a good solution. Rather than being devalued by the teacher, the design process to an extent became secondary to other learning she considered more fundamental. There was reflection on the processes on some occasions. For example, after the pupils had test flown their 3-D models, the teacher asked the class to consider why a model was needed. Overall though, the general lack of explicit treatment of the processes led to pupils dealing with apparently isolated tasks and this caused confusion. For example, J was told by the teacher to draw a full-sized version of her kite when she had finished her 3-D model, without explanation of its purpose. Nor did J have any sense of an overall process to create meaning in the task for herself. Although she was normally a hardworking and motivated pupil, the confusion as to what she should be doing resulted in J wasting the rest of the lesson and doing nothing. Other examples of where processes were explicitly focused on include when pupils were explicitly required to evaluate at various stages in the lesson sequence. However, not until the last lesson were pupils given any structure to the evaluation (through a list of questions to answer). A similar lack of explicit treatment of what the process entails occurred with 'generating designs'. Pupils were asked to produce several designs and they did elaborate sketches of considerable complexity over the holidays. The parameters for choice of design (the specification) were left open to the pupil to allow 'creativity'. M consequently produced a range of colourful and complex kites, but ultimately opted for a simpler design to make, in response to the teacher instruction that pupils should choose a design that would be feasible to make and for which they could obtain materials. Hence the relationship between 'generating designs' and 'modelling' within an holistic design process is disrupted. What the pupils learn is that there is no relationship! The teacher's knowledge that success is essential to keep pupils involved over-rides other concerns; hence class management dominates pedagogy. The demand to produce several ideas and then to implement one can produce the 'veneer of accomplishment' referred to earlier. The alternative designs produced may play little part in the thinking behind pupils' final solutions to 'meeting the need'.

Emergent problems

Since the presentation of the project and individual tasks did not create a consciousness of process elements, the activity for the pupils became a series of separate and unconnected lessons each with their individual challenges in the process of producing a kite. For example, when M was constructing her 3-D model, the activity became one of dealing with *emergent problems* such as:

- deciding which material to use for the frame;
- fixing the joints in the frame;
- getting the frame into the shape she had designed;
- keeping the shape stable (by inserting an extra strut).

In dealing with the third problem, M sought help from the teacher who told her to use the scale drawing she had previously drawn. M had not realised the purpose of the drawing as a template and dealt with the shape as a one-off problem, unconnected to earlier parts of the process. For the pupils we observed, the problems emerged as part of the experience of individual lessons, not 'producing a kite for a special occasion' (the 'problem' for the whole project). These lessons provided their own 'dilemmas and challenges', noted earlier.

The importance of both conceptual and procedural knowledge

Our pilot results also suggest that assuming that learners can access and apply relevant bodies of knowledge from other contexts is unrealistic. Pupils frequently appeared not to have grasped concepts in such a way as to enable them to use them in a practical situation. For example, M, in a conversation with the teacher about her scale drawing, revealed that not only did she not understand the distinction between the actual and scale length of a line, but that even when prompted by the teacher she could not work out the scale. Earlier she had also questioned whether she should scale the angle in the same way as she scaled the length of a line.

Even where attempts were made to teach concepts during the project, there were difficulties with pupils' understanding. The teacher had taught principles of flight (e.g. the aerofoil effect) and the functions of the bridle, tail and fly-line, at several points during the project. Yet it was evident that many pupils never understood what a bridle or a tail did. The teacher was aware of this problem, but did not know how to address it.

Most importantly, this lack of understanding of the functions of the bridle and tail, meant that any attempt to use the procedural knowledge of evaluation failed. When flying their kites, pupils could not evaluate the problems and improve the designs. The result was that they resorted to trial and error. No amount of procedural knowledge will help when there is a lack of relevant conceptual knowledge, a finding established in a range of fields.[16, 17]

Conclusions

Models of the design process which identify clear sub-processes that link in some holistic process, do not reflect the complexity of how pupils undertake 'design and make' tasks, or of what is involved for teachers working across disparate content areas of the technology curriculum. Our pilot findings are not surprising in light of recent research confirming that children do not 'discover' and develop their understanding of procedures simply through problem-solving activity. Certainly, if teachers want pupils to acquire general skills, they need to assist them explicitly. Activities ought to be structured so as to focus specifically on particular processes, such as evaluation, and pupils need to be deliberately taught techniques which enable them to carry out effective evaluation. In order to apply the process in future problem-solving situations, they must further understand what to evaluate and how to evaluate it in the context of various kinds of problems. Similar assistance is needed for other processes. Teachers also need support to understand what tasks and pedagogic strategies are appropriate for developing pupils' strategic understanding of the process, alongside their craft expertise of the different areas of the technology curriculum.

It is evident that technology tasks, even apparently simple ones, make great demands on pupils in terms of their understanding and use of procedures and concepts. For pupils to be successful, teachers need to be aware of these demands, and to carefully select problems within pupils' capabilities and which enable them to further develop and apply their procedural and conceptual knowledge. Teaching in a domain like technology is a highly complex and demanding role, perhaps even more so than it appears.

These initial observations clearly highlight the need to be cautious about the claims concerning problem solving in technology education. The assumptions about what processes pupils learn and how they use their knowledge are rarely based upon close observation of pupil behaviour in the classroom, and need to be urgently re-examined.

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