

How Children's Problem Solving Strategies Develop at Key Stage 1

Abstract

This research traces young children's developing problem solving strategies throughout Key Stage 1. The initial work described a taxonomy of young children's collaborative strategies. The present phase of the study builds upon these findings to compare strategy used at different ages within the key stage. This longitudinal study revisited groups of children engaged in a range of design and technology tasks over three years. It looked closely at their spontaneous, but purposeful, procedural and collaborative skills. The results distinguished between children's emergent, developing, changing, and declining strategies during that time. It was found that, although the same strategies were used, they were used differently at different ages. Questions emerged concerning the factors affecting strategy use, and how teachers and peers can support children in strategy maintenance when appropriate in the classroom.

Introduction

All design and technology is fundamentally concerned with acting creatively and imaginatively to meet challenges and tackle problems. This is done continually throughout design and make activities, whether by engineers, professional designers, pre-school children at play, or pupils in the classroom. Ritchie (1995) suggests that in constantly looking for chances to explore new objects and situations children are both 'problem seekers' and 'problem-solvers'. They are curious about their environment at a very early age and try to influence, improve and change it. Both at home and in school young children are required to choose tools, materials and strategies, appropriately for the task in hand. Constructivist theory (Kelly, 1955; Ausubel, 1968) indicates that children come to design and technology with their own ideas for problem solving. Teachers may feel that they should take account of these ideas. Despite this, there is still little research evidence to support how children learn to design and make (Anning, 1997). Yet it is important that primary teachers understand, as far as possible, the intuitive problem solving skills and strategies that young children bring to design and technology activities in school, and how these develop, so that they may have the opportunity to build upon them if appropriate.

A major reason for teaching design and technology at Key Stage 1 is that it enables young children to begin to learn how to tackle difficult problems in a practical way. It enhances their problem solving skills,

procedures and strategies, and enables the development of concepts in a concrete way. Problem solving in design and technology brings together purposefully, procedural understanding, and conceptual understanding (Kimbell *et al*, 1994). However, there is still some confusion concerning the role of process skills in this procedural and conceptual understanding. In a paper on improving children's performance in the procedures of design and technology, Johnsey (1997) describes three broad inter-linking areas about which primary pupils should learn. These are:

- 1 Practical Capability
- 2 Knowledge and understanding in design and technology
- 3 Procedures of design and technology

which Johnsey describes as the broad procedural skills such as identifying needs, modelling or evaluating, but also talks of as process skills. From his research, Johnsey provides a list of the procedural skills used by children throughout Key Stages 1 and 2. He goes on to proffer the notion of design and technology procedural skills arranged in a toolbox, 'each section containing a set of tools or strategies'. He suggests that each pupil will develop a personal set of strategies for each section of the toolbox and learn to use them in different ways. The teacher's job will be to enable the pupil to develop a wide range of these tools and appropriate ways of using them differently in various circumstances. This suggestion needs to take account of the fact that the strategies children use in design and technology are often collaborative, rather than purely personal, but Johnsey, like many others (Kimbell 1991, Mayo, 1993, McCormick *et al*, 1996), has successfully begun to move away from the simplistic view that there is a single transferable process for designing and making that can be taught to all pupils and used in all situations. His model also begins to provide the basis for a set of identifiable procedures which might be taught and assessed by teachers. It also encourages the notion of personal creativity and imagination. Johnsey further suggests that, paying attention to one procedure at a time, it may be possible to 'sketch out a progression in each one'. He maintains that more research is needed in this area. The research described here begins to sketch out this 'progression' at Key Stage 1.

The purpose of the research

The purpose of the study was to see how children's problem solving strategies develop, when tackling design and technology tasks, without heavy guidance from an adult. Careful consideration needed to be given to

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the most appropriate way of exploring the sorts of goal orientated activities that children used spontaneously during design and technology tasks. It was decided to work with groups of children in their classrooms and try to observe their strategies during problem solving in their first term in school; then to follow the same groups through their time in the infant school observing their problem solving strategies at certain intervals. It was thought most appropriate to watch the children engaged in typical design and technology tasks, and using standard tools and materials

Research questions

There was a qualitative approach to the research design based on the research questions. These questions asked to what extent can we:

identify and classify the intuitive problem solving strategies that young children bring with them to design and technology tasks?

characterise these strategies and the relationship between them by creating a taxonomy of group strategic activities?

chart the use of these strategies in relation to age?

The context of the longitudinal study

This is one of the first longitudinal studies of young children engaged in design and technology tasks at Key Stage 1. Unlike most longitudinal studies however, this research follows groups of children and not individuals. A basic requirement of the design and technology National Curriculum is that children should work collaboratively, and the premise on which this research is based is that children's problem solving strategies develop within a social setting. It is lengthy to continually talk of groups of children, but it must be stated that throughout this study, whenever children or pupils are mentioned, it is groups of children that I refer to, and not individuals. During the work it was thought important to explore children's strategic behaviour over a number of different design and technology tasks using the full breadth of resources and materials, and in a range of familiar contexts. Two primary schools that were well known to the researcher were chosen for the study. It was felt important that the researcher should have a full understanding of the policy and practice of design and technology in the schools as a certain way of teaching may affect the strategies of the children participating in the research. The schools were in a middle income area of a London commuter town often used for poles and sampling as it is said

to have a population that in cultural and socio-economic terms is representative of the country as a whole. The schools were very similar in both social and physical context with an upper working class, multi-ethnic intake, although one was a Primary School and the other an Infant School.

The data collection

The data was collected in the form of audio recordings of the groups' verbal responses to the design and technology tasks, field notes of all observed sessions using naturalistic observational methods with particular attention to children's action and interaction, and photographic evidence to support this. The combination of these data sources provided detailed and annotated transcriptions of the sessions. The tasks were chosen with a number of criteria in mind. Firstly, that they should be representative of typical design and technology problem solving activities engaged in by primary children at Key Stage 1. Secondly, that they should give the children the opportunity to engage in problem solving strategies using a variety of tools and materials in a range of familiar contexts; and thirdly that they should provide scope for groups to exhibit and develop strategies in both a collaborative and autonomous way. A range of tasks were undertaken by all groups in the study, and these were designed to give opportunity for peer collaboration. It was hoped that the role and importance of group discussion in helping children to develop their design ideas, skills and strategies may be revealed through the process of problem solving, the stimulus of the tasks, and use of tools and materials.

A taxonomy of group problem solving strategies

It was found that the groups of children in the study used very similar types of strategies even though they were of a different age, from different schools, and engaged in different tasks. It was possible to identify and classify these. Finding universal use of the same strategies throughout Key Stage 1 enabled the researcher to characterise the strategies and the relationship between them by establishing a taxonomy. The taxonomy represents group problem solving strategies in the form of coherent sets of activities that were intended by the children to fulfil a purpose, within the design and technology task, contributing to the attainment of a goal or sub-goal. The final taxonomy attempts to represent the strategic activities of any of the groups of children undertaking any task, and using any resource. The full details of the taxonomy and work towards it were published in *The Journal of Design and Technology Education* (Roden, 1997).

This taxonomy attempts to represent the design and technology problem solving strategies of any of the groups of children in the study. It provides evidence of children employing collective strategies to solve problems across a range of tasks and using a range of resources. Through charting the instances and location of certain strategies in the lesson, and the contributors to various strategies within the group, the results provided evidence of a set of strategies commonly used by all groups in the study, but also began to show the similarities and differences in the pattern and sequence of those strategies in certain groups as the children grew older. It was possible to compile the taxonomy to include the emerging attributes of each strategy, and the diversity of purpose and utilisation. The complexity of the children's strategies emerged and how collaborative they were, how they linked and built upon each other, or had a different focus at different times. Also evidence appeared of differences in strategy used and location by different aged children.

Strategy development over Key Stage 1

The research then looked in depth at strategy variation as the children grew older. Questions were asked as to whether strategies change with age so are qualitatively different later, whether some remained unchanged in nature but became more or less elaborate, or whether some strategies emerged or declined as children grew older. Detailed qualitative comparisons were made of design and technology tasks undertaken by children doing the same type of task at different ages, showing the difference in the pattern of strategic action. These results began to demonstrate the intricate variation in the children's strategies, as they develop. A picture of variation in the children's design and technology problem solving strategies as they grew older had emerged. It could be seen that some strategies had changed in nature, some declined or even disappeared, and some evolved with age; but this picture was not yet complete. Further evidence was sought as the analysis looked closely across the whole key stage in order to gain a clearer view of the type of variation that can be seen in a very a complex strategy. One strategy in particular seemed to have aspects that interrelated in a particularly interesting way as children grew older. Looking closely at strategies for Practice and Planning helped to explain age dependent variations in the taxonomy, and provide evidence of complex change in young children's group strategies over time.

A Taxonomy of Group Problem Solving Strategies at Key Stage 1

Personalisation

Children sought to relate the task to themselves and make links with past personal experiences of a similar nature. This appeared to aid concept building and helped them bridge the gap between personal and school knowledge.

Identification of Wants and Needs

Children chose tools and materials, requested individual or co-operative working arrangements, and different contexts in terms of space or time.

Negotiation and Reposing the Task

Children tested the boundaries of the task and what was 'allowed' within the classroom culture. Through negotiation they might change or repose the task to suit themselves.

Focusing on the task or on tools and materials

The children used this strategy to interpret and explore the task. Questioning, discussing and investigating its nature, they continually clarified what needed to be done and how tools and resources might be used.

Practice and Planning

The purpose of this strategy was to gain experience of working with certain tools and materials, but there was a strong relationship between children's understanding of practice and early forms of planning.

Identifying difficulties

Children began to pinpoint predicaments in working with the resources, in sharing or working alone, or in the constraints of time or space.

Talking self through problems

Young children used self directed speech, or externalised thinking, in order to reflect aloud on what they had done, alert themselves to what they were doing, and to tell themselves what to do next.

Tackling Obstacles

They became aware of certain constraints, or of having made mistakes, and began to use a range of ways to overcome these.

Sharing and Co-operating

Here children gave advice and assistance to each other and began to use their experience of problem solving to help their peers.

Panic or Persistence

As the lesson came to an end the children realised that, to produce a finished product, the two major routes open to them were sudden panic or slow persistence.

Showing and Evaluating

These strategies served to consider progress, stimulate perseverance and inspire fresh ideas.

Strategies that changed with age

The results showed that some strategies actually changed in nature with age. The strategy of Negotiation was either not used at all, in the reception class, or used in a very limited social way to negotiate if products could be taken home. Groups used some negotiation in Year 1, but were still tentative about extending the boundaries of the task itself. They checked with an adult what was 'allowed' both in the use of tools and materials, and in reposing the task in line with their own interests, while, by the end of Year 2, negotiation was task and skills based. These groups took it for granted that they had a wide frame in which to work, could describe the boundaries of the task clearly to other groups, and negotiated working together. For example:

C1: Can we work together?

C2: You need more than one person to make a Puppet theatre.

C1: Yes. We can be partners and do the stage. I'm making some furniture for the puppets.

C3: You can do men and wife puppets together too. Can we do that?

Negotiation then, emerged with a social focus in the reception class, and changed towards a task and material dependent focus as groups moved through the key stage.

The strategy of Sharing and cooperating also changed with age. During the reception class children worked independently, but alongside their peers, had an awareness of the value of physical help, in Year 1, when as one child put it 'you need three hands', and then an appreciation of the value working with a partner in Year 2. By the end of Key Stage 1 children asked to work together, could scaffold peers in terms of ideas, give useful advice, and also offer physical help. In Year 2, children were also much more aware of their own capabilities and knew when adult help was needed, as opposed to that of a friend.

The nature of the change of Showing and evaluating strategies was more complex. Showing was used predominantly by Reception and Year 1 groups, when evaluation was restricted to short comments concerning personal likes and dislikes. Self evaluation was often used to loudly deprecate own work and gain reassurance. At Year 1 evaluation still reflected personal preference and not product criteria, but by Year 2 there was less open showing, but more critical evaluation of work by peers, and some awareness and self evaluation and of their own learning by the children. There had been a substantial change in the nature of this strategy over the key

stage. This extended evaluation, now lead to some modification of products, particularly by children whose work had been spontaneously discussed by their peers and suggestions made for improvements. For instance:

C1: Are you making a wife puppet?

C2: Yeah.

C3: No, it's too big.

C2: Too big?

C3: Yeah. Men are supposed to be taller. Aren't they meant to be taller than women?

C4: Yes. They normally are.

C3: The men are, the men are higher than girls when they're grown up.

C4: Hey Mrs, you have a little husband here (talks to puppet).

C2: OK. That can be the wife, and that can be the man (changes puppet's gender).

Strategies that remained unchanged in nature but became more elaborate

Some strategies gradually became more elaborate but did not change radically in nature. Panic or Persistence seemed to occur at a consistent level throughout the key stage, with one or two instances of panic in all design and technology sessions throughout the study. All groups seemed to use it to some degree towards the end of the lesson. It was provoked by adult reminder of the need to hurry as time was running out. Perhaps it is debatable whether it could be counted as a strategy, but it was a successful coping behaviour, effective in generating rapid results when necessary, in the form of help or support from peers and adults. Other strategies that also evolved with age, simply becoming more elaborate rather than changing qualitatively, as children grew older were: Identifying wants and needs, Focusing on task or materials, Identifying difficulties, and Tackling obstacles. When identifying needs and focusing on task or materials, reception class children, who were new to school, had limited experience of the tools and materials they would need to design and make in the classroom, and would sometimes watch and wait for adults to provide, but could identify a growing list of basic resources such as card, pencils and glue. They used their experience of similar tasks at home, requesting their favourite colour when using card, regardless of fitness for purpose. They had little idea of choosing resources according to the criteria inherent in the nature of the task, or the condition or effectiveness of the equipment.

However, they gradually began to reflect on previous experience and extend their knowledge of tasks and materials so that, by the end of the reception class, there was an emerging group consensus outlining a simple order of procedure in designing and making. For example when making cards 'First you fold it, then you draw on it, then you decorate it.'

These reception children wanted to focus on all the materials provided, especially new or interesting resources that were attractive in terms of colour, sparkle, shine or softness, regardless of need. They wanted to explore, in depth, the properties of each material, investigating it thoroughly in self structured play, often taking time out of the task in hand to focus on this. They were aware of the need to conserve attractive materials, and began to consider the amount of resources used, and to collect unused material, tidy tools, and clear away after the session. By the end of Year 1, groups could identify an extended list of needs, choose and gather their own resources, and were more proactive, relying less on watching and waiting. They were now more likely to choose colour and materials considering fitness for purpose, but only within those resources displayed. They focused more selectively on tools and materials, discussing their use and function and checking with adults. These children now had firm ideas about appropriate tools for school and home, and about tools and gender. Older Year 1 groups saved resources they would need later in the session and conserved those they valued to share with friends in the group.

C1: I've got to put the glue on first – before the glitter now.

C2: Just get the right amount in the lid and very carefully shake?

C1: How are we going to get the spare glitter back in the tube.

C3: I know, I know.

C1: It is a bit hard (trying to put it back with her fingers).

C3: See the glitter on the card, well fold the card and slide it in.

They began to see peers as a human resource, so that by Year 2, their identified needs included specific requests for help from peers, and expertise from adults. They used imagination to request resources that were not provided, such as double sided sellotape, improvised, and conserved materials for future sessions. Within the Year 2 groups an extended consensus regarding order of procedure reflected the complexity of the

design and technology process, and how the strategies of identifying needs and focusing on materials had become more elaborate, evolving with the children's age.

Similarly, the strategies of Identifying difficulties and Tackling obstacles, evolved with age. Reception groups could identify difficulties but only occasionally act to correct mistakes, and then in a limited way. They could dispense support and sympathy, however, and sometimes give advice, although this was not always acted upon. Sometimes remedies made things worse, like washing glue off card with water. Giving up, or changing course was used as an effective way out. At Year 1, the children were still struggling with manual skills but now had some experience of joining, cutting and measuring materials. They were still sometimes reluctant to accept advice but began to exchange physical help in tackling obstacles. By Year 2, children were more confident in their use of tools and materials, were more aware of where they had done wrong, and had built valuable skills and strategies to tackle difficulties. Not least of these was sharing their problems with others and pooling advice.

C1: Mind your finger in that vice.

C2: Yeah, watch it.

C1: They are quite nasty.

C2: Look he's squashing the wood.

C1: You might pull it all out of shape.

C3: How far up (do I put the wood in the vice)?

C1: Quite far.

C2: You've got to push it down then it will go in.

C1: You can turn it any way.

C 2: Now keep the hacksaw straight. That's it.

Strategies that declined with age

Strategies that actually declined with age were Personalisation and Talking to Self. Personalisation appeared to be used extensively when children entered school, and helped them to relate design and technology tasks, tools and materials, to similar personal experiences at home. By sharing this personalisation, through discussion, the groups were supported in concept building, gathering ideas, and making sense of the task. By the end of Year 1, groups were using past experience to reflect on similar tasks both at home and at school. This aided present work, in both a practical and intellectual way, but

much of the very personal aspect of this strategy was beginning to decline. By the end of Year 2 personalisation had all but disappeared. Groups now seemed not to need it, or maybe they realised that it was not often valued by adults in the classroom.

Similarly Talking to self was used extensively by groups in their first year at school. This revolved around skills and procedures, as children thought aloud about what they were doing, or were about to do. In this way talking to self aided planning. During Year 1, children used some talking through, but this was sometimes aimed at others as well as themselves, and was now more reflective, moving from present to future, then to past. Decorating a thank you card Trina talked herself through:

C1: I could put a bow at the bottom of my bunch of flowers to hold them

together ... How could I do it? I remember I'm not very good at tying ribbon. I know I'll see if there's a bit already tied in the box ... where ... where, where ... um?

Groups of Year 2 children tended not to use talking to self. They discussed their work with friends but, noticeably, there were long periods of self imposed silent concentration as the children tackled the tasks. In this way this strategy appeared to decline, or was perhaps gradually internalised, over Key Stage 1.

Emergent strategies

However, Practice and Planning seemed not to fall neatly into any of the previous categories. Here different aspects changed and evolved in an interdependent way. The complexity of the development is difficult to describe, but it appeared from the findings that on entering school, children did some rudimentary

planning and practising through playing with tools and materials. Later these elements seemed to separate, gradually emerging from an amorphous whole into separate strategies as children grew older. When children entered school the boundaries between practice, play, and planning were very blurred. Reception groups tended to plan in a very short term way, through self directed speech, which was sometimes overheard and discussed briefly by peers. Investigating the materials in self structured play was also a form of planning, as the children tried out materials they would use later when focusing directly on the task. For instance Helen tried tinsel on her friend's hair and against various fabric in the classroom before using it when designing and making her greetings card, and children played with the fur fabric and arranged the sequins in patterns before using them. Year 1 children seemed to view play activity as practise, and used the words practice and play in relation to the same activity, asking 'Can we have a little play with them first ... I mean practise?' Similarly, children in Year 2 sometimes used the words practice and planning in the same interchangeable way. They were now aware of the need to plan and did this in situ in a concrete way, placing materials together before joining, and saving materials for later use; and also in a more prospective and abstract way, drawing or making lists on paper. Both these means were used collaboratively when this group made thank you cards.

C1: I've folded my white paper at the bottom so it's the right size.

C3: This net will be good for sea plants...

C1: I'm not drawing it exactly. It's just my plan so I don't have to draw it absolutely with everything right.

Table 1: Strategy variation over Key Stage 1

Changing Strategies	Evolving Strategies	Emergent Strategies
Negotiation and Reposing the Task	Focusing on Tasks or Materials	Practice and Planning
Sharing and Co-operating	Identifying Wants and Needs	
Showing and Evaluating	Identifying Difficulties Tackling Obstacles	
Unchanging Strategies	Declining Strategies	
Panic and Persistence	Personalisation Talking to Self	

C2: I'm going to do this part then cut some ribbon. I think I'd better glue it with strong glue – white's (strong white glue) better than this stuff from the tube.

C1: I'm going to change it slightly from the plan when I draw it on the card.

You don't see the pattern and I want it bigger. Anyway I'm going to write something down the bottom in the space.

In this way the separate strategies of Practice and Planning emerged from Play, play being used in a less obvious way as children moved through Key Stage 1. Table 1 presents the variation in children's problem solving strategies over Key Stage 1.

Conclusion

In conclusion the research found that although children at Key Stage 1 used the same taxonomy of strategies in general, there was a complex age related variation in the duration, frequency and extended use of these strategies. Some strategies changed in nature with age so were qualitatively different later in the key stage. Some strategies remained unchanged in nature but become more elaborate as the children moved towards Year 2. Certain strategies declined as the children got older or emerged from other strategies. In other words, although the groups used the same strategies, these strategies were used differently at different ages. Why was this? Was it merely a function of age or were other factors affecting children's strategies, and how can teachers and peers support children in strategy maintenance when appropriate in the classroom. Hennessy and McCormick (1993) suggest that teachers must endeavour to make children's problem solving processes explicit. Asking young children questions about what they are doing and what they will do next, and encouraging children to question, is valuable teacher intervention. Also, consciously encouraging peer questioning and evaluation, requiring children to assess and monitor their own progress, should help them become aware of what they are doing and why. However, in order for teachers to discuss young children's problem solving with them, they must first understand the complex nature of their strategies and how they develop and change. Much more research needs to be done.

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