The Investigative Learning Process

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A commitment to an investigative learning approach by a school demands upon both teachers and pupils to adopt a different role to traditional practice. It is a more collaborative process with the teacher helping the pupil to acquire such knowledge, skills and concepts as are needed in a particular situation, rather than prescribing them through text or exercise. Moreover, the pupils are encouraged to talk to one another, discussing and sharing ideas and working as a team rather than individually.

Investigative learning concerns itself with the process by which learning takes place. It is child centred and places importance upon the learner having a greater responsibility for their own learning. It embraces active learning and problem-solving principles.

The past fifty years have produced a number of educational reports stating the importance of discovery within the learning process. Although the Plowden report (1967) was largely responsible for changing the way primary schools operate, a need for more active and experiential methods of learning was sought by the Hadow report (1931):

> The curriculum is to be thought of in terms of activity and experience rather than knowledge to be acquired and facts to be stored.

The actual implication of this statement being, that activity and experience, both physical and mental, are the best means of gaining knowledge and acquiring facts. The Plowden report some thirty-six years later, came at a far more receptive time in education and was more immediately accepted.

> There is, therefore, good reason for allowing young children to choose within a carefully prepared environment in which choices and interest are supported by their teachers, who will have in mind the potentialities for further learning. Piaget's observations support the belief that children have a natural urge to explore and discover, that they find pleasure in satisfying it and that it is therefore self-perpetuating.

More recently other educationalists have substantiated these ideas and recommendations

> I am not sure I understand anymore what discovery is and I don't think it matters very much — but a few things can be said about how people can be helped to discover things for themselves. Bruner, (1970).

Active Learning

Active learning is a means by which pupils gain knowledge and understanding through 'active' investigation, it is a largely experiential form of investigative learning. It involves problem-solving and is considered to be an important component of study within all subjects. An active learning practitioner would hold the view that learning retention is dependent upon:

- the 'reality' of the learning experience.
- the directness of the experience and the number of senses involved.
- the degree of uncertainty for the learner.
- the learner presenting their own statements and evaluations.
- teachers being 'clarifiers' rather than leaders.
- specific educational outcomes not always predictable.

> Active learning is more efficient than passive learning... pupils who use information that they are trying to learn, who challenge and grapple with their new knowledge, or who use it to solve new problems, tend to learn more effectively. Jerstedt, (1980).

Problem-solving

Problem-solving is central to an investigative approach to learning. It assists in the development of thinking skills and is a means by which children form important learning patterns. It is an approach that requires both the teacher and the child to be involved in asking questions that help identify problems and find appropriate solutions.

While children are exploring, discovering and investigating the world around them, they are inevitably involved in problem-solving of various kinds. The development of skills that can recognise, analyse and then solve problems are fundamental to intellectual development and are, when suitably planned, exercised and monitored the vital skills of 'learning how to learn'. Problem-solving is a structured element within a general investigative approach to learning having a defined methodology. It's value is in structuring and organising thinking and doing skills throughout the process of coming to a solution. Ideally, pupils should be provided with a programme of learning that consistently and progressively develops the use of these skills from early childhood, they should then become second nature by the time they reach secondary schooling.

As a learning strategy problem-solving can operate at all levels and in all situations when an objective needs to be reached. It applies across the whole curriculum and as much to teachers in their work as it does to children. The posing of open-ended questions, or tasks are the tools of the problem-solving ideal. The failing of many who profess to be problem-solving practitioners is that they are blind to the real value of its approach. The degree of open-endedness employed is critical to the outcome. Questions or tasks can, on the one hand guide pupils to the discovery of specific concepts; whereas on the other hand they can be broadly planned in order to place them in situations that are more complex. A successful approach must include stages of progression which will require planning and record keeping on the part of the teacher and the pupil. The whole thing will fail if it is insufficiently rigorous in its preparation. It is vital for the approach to be adopted and practiced throughout the school and developmentally through the age groups and levels of ability. A lack of

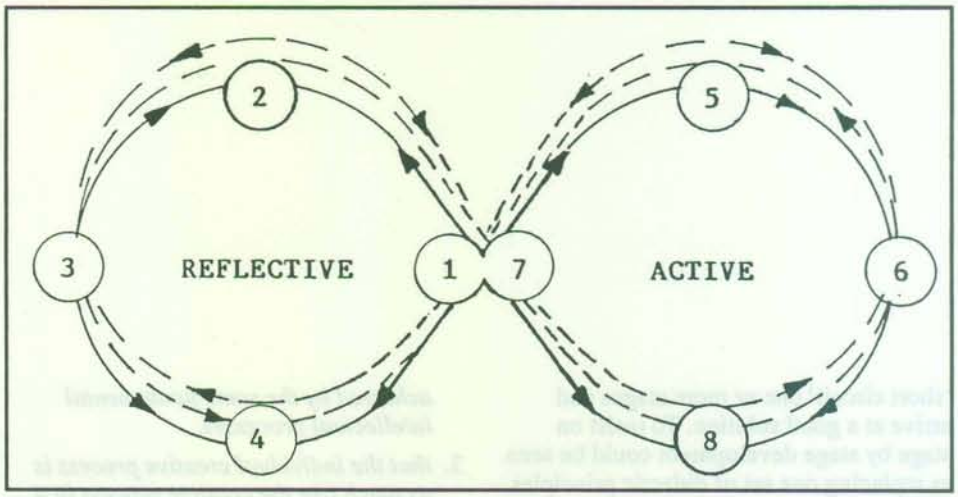

Figure 1: The Practical Problem Solving Model: Graphic Interpretation.
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consistency will result in confusion. In fact, to be truly successful it should be made a school policy for all. Marland (1981) complains:

> Learning to learn is rarely specified as a curriculum aim. It seems to be presumed by those planning school syllabuses that the processes will be assimilated while subjects are being studied'.

The Practical Problem-solving Model

The following problem-solving model was constructed by the author, 'Development of Design Departments in Secondary Schools' (1970), for the purposes of developing practical problem-solving skills in design education; it was used by SATRO's (Science and Technology Regional Organisations) in their in-service initiatives 1984/5, and was, more recently adopted by the 'National Project: Practical Problem Solving 5-13' (1987/90) for use in both primary and secondary schools. It is not totally unique as it closely resembles other models, however, it was the first model constructed for practical learning at school level. The national curriculum attainment targets for design and technology follow a similar pattern, as do many other design models. This, again, is not exclusive to design; other learning models preceded the 'design loop' by some time. It is, nonetheless, a necessary model in guiding teachers in the development of practical learning strategies and questioning procedures. It also describes the importance of managing the development of a task.

The Thinking, Sharing and Interactive Stages

At each stage different thinking skills are exercised

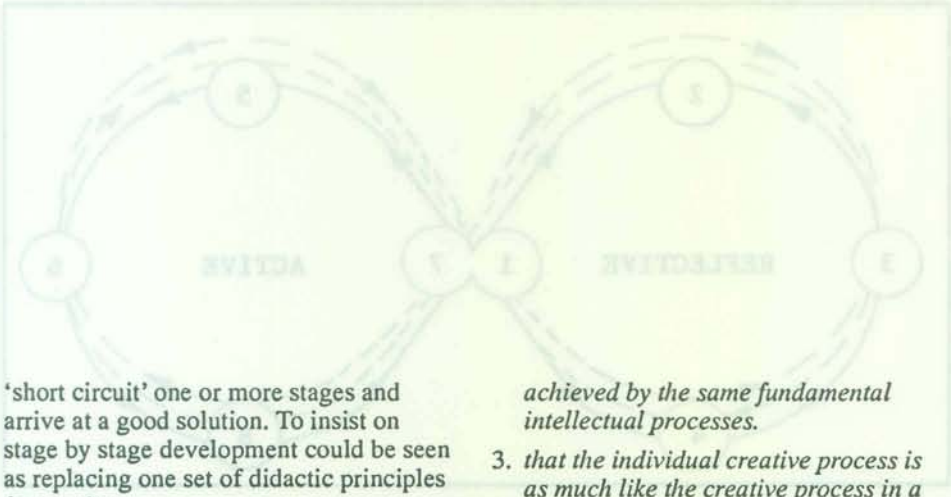
1. **What is the problem?**
   The problem must be defined; this stage involves coming to a clear understanding of the final objective, or analysing the true nature of what is required.
2. **What possible solutions are there?**
   Problem solvers must resort to 'creative' or 'lateral' thinking, extending their thoughts to all ways in which a solution might be found. There are no wrong solutions. In the process of choosing those ideas most likely to achieve the desired result, brainstorming, particularly in groups of young children, generates frenzied interaction. Thinking is active and quick. To be used to its greatest effect, it must be managed through phases of both broad and focused attention. It is a stage the teacher must prolong, so as to draw out all possible ideas. It is important that these ideas are recorded.
3. **Choose 'possible' solutions**
   Analytical thinking is employed at this stage, breaking down each idea and discussing its feasibility. The number of ideas advanced during the brainstorming session must be reduced to the ones that can be achieved with the resources available. Are there sufficient materials? What time is available? Have we the expertise, skills and knowledge?
4. **What solution is the most appropriate?**
   This stage involves decision-making, negotiation and comparison, employing a thinking process that is judgmental; it consists of weighing up one idea against the other, discussing its merits and drawbacks, until one solution is agreed upon.

The Making and Doing Stages

5. **Try out your chosen solution**
   We now arrive at an active, 'making' stage. It employs the type of thinking associated with structuring, predicting, measuring, estimating, assembling, trial and adjustment until the solution has been carried out.
6. **Test your solution**
   This stage necessitates accurate observation, recording and fair testing, to decide whether the solution meets the specification.
7. **Evaluate the results.**
   The problem solvers should reflect upon their outcomes and ask themselves the following questions:
   — Have we been successful?
   — Could we have done better?
   — What have we learned?
8. **Modify, if necessary.**
   —Does the solution need to be modified?
   — Does it need to be changed to meet the specified criteria?

The process is iterative in its interaction between the active and the reflective modes. Progression takes place as concepts are established, relevances are made clear and skills learned. This is illustrated as spiralling upwards within the double helix throughout the developmental stages (see Figure 1).

The process employs many forms of thinking and communication, both verbal and visual: words and diagrams can be used in explaining the problem to others, discussing solutions and trying them out. This structures thinking at all levels and at each stage. During the process there will always be the problem of the moment, and the overall problem — the main objective. However, the teacher should not insist upon a slavish adherence to the method stage by stage, pupils who have had the opportunity to develop creative thinking processes could well



'short circuit' one or more stages and arrive at a good solution. To insist on stage by stage development could be seen as replacing one set of didactic principles for another.

It is often said that the main purpose of adopting a problem-solving approach is to develop lateral or creative thinking skills. If these were the only thinking skills it developed we could be justifiably accused of producing an eccentric population with wild ideas and little structure to their thinking processes. A majority of 'learning how to learn' approaches, however, do stress the importance of developing creative thinking as an important component within their models: 'Brainstorming' Osborn, (1957), 'Lateral Thinking' De Bono, (1970) and 'Synectics' Gordon, (1961), contain within their methodology the objective of freeing a person from the usual inhibitions that operate to block the creative process.

> The primary aim of the brainstorming approach is to free the individual, whether working alone or as a member of a group, from the effect of using critical judgement prematurely.' (Osborn).
>
> Lateral thinking is concerned with changing patterns. Instead of taking a pattern and developing it as is done in vertical thinking, lateral thinking tries to restructure the pattern by putting things together in a different way'. De Bono, 'Lateral Thinking' (1970).

Alternatively, 'Synectics' means the joining together of different and apparently irrelevant elements. Synectics theory is based on three assumptions:

1. *that the creative process in human beings can be concretely described and that this description can be used to develop teaching methods that will increase the creative output of both individuals and groups.*
2. *that invention in the arts and in sciences are much alike and are achieved by the same fundamental intellectual processes.*
3. *that the individual creative process is as much like the creative process in a group.*

The advocates of synectics theory believe that people who understand what psychological processes are required can markedly increase their own creative efficiency. In the creative process the emotional aspects of a task are seen as more important than the rational aspects. Understanding these emotional aspects of the task is considered most necessary if success in problem-solving is to be increased.

The theory is that there are four psychological states that characterise the creative process. The first of these is called *'detachment-involvement'*; in this state a person tries to remove a problem from its usual context, in order to see it differently, and then to become sufficiently involved with it to develop new insights. The second mental stage is *'deferment'* which is resistance to the first solution that comes to mind in favour of waiting to see if a better one comes along. The third state is *'speculation'* or permitting the mind to run free. The fourth mental state is called *'autonomy of the object'* which is what happens when ideas about the solution of the problem seem to crystallise and develop a life of their own.

The members of the synectics group were wise in their recognition of the futility of merely recommending to people that they become involved, or speculate, or detach themselves. Accordingly they have developed what are called *'operational mechanisms'* to help produce each of these mental states. Making the familiar strange and the strange familiar are synectic goals. Four mechanisms are used to help make the familiar strange. *'Personal analogy'* is used, as in imagining how one would react if one were a molecule. *'Direct analogy'* is used, as in studying the way a clam opens and shuts in the process of designing a self-closing dispenser. *'Symbolic analogy'* is used, as in making a comparison with the Indian rope trick in the process of designing a hydraulic jack. And, finally, *'Fantasy'* is encouraged — the free and capricious use of imagination. In synectic training efforts are made to go beyond the traditional or 'expert' way of viewing the world to a 'fresh' view of things. This approach goes considerably beyond basic 'brainstorming' methods, it is an approach quite foreign to the usual concept of the scientific method, but it seems most logical when compared to the processes remembered by inventors.

The structured development of creative thinking is an area that must be worked upon during in-service programmes with teachers. The present situation in schools is such, that little information or advice is available to teachers, therefore, it is not surprising to find teachers encouraging the pupil who has reached a sticking point in their work to 'brainstorm' — 'Brainstorm how?' the pupil might respond, for there are numberous ways in which this might be directed. A page full of halfhearted comments is hardly the answer to every problem. Pupils lacking proper guidance will be unsure and frustrated and will produce low quality work as a result. In all fairness much has been done in recent years to develop an awareness of the value of investigative learning; now is the time to build in a structure and a means of progression.

If learning to learn is to be achieved, the basic patterns must be laid down early in schooling, certainly at first school level. Teachers wishing to develop sound investigative learning processes within their school need to structure their own thoughts and be considered in their approach, otherwise the outcome will be unsound. Nisbet and Shucksmith (1986), recommend teachers to develop:

'Cognitive Goals' Establish clearer cognitive goals for yourself and for the children you teach. Distinguish between outcomes and processes of learning. Divide tasks into constituent parts. Relate goals to pre-planning and subsequent reflection sessions with the pupils.

'Metacognitive Knowledge' Explore how your own knowledge of your learning, the task and the learning context influence performance, and share this with pupils by 'modelling'. Allow them to explore their own metacognitive knowledge by discussion and by exposure to a variety of contexts or circumstances.

'Learning strategies' Attempt to discern general strategies used across tasks. Distinguish these from skills. In teaching, stress these common strategic elements and reinforce their successful use where possible. Identify how strategies change in line with goals, knowledge and context. Encourage the children to generate search procedures or 'Trigger' routines that enable them to scan and make full use of their available strategic repertoire.

The Role of Questioning Within Learning

It will take time, expertise and patience to effectively develop investigative learning skills, there are no short cuts and it is not possible to merely introduce them as a 'magic' formula. This may have results with older students when introduced as a remedial action but a different strategy is necessary for those new to schooling. The model can, for instance, be used as an aide memoire, to be used by the teacher as a guide to the way they structure children's thinking through a questioning technique. An ability to stimulate thinking through questioning is an important aspect of a problem-solving approach, however, research shows that teachers receive little instruction in questioning techniques, either in their initial training or through in-service education. *'The Oracle Report'* Scarth (1986), found that during a school day,

> 45.8 percent of teachers' communications with the class took the form of statements. Only 11 percent of the communications took the form of questions, and of these only 0.6 percent were sufficiently open-ended to require considered answers.

'The National Project: Practical Problem Solving 5-13' confirmed these findings when observing teachers in the initial stages of the project. Even more worrying was their observation that as pupils progressed through schooling less open-ended questions were asked of them. This was found to be particularly true in secondary schools, many subject specialists seemed reluctant to place themselves in the position where they appeared not to know an answer. This was thought to happen because teachers believed their status and subject 'know how' would be threatened if they appeared to be ignorant of basic facts concerning their own subject.

The way a question is asked, its structure and emphasis, indicates to a pupil the kind of response that is required. The simple question 'what are you doing?' can be a reprimand or alternatively, show interest. A changed structure can place a stronger emphasis. The question 'and what do you think you are doing?', demonstrates strong disapproval, whereas 'tell me what you are doing?' indicates approval and interest. Most questions asked by teachers are closed questions, to which there is only one correct answer. Open-ended questions are the most productive when learning is required. They require the pupil to weigh alternatives against each other and make a considered response, however, they should not be seen as exclusive. A number of different types of questions may be asked in order to reach an objective.

> **— To draw out information:** Teachers use a particular form of questioning to patiently draw out information from a child or group of children. It often consists of a number of sequential questions that help children to reach an understanding. The teacher needs to carefully listen to the child's own ideas so that they can be guided towards their goal. The danger is that teachers sometimes make assumptions about what a child has understood and force a premature outcome.
>
> **— To analyse a problem:** Questioning of oneself or others is a valuable thinking skill. It is vital that children acquire the ability to breakdown a problem into parts, exclude irrelevances and recognise its true nature.
>
> **— To develop creative thinking:** Most children rush into early decisions as to what they are going to do. They treat a project as if it were a competition and want to be the first ones to start making and doing. They need to learn that exploring the widest range of outcomes is a necessary stage. It provides a greater choice of alternatives, and is a discipline essential to the problem-solving process. This is a stage when the 'Synectic' theory applies.

It may be worth considering what kind of lead the teacher can give to pupils when talking to them about their ideas. Neutral questions can be developed which allow pupils the scope to think about these ideas without being influenced by the teacher. Examples:

- tell me what you have been working on?
- did you have any difficulties?
- which do you think is better?
- what do you mean by better?

Other strategies that help to develop effective thinking skills:

- responding to pupils questions with further questions which prompt them to think for themselves.
- encourage them to pose questions to each other rather than the teacher.
- encourage pairs or groups to 'build' answers and solutions between them by discussing problems and pooling knowledge and experience.

Brown and Campione (1979), suggest a *'Socratic teaching method'* to be a way of transferring appropriate learning strategies from teacher to pupils. In this method the teacher constantly questions the student's basic assumptions and premises, plays the devils advocate and probes weak areas. The aim of the exercise, they say,

> is not just to get the child to know on one occasion that he is wrong or mistaken and therefore needs to re-learn and rethink, but that through this form of interrogation the teacher is 'modelling' for the pupil the sort of self-questioning, diagnosing and correction strategies that most adult learners perform internally and intuitively when working on their own.

Planning For Progression

The 'National Project: Practical Problem Solving 5-13' (1987/90) worked with teachers planning a framework for progression in practical learning activities using a cross-curricular approach. They matched the development of children to a problem-solving philosophy using three broad stages.

1. **Structured Play.**
2. **Guided Discovery.**
3. **Independent Learner.**

Although these stages correspond to age/ability-related development, they should be familiar to all of us as a natural reaction to something new. When, for example, we unpack a new microcomputer, the first stage is to 'play' with it — pressing various keys to see what happens, and moving the cursor across the screen. Guided by the instruction manual, we gradually learn what the machine can do. As our confidence increases we learn how to produce sophisticated documents without continually looking at the instruction manual.

1. **Structured Play**

On encountering something new, children will engage in free play. This can be structured by the teacher asking challenging questions; the children consequently become more familiar with the new object or idea, and their confidence increases.

Children should be encouraged to play with a variety of shapes, educational kits and building materials and be provided with stimuli with the aim of achieving specific objectives. Through structured play they will come to understand that they can control things: they can arrange flat shapes into simple compositions, place objects on top of one another to make tall structures and make models by joining materials, boxes, tubes and other forms together with glue, sellotape or string. They will also find that they can make things move by pushing, pulling or throwing, they will learn to guide moving objects such as balls, rollers, or wheeled toys by means of tunnels, paths and slopes.

2. **Guided Discovery**

At this stage, teachers can supply starting-points for investigations, and guide the children, again through open-ended questioning, towards a range of possible solutions. The period of guided discovery is most effective during the late infancy and junior phase. They usually enjoy the responsibility of working in groups, although they need guidance, particularly in how they can plan and discuss the direction of their investigations and possible solutions; this type of activity leads them towards a more independent way of working. The best tasks are those that expand and concepts previously introduced and extend and build on the skills acquired through structured play.

3. **Independent Learner**

The result of a well-planned and consistent investigative programme of learning needs to progress from structured play in early infancy, through guided discovery at junior school, to the more self-assured and more independent student at middle and early secondary school levels. The student will have his or her own ideas, and should be capable of following a project through from its initial concept to final conclusion.

At this stage, the student will be able to discuss with the teacher how to turn their ideas into action. Group work will still develop and become more successful, particularly when it is properly planned. Work should stem from broader open-ended tasks, drawing not only on previous experience, but also on the strengths and interests of the students. They should be capable of identifying projects for themselves, organising team strategies and setting a criteria by which the task can be evaluated.

Language and Vocabulary

Language is thought to play a crucial role in the development of the young child's thinking. The work of Jean Piaget has suggested that children are surprisingly weak at logical thinking, being far below adult standards up to at least the age of eight when language is virtually fully developed; although doubt has been cast upon some of Piaget's work, the 'National Project: Practical Problem Solving 5-13' were convinced that conceptual understanding was unravelled and more readily realised when described verbally by children. It was also seen to become substantiated and made concrete when the childs vocabulary was developed in association with an activity. What-is-more, it was found that gender bias was largely eliminated when the prime words associated with a learning activity were identified by the pupils rather than by the teacher. It was seen to be particularly divisive when prime words were introduced at the beginning of a new exercise; for example. 'Today we are going to learn about *levers.*' This type of introduction appeared to establish the exercise as a masculine activity and consequently alienated many students. Many national project schools developed class dictionaries, pupils added new words together with their meaning as they were learned. They were also illustrated by the pupils.

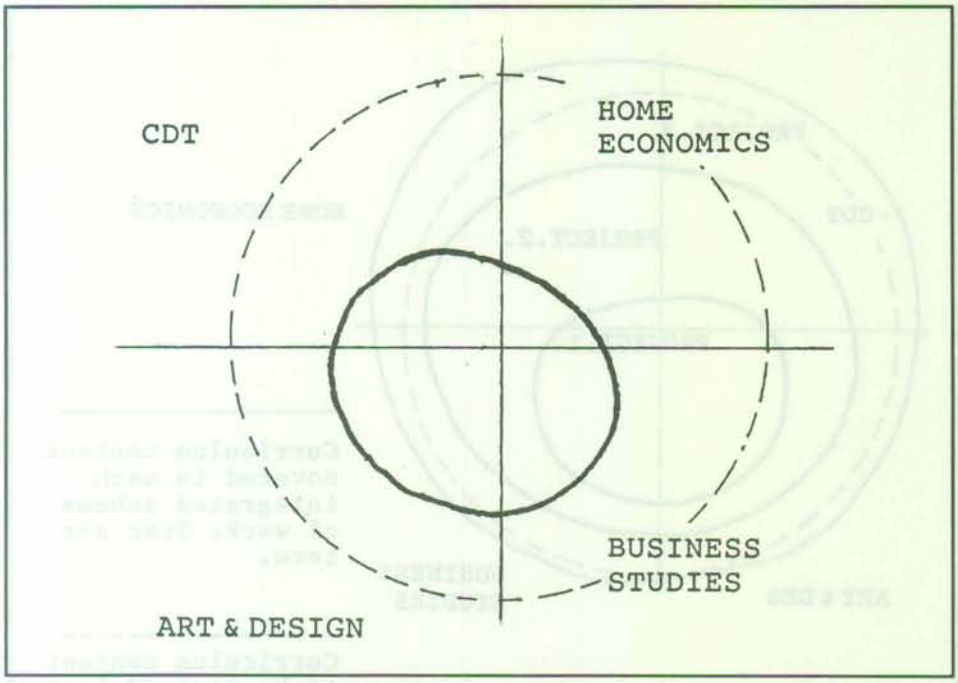


Figure 2: The 'mapped' content of an integrated scheme of work incorporating: Art, CDT, Home Economics and Business Studies.

A problem-solving activity that had been carefully constructed to develop the concept without the initial introduction of a technical vocabulary usually succeeded with all pupils. Furthermore, when the opportunity was provided for children to discuss their outcomes and they were asked such questions as: 'What do you think this is called?' they learned to surmise, reflect and, with luck, eventually correctly name the action, part or principle that they had discovered. They had, as a result gained ownership of their discovery and were also able to put a name to it. This is a powerful learning tool at any age. An important discovery made when developing this approach in schools was that girls consistently out performed boys in problem solving exercises and they were also found to be more imaginative in their solutions.

Childrens language can be extended and enriched by a creative and questioning approach, and they will gain in confidence and understanding when encouraged to experiment with words and descriptions. Gregory, 'Mind in Science' (1981) suggested that

> language structure had the power to direct (and sometimes mislead) thought: It is surely true of all tools, that by making some things easier they direct activity and thinking from things that are difficult; but what is easy and what is difficult are partly set by the available tools, and so we are carried along by a sequence of largely arbitrary and sometimes unfortunate features of our technology, including our language. Human intelligence is very largely Artificial Intelligence, and even our hopes and fears (and moral commitments, for they are set by possibilities of achievement) are largely set by existing technology.

The ability to ask the right questions, using suitable language, is a skill that needs constant practice and review. The language used by the teacher can, if inappropriate, be counter-productive and destroy a child's confidence. The curriculum areas of science and technology present particular problems as a result of their specialist words and phrases. For example, teachers should try not to use a terminology that the child is unlikely to understand; the wording of the instruction 'construct a mechanism that will...' is appropriate at one level, but inappropriate at another. It is important that the child is confident and understands the words used. Words can, in themselves, either limit or extend the scope of a question or problem. For example, instructing the child to 'make a vehicle that will...' is likely to limit their thinking because the word 'vehicle' will be interpreted by most children as something that has wheels, such as a lorry or a car. The question 'can you make something that will...?' is more open-ended and is likely to lead to a wider range of solutions. Some caution is also necessary in devising open-ended challenges. The challenges must not be so open-ended that they have no boundaries — there is no useful purpose in saying, for example, 'make anything you like!' It is important to define the task so that just enough guidance is given to help, but without unduly limiting their ideas. As stated earlier, the language used in practical problem-solving can easily become gender-biased, particularly if the teacher sees 'constructing things' as a masculine activity. A careful balancing of tasks will help to develop a broad and comprehensive view on the part of the children.

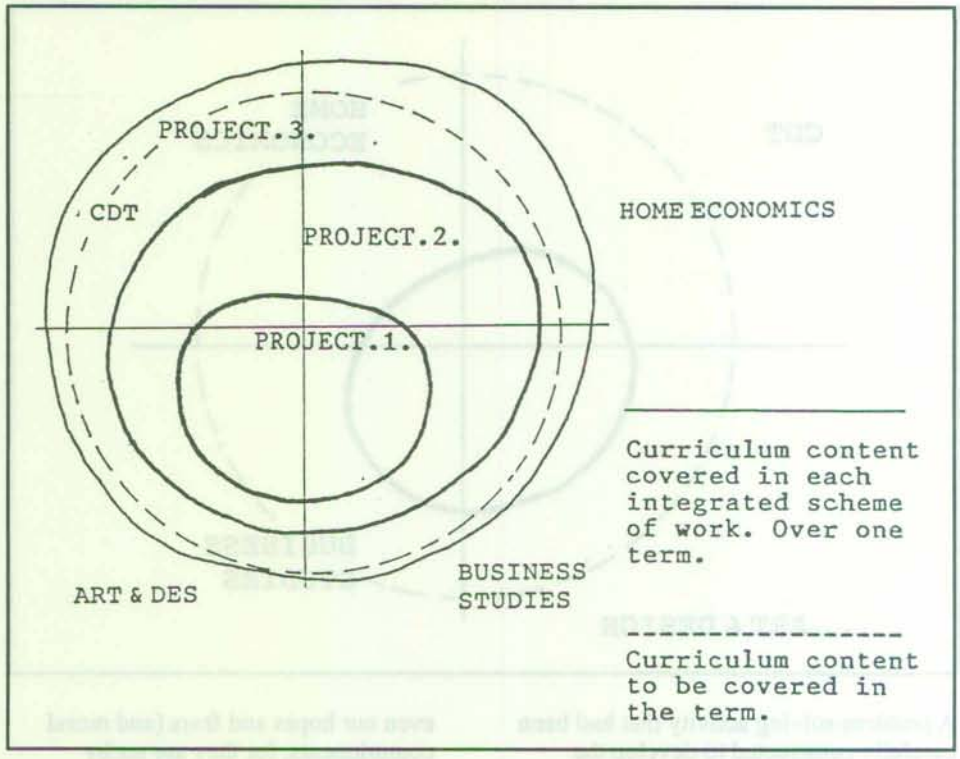
Cross-Curricular Learning

Primary teaching, is considered by many teachers, to function more effectively when it works across the curriculum. After a number of failed 'kick-starts' it has now become more of a feature in secondary schooling, where it is most commonly found as a grouping of related subject areas, rarely across the whole curriculum. It has shown to bring greater relevance and meaning when delivered through a topic or theme, however, it is essential for these to be carefully balanced and meticulously planned. A criticism of the topic approach has been that some teachers have planned too much work around their own strengths and special interests. On investigation, a school used its LEA as an exemplar in this way of working was found to have over 80% of its topics biased towards the natural world.

Accurate recording, assessment and evaluation procedures are vital in ensuring a balanced progression. All topics will have a bias in one direction or another and it is important that each is planned to compliment previous studies. Progression in individual subject areas can be 'evened-out' over a period of two or three topics. (see Fig. 3.)

Most good teachers are aware of the dangers of becoming 'topic bound', there will be many times when it will be more relevant to develop important skills and concepts in isolation. Tasks set for children must match their learning requirements. When specific skills need to be taught it is probably best that they are learned by instruction, at other times a more open-ended task will be appropriate. These can be reinserted back into a contextual framework when greater relevance is needed.

Figure 3: The 'mapped' content of three consecutive schemes of work. This shows how well planned topics will compliment one another over a period of a term.



Whenever pupils are engaged in practical activity they will be involved in cross-curricular work of one sort of another; making a model will require measuring skills, marking and cutting to scale and being aware of proportion — skills associated with mathematics. If the model is of a boat or a house it is likely to fit a style or age — History. Language is constantly being used, exercised and developed. The properties of materials, their structure and potential can be identified as science. Relationships across the curriculum are numerous and genuine, these cross-curricular aspects of practical work are often referred to as one of it's major contributions in unifying the curriculum. However, one disturbing outcome is that a number of educationalists when speaking to non-specialist teachers often refer to how these important concepts are 'implicit' within a practical activity — 'You are doing it already, all the basic discoveries are being made while they are making these wonderful models.' It is important to guard teachers against this patronising approach by emphasising the fact that unless these 'implicit' concepts can be identified, drawn out and made 'explicit' they will remain undeveloped within the child. What is being referred to here is the identification of transferable skills and understandings, not the more complicated issues related to 'latent learning' illustrated in Figure 4.

Co-operative Learning

An investigative approach to learning is most successful when students work in co-operative learning groups. In the early stages groups are most efficient when engineered by the teacher who has a sound knowledge of the qualities of each individual within the class, and is able to balance skills, knowledge, temperaments, and personalities. Later, after some experience, pupils should be allowed to construct their own teams and balance skills against the demands of the task. The benefits of the approach are manifold, it develops positive attitudes towards others, co-operation and respect. The group, dependent upon age and ability, should be able to record their own achievements and be encouraged to make honest assessment of each others contributions.

Organisations and Management

To maximise the potential of learning through an investigative approach, careful consideration must be given to classroom organisation and management. Efficient, structured and well planned organisation is the key to providing a stimulating environment that inspires quality learning. The following factors need to be considered:

1. **Organisation of the working environment.**

A classroom, studio or workshop must be arranged to meet the needs of a variety of teaching strategies and classroom situations. It will need to be stimulating with relevant displays, resources and materials. The space will need to be organised to cater for: group work, individual work, practical work, quiet work and study. Areas need to be clearly defined so that pupils know how to work in each section, and how to care for and tidy each area.

2. **Organisation of resources.**

It is important to note that when looking to build on the qualities of an investigative learning approach, it is vital that resources for learning are readily accessible to the students. An investigative approach will flounder if not supported by a wide range of the necessary resources. Even if there is not enough room to have a permanent collection of books, it is necessary to have a range of relevant reading materials to support the needs of the current scheme of work.

Assessment

Many teachers experience difficulties when required to make assessments of individual pupils who have been working in groups for an activity. Pupils and teachers need to be clear on what is to be assessed. Is assessment being made of the performance and quality of the group-work? In which case it may be that individual performance is seen by pupils as less important so long as they are doing something purposeful within the group. Or is assessment being made on an individual performance within the setting of group work? If this is the case then careful management may be required to avoid uncooperative or unduly competitive behaviour. It will become necessary for pupils to play an important role in assessing their own contributions towards the group project, the part they played, their ideas and the things they produced.

Pupils will need to make sure that their individual work and group work contribution is being evidenced. Activity time should be structured so that they do not lose sight of themselves as individuals within the group. The following staging could help to determine the individuals role and contribution:

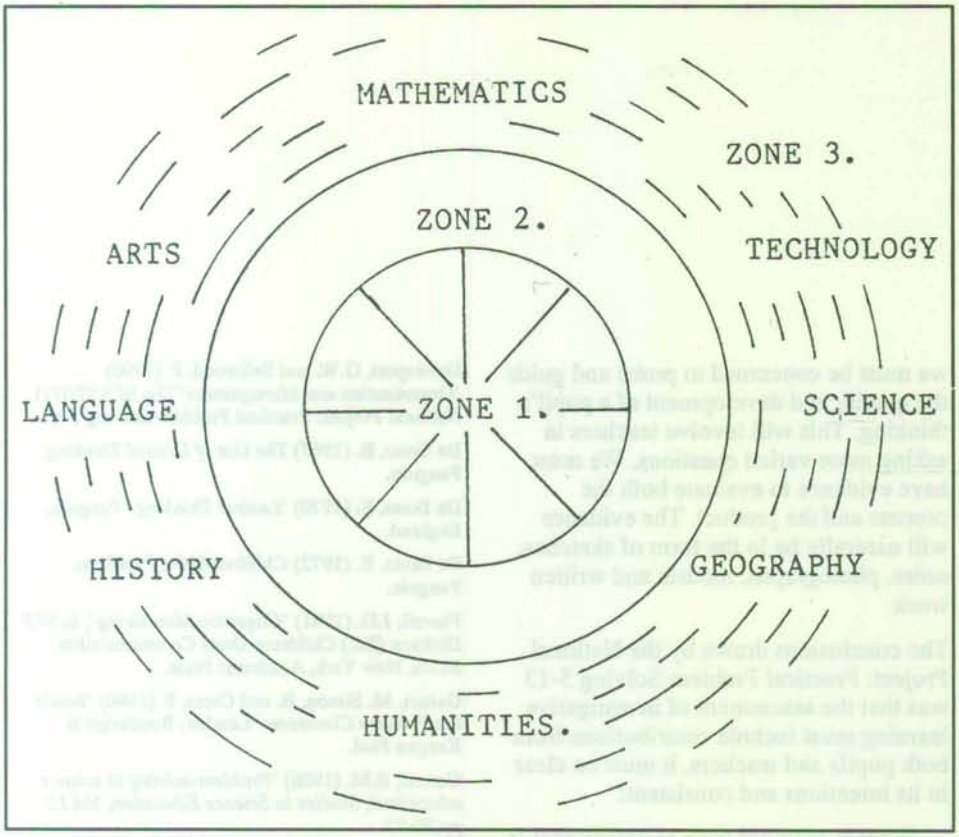


Figure 4: Comparable content achievements in:

1. subject based learning programmes.

2. Integrated (cross-curricular) schemes of work.

3. Integrated schemes of work taught through an investigative learning process.

- regular points when pupils individually review the progress they are making.
- regular points when pupils individually plan what they still need to do, think about or find out.
- a regular point when pupils individually modify their plans and proposals in relation to what they are doing and finding out; and in relation to what others in their team are doing.

As well as being asked to appraise their own work, pupils may be asked to appraise the work of others. One group could make an appraisal of another group's work. The group can then address the comments which others have made of them to see if this helps them to recognise their own strengths and weaknesses.

When working investigatively, it is vital that pupils decide upon the criteria by which they will make their assessment. This will prompt them to focus on particular aspects of their work rather than making vague generalisations without addressing any specifics, or just for the sake of criticising others. These points also exist when they are involved in the critical study of a work of art, a piece of architecture or the design of a product.

No form of assessment will accurately reflect what a pupil has learned, it is, at best a rough guide. That is not to say that it is unnecessary; of course it is. Pupils learning investigatively will have learned far more than the direct requirements set out by the teacher in a programme of work. Some of this 'extra' knowledge and half-formed concepts will not immediately make sense, or be relevant, nonetheless it will lie dormant until other strands of learning make the vital connections that bring enlightenment. This was referred to as 'latent learning' by the 'National Project: Practical Problem Solving 5-13' team, who noted that for some pupils there was a considerable incubation period following broad open-ended projects. Children regularly confounded their teachers, and members of the project team with the amount of understanding that appeared, as if by magic at a much later stage.

Interpretation of Figure 4

Zone One The inner segmented circle represents the content of learning gained through a subject based learning programme when taught didactically. The content is restricted by the boundaries set by the teacher. It can effectively reach the set objectives but no more.

Zone Two The second circle represents the extra knowledge gained by teaching through integrated programmes of work. This further understanding is cumulative and is gained through recognising the relevance of one subject to another, particularly when learned within a context. Example: colour harmony taught within art recognised as camouflage when studying wild life and habitats in an integrated scheme linking art and environmental studies.

Zone Three The outer areas beyond the second circle represents the 'larder'. This is where pupils store half-held concepts, insights and information. At a later stage further connections will substantiate them and make them 'concrete'. It is the bonus gained from a well-planned investigative learning programme. This domain is the key to self-motivation as it provides the evidence to the pupil of how it is learning 'how to learn'.

Skills Supporting An Investigative Learning Process

It is important that before embarking upon any programme of work to list and categorise the essential skills required. Most skills can be developed sequentially, which provides a means of assessing the quality of pupils performance at all times. The skills of observing, recording, collecting evidence and using evidence are all skills that are developmental, yet it is rare to find teachers who have constructed a means of grading these skills.

In conclusion

It is clear that the ways practical activities have been approached in the best primary schools may in the future form a model for all schools. The topic approach when carefully structured offers an open educational environment where investigative methods thrive. Such an approach will answer the challenge posed by Hicks (1983):

> Teaching facts is one thing; teaching pupils in such a way that can apply facts is another, but providing learning opportunities which encourage pupils to use information naturally when handling uncertainty, in a manner which results in capability, is a challenge of a different kind.

The National Project: Practical Problem Solving 5-13 stated that

There is a wide spread confusion amongst school over what is required of them for assessment, recording and evaluation for practical activities. Some have already made their own attempts to gather information — often resulting in large quantities of work, tick charts, annotated files, audio and video tapes. The collection of such large quantities of data is almost always self-defeating.

The non-statutory guidelines for Technology contains the following points:

> Record keeping will need to be *efficient:* in technology unlike other subjects, pupils will be choosing their own solutions to develop, and will cover different parts of the programme of study. It is difficult to envisage a class record system which could record that one child made a product from wood, another used card and a third used both materials.
>
> ... recording Pupil Progress — Good record keeping is essential if progression, continuity and balance are to be maintained for all pupils. For each class, or group of pupils, records will need to indicate:
>
> - Topics/themes covered, and contexts introduced for design and technology activity:
> - Design and technology products —
> - In addition, individual records of each pupil's experience will be needed. Each record will require updating every half-term and should include:
> - Brief information about the product developed, with an indication of whether it is an artefact, system or environment;
> - Brief information about the materials used.

When considering cross-curricular practical activities it is of paramount importance to remember that evaluation of such activities involves more than simply the evaluation of the end product, we must be concerned to probe and guide the quality and development of a pupil's thinking. This will involve teachers in asking more varied questions. We must have evidence to evaluate both the process and the product. The evidence will naturally be in the form of sketches, notes, photographs, models and written work.

The conclusions drawn by the National Project: Practical Problem Solving 5-13 was that the assessment of investigative learning must include contributions from both pupils and teachers, it must be clear in its intentions and consistent:

> What is required is an approach that is efficient and contains information about the processes and products of the educational experience, and takes account of the principle of pupil self-accounting. If assessment and recording is to fulfil its promise, then the quality of the approaches taken needs to be optimised, whether it be simply a matter of ensuring consistency of photographic records or the right approach to observing and recording the processes of young peoples' attempts to deal with practical problems.

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