
From Thinking Skills to Thinking Classrooms: a review and evaluation of approaches for developing pupils' thinking

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EXECUTIVE SUMMARY

In October 1998 the Department for Education and Employment commissioned a review and evaluation of research into thinking skills and related areas. The purpose of the review was (1) to analyse what is currently understood by the term “thinking skills” and their role in the learning process; (2) to identify current approaches to developing children’s thinking and to evaluate their effectiveness; (3) to consider how teachers might be able to integrate thinking skills into their teaching both within subject areas and across the curriculum; (4) to identify the role of ICT in promoting a positive approach to thinking skills; and (5) to evaluate the general direction of current and future research and how it might translate into classroom practice.

Key Conclusions

1. Current attempts to teach thinking are part of a more general thrust in educational reform which emphasises the **quality** of thinking processes and thinking skills as a means to raise educational standards and to prepare children and young people for lifelong learning. Raising standards requires that attention is directed not only on **what is to be learned** but on **how children learn** and **how teachers intervene to achieve this**.
2. Sufficient research and practice has accumulated to identify **core concepts in a framework for development** of thinking skills. Although theoretical emphases can differ, the general framework now includes: the need to make thinking skills explicit in a curriculum; teaching through a form of coaching; taking a metacognitive perspective; collaborative learning (including computer-mediated learning); creating dispositions and habits of good thinking; generalising the framework to thinking curricula, thinking classrooms and thinking schools. Considerable **evaluation** work remains to be done in order to link the critical features of the framework to **learning outcomes** in different contexts.
3. For comparative purposes in the review, **three models for delivering thinking skills were identified**. Interventions can be directed towards general thinking skills (e.g. Instrumental Enrichment), they can target subject-specific learning such as science (e.g. Cognitive Development through Science Education (CASE)), mathematics, (e.g. Cognitive Development through Mathematics Education (CAME)) and geography (e.g. Thinking through Geography), or they can be infused across the curriculum, (e.g. Activating Children’s Thinking Skills (ACTS)). Whatever approach is adopted, the methodology must maximise transfer, that is, adopt teaching strategies (eg bridging, deliberate teaching for transfer) which ensure that the learning transfers beyond the context in which it occurs.
4. A successful **prototype for developing curriculum materials was identified**: strong theoretical underpinning; well-designed and contextualised materials; explicit pedagogy; teaching support and programme evaluation. Curriculum materials alone are not sufficient. These requirements can be applied equally to computer mediated curriculum materials.
5. Several large scale **classroom evaluation studies** have successfully linked teaching thinking methodologies with **learning outcomes** both in the short term and the longer term, although **not all interventions are equally successful**. CASE, for example, succeeded in raising pupils’ grades in GCSE public examinations (on average 1 grade) two to three years after the programme had been completed. Philosophy for Children has an impact across a wide variety of cognitive and social development measures. On the other hand, Blagg’s evaluation of Instrumental Enrichment showed no direct learning gains but did impact positively on attitudes and behaviour.

6. Teaching from a thinking skills perspective is particularly **evident in the sciences and mathematics and, increasingly so, in history and geography**. There is scope for considerably more systematic work within subject areas in order to link together existing research which is not so readily identified as “thinking skills” (eg in creative arts, moral and social development) as well as to examine commonalities and differences between thinking skills as they are exercised in disciplinary contexts.
7. Subject specific and infusion approaches present opportunities for **embedding thinking skills within and across the curriculum** and there are clear arguments in favour of doing this. Nevertheless, the challenges of adopting an infusion approach should not be underestimated, especially the risk that the thinking skills framework may become trivialised or “watered down”. Evidence suggests (eg ACTS) that teachers experience difficulty keeping the twin perspectives of thinking skills and topic content simultaneously in view (together with the other aspects of classroom management and practice).
8. **Information and communication technologies** can be linked to the **thinking skills** framework in several ways. Interactive exploratory environments help make thinking more explicit, they enable pupils to hypothesise and experiment with immediate feedback and facilitate discussion and reflection with peers. Multi-media technology permits students to form rich images of problem situations in multiple modalities and prompts alternative perspectives. Local and networked communication (databases, email, WWW, National Grids) provide unique opportunities for collaborative learning. Although several well-researched examples which link computer mediated learning and thinking skills have been reported in the literature, additional evaluation studies on learning outcomes are needed, particularly for whole class (rather than individual) learning.
9. Much of the research on the efficacy of teaching thinking was conducted under optimal learning conditions and **problems with scaling up** and transferring the effects of everyday classrooms have been identified. In particular, the most successful interventions have been characterised by explicit models of teacher development and teacher support (eg CASE, Thinking through Geography, ACTS).
10. The shift from **thinking skills to thinking classrooms** can be clearly seen through within-the-curriculum and across-the-curriculum approaches but the idea of thinking classrooms, and schools as thinking communities, requires further articulation and interpretation, and the research base is in its infancy. Nevertheless, thinking classrooms brings thinking skills analysis the full circle and links with emerging research on school ethos.

1. Aims and Outline Plan

The purpose of this review is:

- ☐ to analyse what is currently understood by the term “thinking skills” and their role in the learning process;
- ☐ to identify current approaches to developing children’s thinking and to evaluate their effectiveness;
- ☐ to consider how teachers might be able to integrate thinking skills into their teaching - within subject areas and across the curriculum;
- ☐ to identify the role of ICT in promoting a positive approach to thinking skills;
- ☐ to evaluate the general direction of current and future research and how it might translate into classroom practice.

This review draws partly on previous work reported by the same author and colleagues (McGuinness 1990, 1993, 1996; McGuinness & Nisbet, 1991; McGuinness, et al, 1996, 1997). In particular the ACTS (Activating Children’s Thinking Skills) project which was funded by the Northern Ireland CCEA is acknowledged. The author was director of the ACTS project.

The theme to be developed in the review is that earlier attempts to teach thinking focused on bolt-on thinking skills programmes and measured students’ cognitive achievements. Evaluations of these programmes, and an emerging conceptual analysis of successful teaching methodologies, shows a shift towards the concept of thinking classrooms. In thinking classrooms, high cognitive demand and challenge is embedded in a range of pedagogies which include - making thinking skills explicit within curricular content, focusing on talk and discussion about thinking, collaborative learning and maximising technological advances. Characteristics of high quality learning in classrooms are being identified with implications not only for students’ thinking but for teacher development and teacher thinking as well.

The review is divided into ten sections. Sections 2, 3 and 4 explain the core concepts which underpin current attempts to teach thinking and outline general strategies. Sections 5, 6 and 7 review examples of the three main approaches to developing thinking skills: structured thinking skills programmes, teaching within specific subject areas, and infusion approaches - and examine evaluations of learning outcomes. Section 8 analyses the role of information and communication technologies in developing thinking and places it within the more general thinking skills framework. Section 9 briefly considers implications for teacher development and support. Finally, Section 10 highlights the main conclusions from the review and points to future research directions.

2. General Concepts about Teaching Thinking

2.1 Introduction.

“.....before the century is out, no curriculum will be regarded as acceptable unless it can be shown to make a contribution to the teaching of thinking.” (Nisbet, 1993)

To respond to the learning challenges of the next century means that people must be enabled to take charge of their own learning - to “learn how to think” and to “think how to learn”. Learning by heart and rote learning are not sufficient. High quality learning and thinking demand more than the transmission of facts and the routine application of familiar procedures. If students are to become

better thinkers - to learn meaningfully, to think flexibly and to make reasoned judgements - then they must be taught explicitly how to do it. We cannot suppose that they will spontaneously learn how to think from teaching science or mathematics or history. Thus, teaching thinking is part of a more general thrust in educational reform which emphasises the quality of thinking processes and thinking skills as a means for raising educational standards and in preparing students for life-long learning.

The idea of teaching thinking is not new. Improving the quality of thinking has always been a central aim of education. In the 19th century, for example, studying the classics or mathematics was seen as a means to develop greater reasoning powers; much the same argument is currently applied to studying computers. What is new is the growing body of psychological research and educational practice which might turn the vague hope of teaching thinking into a reality.

For most of the 20th century, the notion of thinking power or intelligence as a fixed ability, which determined our capacity to think and learn, was dominant in educational theory and practice. The general view that thinking ability was fixed and stable over the life-span was not consistent with instructional efforts to promote better reasoning powers. Consequently, teaching thinking was not pursued at the level of mass education and was generally confined to specific populations (e.g., higher education, A-level study, gifted children, educationally disadvantaged).

During the latter half of the century, the theory and research base for learning and thinking shifted; information-processing, constructivism and social-historical views on learning now dominate the research agenda. Instead of knowledge being viewed as something which is transmitted, the prevailing view is that knowledge is actively created and constructed by learners through interactions with their physical and social environment and through reorganisation of their mental structures and frameworks. The primacy of individual learning has shifted towards social, cultural and historical contexts for learning.

Additionally, cognitive psychology and instructional research has witnessed some shift in methodology away from laboratory-driven studies toward studies which are more directly relevant to school learning and classroom instruction (Chipman, et al, 1985; Segal, et al, 1985; Nickerson, 1988; Bruer, 1993; McGilly, 1994; Perkins and Grotzer, 1997). A monumental volume in the form of a handbook of educational research provides exhaustive reviews of the direction of the current research effort with implications for practice (Berliner & Calfee, 1996). These authors point out two features which characterise contemporary educational research - the renewed engagement with issues of practice and the emergence of cognition as the prevailing theoretical framework.

We have drawn upon this body of educational research and practice in order to identify the core concepts for developing thinking skills which we consider best represents the current state of the science.

2.2 A Comment on Thinking-as-a-Skill.

Some writers express reservations about using the term 'skill' to refer to the mental processes involved in thinking, preferring to confine the term to forms of cognition such as perceptual-motor skills, reading skills or numeracy skills. Other terms are also used to describe thinking such as thinking strategies, higher order thinking, thinking acts, habits of mind, thinking dispositions. Although there are theoretical distinctions between the meanings of these terms (and some will become apparent as the review progresses), the idea of thinking-as-a-skill continues to have both theoretical and instructional force. Firstly, it places thinking firmly on the side of "knowing how" rather than "knowing that" in the long standing philosophical debate about the nature of knowing.

And secondly, much of what we know about skill learning can be usefully applied to developing thinking - being explicit about components of the skill, learning by observation and modelling, the importance of practice, feedback and transfer of learning. Additionally, some of the characteristics of situations in which traditional skills are learned and honed (apprenticeships, realistic tasks, etc) are increasingly being acknowledged as important in the research literature on developing thinking. For these reasons thinking-as-a-skill has assumed the status of a metaphor and continues to be used in the literature in a general way alongside other terminology.

3. Thinking Skills and Learning: Core Concepts

3.1 Although it may seem self-evident, focusing on thinking skills in the classroom is important because it **supports active cognitive processing which makes for better learning**. Thus, pupils are equipped to search out meaning and impose structure; to deal systematically, yet flexibly, with novel problems and situations; to adopt a critical attitude to information and argument; and to communicate effectively. Many writers argue that setting standards is not sufficient for raising standards. **Standards** can only be raised when attention is directed not only on what is to be learned but on **how children learn and how teachers intervene to achieve this**.

3.2 Developing thinking requires that interventions are made directly at the level of cognitive processing. If we want students to become better thinkers, we must make **explicit** what we mean by these better forms of thinking and devise ways of **educating directly for thinking**. A variety of terms are now used to capture the same meaning - cognitive education, cognitive coaching, cognitive instruction, cognitive intervention.

3.3 Most attempts to teach thinking are based on some formal analysis of the nature of thinking, but what they are all trying to do, irrespective of their precise theoretical foundation, is to develop the person's thinking to a qualitatively higher level - to change thinking into a higher gear (Adey & Shayer, 1994).

There are several general **taxonomies of thinking** available (Marzano et al., 1988; Presseisen, 1986; Swartz & Parks, 1994). Examples of the different kinds of thinking are: sequencing and ordering information; sorting, classifying, grouping; analysing, identifying part/whole relationships, comparing and contrasting; making predictions and hypothesising; drawing conclusions, giving reasons for conclusions; distinguishing fact from opinion; determining bias and checking the reliability of evidence; generating new ideas and brainstorming; relating cause and effect, designing a fair test; defining and clarifying problems, thinking up different solutions, setting up goals and subgoals; testing solutions and evaluating outcomes; planning and monitoring progress towards a goal, revising plans; making decisions, setting priorities, weighing up pros and cons (after Swartz & Parks, 1994). What is included and excluded can be arbitrary, dependent on the age group, the degree of challenge and context/subject matter being taught. Other frameworks identify multiple intelligences for enhancement, for example, linguistic, logical-mathematical, musical, interpersonal, or kinesthetic intelligence (Gardner, 1993).

Resnick (1987), chair of a working party who reported to the National Research Council in the US, pointed out that although high quality thinking was difficult to define, it was easy to recognise. The following characterisation was advanced:

High quality thinking

- ☐ Is not routine - the path of action is not fully known in advance;
- ☐ Tends to be complex - the total path is not “visible” from a single viewpoint;
- ☐ Yields multiple rather than unique solutions;
- ☐ Involves nuanced judgement and interpretation;
- ☐ Can involve the application of multiple criteria which may conflict with one another;
- ☐ Involves uncertainty - not everything about the task at hand is known;
- ☐ Involves imposing meaning - finding structure in apparent disorder;
- ☐ Is effortful - considerable mental work is needed for the kinds of elaborations and judgements required.

These types of thinking can be required in many contexts across all ages - for reading comprehension and writing composition, for mathematical problem-solving, for thinking in science, for interpreting historical materials, for critical argument, and for aesthetic appreciation.

3.4 Developing thinking requires that children are given **the time and opportunity to talk about thinking processes**, to make their own thought processes more explicit thus enabling them to clarify and reflect upon their strategies and gain more self-control. **Becoming reflective thinkers** - or acquiring metacognitive skills as they are sometimes called - has emerged as a powerful tool for promoting a thinking skills curriculum. A variety of methods are available to enhance reflection and to promote self-regulation, e.g., thinking aloud, pair problem solving, co-operative learning, reciprocal teaching, group discussion (McGuinness, 1990, 1993, McGuinness and Nisbet, 1991). The characteristics of powerful learning environments have been identified.

3.5 Developing thinking recognises that children do not enter classrooms as “empty vessels” waiting to be filled with knowledge. Rather, they bring their own conceptions (or misconceptions); new knowledge and alternative strategies for thinking are socially constructed in the classroom not only through informed teacher instruction, but through practical activities, reflection, dialogue and discussion with peers and adults. The opportunities for **developing thinking skills through socially mediated activities** should not be underestimated. Such socially mediated activities cannot be left to chance but need to be designed by the teachers drawing on knowledge of children’s thinking processes, pedagogy and content.

3.6 Developing thinking recognises that cognitive competence is increasingly viewed as being distributed - dependant on physical, social and symbolic support for development and enhancement. In this context, the **new information and communication technologies provide a powerful tool for enhancing children’s understanding and powers of reasoning** through exploratory environments/microworlds, multi-media and hypermedia. In particular, networked communication (local and wide area) provide unique opportunities for collaborative learning.

3.7 Developing higher order thinking may have as much to do **with creating a disposition to be a good thinker** as it has to do with acquiring specific skills and strategies - developing a will as well as a skill (Perkins, et al, 1993). For this reason, classrooms need to have open-minded attitudes about the nature of knowledge and thinking and be able to create an educational atmosphere where talking about thinking - questioning, predicting, contradicting, doubting - is not only tolerated but actively pursued.

3.8 Developing thinking has created its own conceptions for learning and has shifted from the thinking-as-a-skill metaphor to ideas of a thinking curriculum, thinking classrooms and learning communities.

4. Approaches to Developing Thinking Skills

A distinction can be drawn between cognitive interventions which target **general** cognitive processes and approaches to thinking development which are **subject or domain specific**, for example, thinking in science, mathematics, physics, history. A third way is to adopt an across-the-curriculum approach by **infusing** a methodology for developing thinking skills across all lessons. The more wholistic curriculum approach is giving way to ideas of a Thinking Curriculum, Thinking Classrooms, and Learning Communities.

4.1 General Approaches.

The generalists argue that cognitive development is driven by a general central processor and that intervention at this level will have widespread effects across many thinking domains. This view is most strongly linked (though not exclusively) with Piagetian and post-Piagetian theories of cognition. Within the generalist approach some programmes are context-free; they consist of specially designed materials which do not require specific content knowledge (puzzle-type materials) and are normally timetabled separately from other curricular areas. Some of the most widely known thinking programmes are of this kind, for example, Feuerstein's Instrumental Enrichment, Blagg's Somerset Thinking Skills, de Bono's CORT and Lake & Needham's Top Ten Thinking Tactics. Other general interventions are context-dependent; although targeting general cognitive development they are situated within a curricular area, where they deliberately use the thinking opportunities provided by that domain (e.g., CASE, Cognitive Acceleration through Science Education).

4.2 Subject Specific Approaches.

In contrast, other interventions are based on the view that high quality thinking is inextricably linked with the knowledge structures, the methods of enquiry and ways of thinking associated with different disciplines or domains. Students' misunderstandings and inadequate strategies are most transparent at this level; hence interventions are best positioned within specific domains. This view draws on an extensive research base that compares experts and novices reasoning and solving problems within their own domains; the evidence points to the uniqueness of domain-specific thinking and to the fact that experts in one area do not necessarily show high quality thinking in other areas. Many examples of innovative computer software designed to enhance reasoning and problem-solving, focus on domain specific thinking, particularly in mathematics and science.

4.3 Infusion Methodology.

A middle way, which attempts to both capture a situated view on learning while at the same time keeping general cognitive development in mind, is to develop a "thinking curriculum" where teaching thinking is infused across all areas of the curriculum. An infusion methodology required that contexts are first identified within the curriculum where particular thinking skills and strategies can be developed (e.g, problem-solving, causal reasoning, classification). Then lessons are developed where thinking skills and topic understanding are explicitly and simultaneously pursued.

This approach has been most clearly developed in US by Robert Swartz, David Perkins and Sandra Parks (Swartz & Parks, 1994) and has been adapted as the methodology for the ACTS project in Northern Ireland (McGuinness, Curry, et al, 1997). It can also be seen in some multiple intelligence programmes, for example, in Gardner and colleagues' practical intelligence for schools or PIFS curriculum (Gardner, et al, 1994).

4.4 The Issue of Transfer.

Deciding on what type of intervention to pursue mirrors a deeper theoretical debate about the nature of cognition. It involves more than the pragmatics of deciding where to timetable thinking skills within the curriculum. Whatever model of cognition is adopted, maximising the transfer of learning beyond the context in which it was learned is at the heart of the matter (Perkins & Salomon, 1988, 1989; Salomon & Perkins, 1989). All cognitive interventions - general, domain-specific, and infused approaches - seek to produce transfer effects and all approaches run their own risks in this regard. If general thinking skills (context-free) are targeted in a separate programme in the curriculum, then they may become "locked in" and fail to transfer into the mainstream curriculum. The same risks are associated with interventions that are confined to only one area of the curriculum. And the alternative of infusing higher order thinking approaches across the curriculum runs its own risks; they may get lost in the midst of subject knowledge-based teaching and/or pupils may fail to see the connections between similar types of thinking in different subject areas. To be successful, all programmes need to adopt methods to minimise these risks.

4.5 Size and Scale.

Some interventions are highly developed, with commercially produced curricular materials, staff training opportunities, and full-scale evaluations in classroom settings. Others are at the level of the smaller-scale research-based "teaching experiments" conducted in optimal settings. Their robustness in terms of how they transfer to ordinary classrooms have not yet been tested. Nevertheless, the research base on the development of thinking is substantial and constantly growing. Curricular materials are becoming more readily available and methodologies on how to develop thinking are being established. Information and communication technologies are opening up new horizons on the question of developing thinking - by enabling students to explore environments through microworld and multi-media technology, and to engage in both local and distance collaborative learning.

During the 1980s the main work came from the US (for reviews see Nickerson, 1988; Resnick & Klopfer, 1989) which continues to be a prime mover in the effort to translate cognitive theory into classroom practice (e.g., Bruer's (1993) *Schools for Thought*, McGilly's (1994) *Classroom Lessons*). Teacher centres and professional publications for teachers promote the approach (e.g., *Educational Leadership* published by the Association for Supervision and Curriculum Development, West Virginia).

McGuinness and Nisbet (1991) described developments in teaching thinking in Europe. The perceived need for that paper came directly from an OECD/CERI International Conference held in Paris in July, 1989, on Learning to Think-Thinking to Learn, attended by delegates from 22 countries including the US. One outcome of the conference was to recognise that European work on teaching thinking was not well enough known, even within different countries in Europe. A similar concern led to the formation of the European Association for Research on Learning and Instruction (EARLI) who now publish their own journal, *Learning and Instruction*.

The UK has been slower in its response to the issue. Ten years ago, Coles and Robinson's (1989) survey on teaching thinking programmes was slim, primarily because of the absence of relevant UK-based research and practice. However, that has radically changed in the last decade. The research base is steadily accumulating. Several classroom-based research initiatives have been successfully completed and evaluated and will be reviewed in the following sections. Teacher development networks and professional publications on the issue are coming on stream. Nevertheless, the impact on ordinary classrooms is very small. There are pockets of high levels of awareness and innovative practice. But in general, from a survey of Northern Ireland teachers and teacher advisers, it was clear that, although teachers could readily point to topics which presented "thinking" difficulties for primary pupils (e.g., fair test, concepts of time, mapping skills), their practice was not sustained by a systematic "thinking" framework nor was there an explicit emphasis on a cognitive intervention/coaching methodology (McGuinness, et al, 1996).

5. Structured Thinking Skills' Programmes

This section reviews a number of well-established structured programmes for developing thinking with particular reference to the UK context.

5.1 Feuerstein's Instrumental Enrichment.

Perhaps the best known structured thinking skills programme world-wide is Feuerstein's Instrumental Enrichment (IE) which was initially developed some 40 years ago (Feuerstein, et al, 1980). Remedial in its outlook, it was intended for culturally disadvantaged, low-performing Israeli adolescents; it is now used across wider age groups and abilities.

IE is a context-free cognitive intervention programme - it focuses on cognitive processes, not on any specific content. Feuerstein deliberately advocates that the programme is taught outside the traditional classroom curriculum where initial "bad habits" of thinking were practised. The idea of "mediated learning" is central to Feuerstein's theory of cognitive development. Cognitive mediation means that some agent (normally an adult) intentionally shows or instructs a learner about cognitive methods for interpreting information, for solving problems, or for learning something. For example, an adult might illustrate the usefulness of categorising a piece of information and then go on to demonstrate a technique for doing it. Cognitive "deficit" is the result of mediation deprivation which can be seen in terms of "blurred" and sweeping perceptions of the environment, impulsivity, inability to select relevant cues and define problems, trial and error responses, imprecision in communicating responses, and so on. IE is designed to overcome these deficits through systematic mediation at a later stage. Feuerstein argues that enhancing learners' basic abilities has a snow-balling effect in that children then become capable of additional and even more complex learning and thinking. These effects should transfer to the mainstream curriculum.

The programme consists of 14 progressively more demanding instruments (hence Instrumental Enrichment) that provide the context for mediation, to be used over a 2-3 year period. The early instruments cover pattern detection, pattern comparisons and orientation in space; the later instruments move on to more complex reasoning and problem solving (e.g., syllogisms, transitive relations, representations). The teacher plays a critical role in a mediated learning session, exploring problem definitions, encouraging students to evaluate their strategies, helping them to develop a language for discussing their thought processes, as well as engaging in "bridging" exercises to encourage transfer to the mainstream curriculum. On the front page of each instrument is the

slogan “Just a minute - let me think”. That slogan alone provides the opportunity for the students to “think about thinking” by talking about thinking.

Savell, et al, (1986) reported a substantial review of evaluation studies on the effects of IE on subsequent intellectual performance. They concluded that:

1. Statistically significant differences had been reported between IE trained groups and controls in at least four different countries (Canada, Israel, US, Venezuela), in middle and lower social class groups, and in groups considered normal as well as groups considered educationally disadvantaged.
2. The post-training effects most commonly reported were on standard nonverbal measures of intelligence (largely on processing figural and spatial information). Other effects such as increased self-esteem, improved classroom behaviour, and better performance on attainment/achievement tests were more inconsistent and difficult to interpret.
3. Studies showing positive effects had a number of features in common - at least one week of training for instructors, 80 hours or more exposure to IE over a 1 or 2 year period, and IE taught in conjunction with some other subject matter of interest and importance to the student.

Shayer and Beasley (1987), reviewing the American and Israeli studies, came to essentially the same conclusion. However, they pointed out that all evaluations of IE had been completed at the end of the intervention period - no follow-up measures were collected which might show the effects of the intervention on subsequent or fresh learning. Shayer and Beasley argued that if IE is delivered intensively with adequate training then it has “a potential which could transform the professional training and skills of teachers involved with the less able secondary pupil”.

In a meticulously conducted UK evaluation of an IE intervention with 14 year old low-achieving adolescents over 2 years in four schools in Somerset, Blagg (1991) reported no significant improvements in the IE trained groups compared to the controls on subsequent intellectual performance or on tests of reading skills, mathematics skills and work study. There was some evidence of positive attitudinal and behavioural change for both pupils and teachers. These disappointing effects were attributed to the non-optimal conditions of training for the teachers, and to dissatisfactions with the “abstract” nature of the IE instruments which led Blagg and his colleagues to develop The Somerset Thinking Skills Course.

It should be noted that many of the users of IE (in research settings) are critical, not of the theoretical foundations and practices of IE, but of how the curricular materials are controlled. The materials are available only to those who have been trained in their use; only trained teachers can “train” other teachers if they have been trained as trainers, and so on. The originators of the materials vigorously resist any form of adaptation and change in the instruments. The risk is that the materials will become fossilised and reach only a tiny proportion of those who might benefit from them (Shayer & Beasley, 1987; Blagg, 1991).

Accredited IE training is available in the UK from The British Institute for Instrumental Enrichment in Bognor Regis, and from The Binoh Centre in London.

5.2 The Somerset Thinking Skills Course.

These are a set of curricular materials which were designed by Blagg and his colleagues (Blagg, et al, 1988) as a result of dissatisfactions with the IE instruments. They consist of a handbook and seven modules - foundations of problem solving, analysing and synthesising, positions in space and time, predicting and deciding, and so on. They differ from IE in that the materials are pictorial and

naturalistic rather than abstract and content-free. In other ways they are very similar to IE, drawing on similar theoretical principles with regard to mediation, bridging and transfer.

Like other general thinking skills courses, the Somerset course can be timetabled as a separate course or used more generally across the curriculum. The curricular materials are now widely available and are being used at the top end of primary school to support other problem-solving and investigative approaches. At the secondary level they are being used with mixed ability classes and are related to national curriculum subjects. At a more intensive level, they are suitable for special needs pupils.

No large scale evaluation of the effects of this course on subsequent intellectual performance is available. Because of such flexible use, it is difficult to see how an evaluation study could precisely pin down its effects at this stage. However, in professional journals there are many positive reports from teachers about the modules (e.g., Hickling (1990) on using the modules in English and Art).

More recently, Blagg and his colleagues (Blagg, et al, 1993) extended their work into occupational settings and produced another set of modules, Thinking Skills at Work (TSAW), funded by the Employment Department in Sheffield. Modules include Preparing for Work, Administration, Business & Commerce, Hotel Catering & Licensed Trade and Engineering. They are particularly suitable for meeting the core skills requirements of GNVQs, NVQs, BTECs, and so on.

Fourteen controlled studies, evaluating TSAW modules, were conducted across a range of contexts, vocational areas and types of trainee. In twelve of the fourteen studies, the modules produced significant benefits for both trainers and trainees. For example, trainees became more able to recognise and understand complex problems, more inclined to plan, check and review, became more interpersonally skilled and more self confident. Trainers became more positive about their job role and more optimistic about the trainees' abilities. They also became more aware of training for transfer.

Awareness days and 2/3 day interactive workshops for both The Somerset Thinking Skills Course and the Thinking Skills at Work modules are available from Nigel Blagg Associates in Somerset.

5.3 CASE (Cognitive Acceleration through Science Education).

This is a context-dependent cognitive intervention based on a Piagetian analysis of cognition developed at King's College, University of London. A full report of the theoretical foundations of the intervention, together with the development and evaluation of the curricular materials, can be found in Adey and Shayer (1993, 1994). The project was under development for over 15 years.

The goal is to advance pupils' thinking to the level of formal operational thinking such that they can tackle the instructional objectives of the traditional curriculum. The intervention is set in the science curriculum and the materials are directed towards scientific-type thinking, but the purpose is to intervene directly at the level of general processing in order to "accelerate" development. Adey and Shayer argue that the science curriculum is not alone in demanding higher order thinking at the formal operational level. Curricular materials could be developed to suit English or History or Mathematics. In the final chapters of their book on *Really Raising Standards* (Adey & Shayer, 1994), they advocate this approach and point to potential developments in that direction. There is now a parallel programme targeting mathematical thinking, CAME - Cognitive Acceleration through Mathematics Education.

The impetus for CASE arose from a large survey (14,000 pupils in 45 schools from ages 6-16 years) of the English and Welsh school population (Adey & Shayer, 1981, chapter 2 *Really Raising Standards*). The study found that not more than 30% of 16 year olds were showing evidence of even early formal operational thinking which is required to test hypotheses effectively, to judge critically between the merits of two arguments or to cope with proportionality. The implication is that the majority of pupils cannot think at a level required for the science curriculum (or indeed other curricular areas).

The CASE curricular materials, *Thinking Science*, consist of 30 activities which target some aspect of formal operational thinking in a progressive way (Adey, Shayer & Yates, 1989). The early activities concentrate on the control and exclusion of variables and then they progress to proportionality, probability, correlation, compensation, formal models and so on. Each activity is accompanied by both pupil and teacher worksheets and is concretised with specific examples and activities. The course is designed to be taught over a two year period to 11/12+ year olds (it is now used with older pupils, 13/14 year olds).

But the curricular materials themselves do not constitute CASE. Accompanying the materials is a set of instruction methods which form the basis for teacher training. When targeting the reasoning patterns associated with formal operational thinking, CASE works from concrete materials to abstract generalisation; to do this students need to develop a vocabulary for talking about thinking. CASE makes extensive use of metacognitive strategies through enabling students to make their thought patterns explicit by reflecting on, explaining, and evaluating their problem solving strategies. CASE teachers are trained to maximise cognitive conflict, that is, to create learning experiences which are puzzling or discordant with the students' current level of understanding. Finally, CASE makes extensive use of bridging (a term borrowed from IE) in order to promote the transfer of a thinking skill learned in one context to others, and to generalise the learning (Adey, 1992).

Adey and Shayer (1993) report an evaluation of the impact of CASE which shows striking results. Twelve classes (average class size 28) together with matched controls, participated in the study for two years (4 classes were 11 year olds and 8 classes were 12 year olds at the beginning of the study). They received one period (about 70 minutes) of *Thinking Science* every two weeks, about 25% of the regular science curriculum. Participating teachers received extensive training and support during the delivery of the programme. Nine classes completed the programme. The students were tested immediately at the end of the programme for changes on Piagetian-type reasoning tasks (to check for direct changes in formal operational thinking) and on science achievement tests. They were tested again after one year on both types of tests. Two years later (or three years in the case of 11 year olds) their GCSE grades in Science, Mathematics and English were examined for evidence of long term and transfer effects.

The immediate test results were not impressive, only the 12 year old boys (i.e., 12 year old at the beginning of the study, then 14 year olds) showed a significant gain on the Piagetian tests, and no significant differences were apparent on the science achievement tests. After one year, all groups showed gains on a science achievement test, but the effects were statistically significant for the 12 year olds boys and the 11 year old girls only.

The most striking results occurred after two year follow-up in terms of GCSE grades. Compared to the control groups, the accelerating groups (12+ boys and 11+ girls) showed average gains in the order of one grade in Science and slightly smaller gains in Mathematics and English. For English, 12+ girls also showed statistically significant gains. Even among the 11+ boys, where there was no overall effect, some boys showed substantial gains compared to the controls. It should also be noted that although average gains were around 1 grade, some pupils showed 2 or 3 grade gains. The

results were variable; nevertheless, the data do show that CASE produced the predicted accelerating effects such that ex-CASE pupils were able to use their new repertoire of thinking schemas to maximise new learning - both within the science curriculum and beyond.

Thinking Science curricular materials are now widely available and extensive INSET training and support on the use and evaluation of CASE is provided from King's College in London. Because of the extensive CASE network and the in-built evaluation "kit" which accompanies all CASE training, new evaluation data are constantly becoming available. Using value-added statistics and examining the performance of over 4,500 pupils, Shayer (1996) concluded that the CASE methodology, even when tried for the first time, produced increases of between 10-20% of pupils gaining C-grade or above in GSCE Science, Mathematics and English, compared to national averages. Results for Key 3 assessments were even more impressive. Additionally, Adey (1997) has been tracking the factors which influence the uptake of a large scale innovation in schools which shows that teachers' commitment and level of use of CASE is related to several school factors - degree of unity of vision between the headteacher and head of science, the presence of one other person who is deeply committed to the innovation, as well as the reasons for getting involved in the first instance.

The distinctive features of CASE - strong theoretical underpinning, well-designed and contextualised materials, explicit pedagogy, teacher support and programme evaluation - provide a very strong model for successful cognitive interventions.

5.4 Philosophy for Children.

A well-developed programme emerging from the critical thinking/philosophical approach is Martin Lipman's Philosophy for Children (Lipman et al 1980, Lipman 1985, 1987, 1991), associated with The Institute for the Advancement of Philosophy for Children at Montclair State College in New Jersey, USA. Although it can be used as a separate programme, more often it is integrated into other parts of the mainstream curriculum.

Based on the assumption that children are "natural philosophers", the programme seeks to harness that inclination, thus helping children to think for themselves by exploring alternatives, considering evidence logically and objectively, and searching for reasons for their beliefs. The programme stresses class discussion as the foundation for thinking skills: by sharing ideas and reasoning collaboratively the classroom becomes a "community of inquiry".

The programme consists of a set of mini-novels to be read by pupils, together with instruction manuals for teachers. The characters in the novels are children and adolescents who are figuring out for themselves the laws of reasoning, producing counterexamples, looking for evidence for different points of view, and, in general, arguing in a philosophical way. The basic novel, Harry Stottlemeier's Discovery (suitable for 8-11 year olds), consists of 17 chapters each of which can be read in a few minutes. Each chapter has a leading idea such as - the process of inquiry, inference, contradiction, what is a possibility, causes and effects. Other novels are available for older age groups - Tony: Reasoning in Science, Lisa: Reasoning in Ethics, Suki: Reasoning in Language Arts, Mark: Reasoning in Social Studies.

The novels are intended to provide a model, and indeed a language, for discussing thinking which can be exploited by the teacher in the classroom. Lipman advocates a Socratic framework and has strong views on how philosophical discussion should be guided. (He proposes that teachers should be taught in the manner in which they are expected to teach). Lipman exploits dialogue in two ways; by modelling philosophical dialogue in the written works and by structuring classroom activity in ways which promote dialogue.

Several controlled evaluations of the programme have been reported by Lipman, the most extensive was carried out by the Educational Testing Service of Princeton, New Jersey in the late 1970s (reported in Appendix B, Lipman et al., 1980). Two hundred students, aged 10-13, participated in two locations over two years. Teachers were given training of two hours per week for the first year and students were exposed to the programme for approximately 2 hours per week. The test results generally showed that the programme had an effect on intellectual performance, in particular, improvements were noted in reading and mathematics and on measures of both creative and formal reasoning (it was difficult to assess these results because of the lack of detail provided on the control groups).

Philosophy for Children is now a world wide network and is particularly strong in South America. In the UK, work is supported by SAPERE (Society for the Advancement of Philosophical Enquiry and Reflection in Education) which publishes *If...then, the Journal of Philosophical Enquiry in Education*. A centre for research and training has recently been set up at the University of Glasgow.

The work of Robert Fisher (1987, 1990, 1995) who runs the Centre for Thinking Skills at Brunel University has long been associated with the philosophy for children approach. In his most recent publication (Fisher, 1998), he deliberately sets out to illustrate the theory and practice of philosophy for children with illustrations from children and teachers in the UK. He examines how the approach can be used for teaching thinking across the curriculum, particularly in the context of social and moral education where the philosophical emphasis on questions and questioning is important. Fisher points out that because of wide ranging goals of philosophy for children, evaluation can be along many dimensions other than standard achievement tests. He lists a variety of studies which show positive effects on children in terms of quality of discussion and argumentative skills, ability to formulate questions, self-esteem, development of community values and so on.

Distinctive features of philosophy for children are the emphasis it places on the development of questions and questioning which has long been identified as a weak link in classrooms; the ways in which classroom discussions are orchestrated; and the more general idea of a classroom as a community of learners. A pictorial version of philosophy for children has been designed by Murriss (1992). In Australia, Splitter and Sharp (1995) have promoted the development of philosophy for children and communities of enquiry.

6. Teaching Thinking within Subject Areas

There is somewhat of a renaissance in learning and teaching research in school subjects, posing questions about what is the kind of thinking, reasoning, wondering, feeling, collaborating which characterises work in history or mathematics or literature (Shulman & Quinlan, 1996). Connections are then made between disciplinary knowledge, curricula and the minds and motivations of children in classrooms. This research base is slowly finding its way into small scale teaching experiments (as well as into structured programmes) which aim to enhance thinking in subject-specific or domain-specific contexts. Several points are worth noting at the beginning. Mathematics and the sciences have been prominent in these developments, and many of the innovations are technology-based (the role of technology will be more fully discussed in Section 8). There is scope for considerably more systematic work in this area in order to link together existing research which is not so readily identified as "thinking skills", for example, from creative arts education and from education for moral and social development.

6.1 Mathematics.

In recent decades, mathematics education has become a field in its own right, see Grouws (1992) and De Corte, et al, (1996) for comprehensive reviews. Several trends are evident: a focus on the aptitudes/knowledge required for mathematical problem-solving; an emphasis on the social construction of mathematical knowledge in classrooms as well as in cultures; and a recognition of the importance of the beliefs which teachers have about the nature of mathematics and children's learning. Teachers' beliefs have been identified as crucial for the effective teaching of numeracy in the recent numeracy project conducted by King's College and sponsored by the Teacher Training Agency (Askew, et al, 1997).

6.1.1 Teaching Problem-Solving.

An example of the instructional consequences of some of the research can be seen in Schoenfeld's (1982, 1985, 1992) method for teaching mathematical problem solving to college students. Schoenfeld starts from the point that it is not sufficient to teach students heuristics alone, they must know when and how to use them appropriately. His method incorporates features of modelling, coaching and self-reflection. First, he models general problem solving heuristics - analyse the problem (draw a diagram, simplify the problem), explore the problem with the purpose of coming up with a solution path (relate the current problem to a similar one), verify the solution (check if the solution uses all the data, can another procedure be used). He also shows students how heuristics alone are not sufficient, the good mathematician has to make decisions about what strategy to use, what course of action to take, when to abandon a solution path (control strategies) - as well as the importance of productive beliefs about one's own mathematical ability ("I can solve this problem, it's not impossible"). Explicitly teaching these elements of expert practice yields a new understanding of mathematics for students.

Then, students practice problem solving in small groups where Schoenfeld acts as a consultant, soliciting solution techniques from the students, while continuing to model control strategies about how best to proceed. At this stage, he is handing over a portion of the problem-solving process to the students. Problem solving sessions are followed by a post-mortem analysis which enables student to reflect upon their strategies and to generalise their methods.

Comparisons of problem solving before and after Schoenfeld's intervention, as well as comparisons with students in other mathematics courses, show that the course had substantial impact. Students performed better on problems similar to the ones covered in the course as well as on those which were different (evidence of transfer).

Schoenfeld concludes that different layers of competence are necessary for successful mathematical problem solving - specific mathematical knowledge (facts, symbols, conventions, concepts, rules, etc), heuristic methods (analysing the problems, drawing a diagram, specifying sub-goals, etc), metacognitive skills (recognising the limits of cognition, self-regulation and monitoring, reflection and verbalisation), as well as affective components (confidence, attitudes and beliefs about mathematics and mathematics learning).

6.1.2 Metacognition and Powerful Learning Environments.

The importance of metacognition as a tool for developing thinking is further illustrated by the successful teaching experiments reported by De Corte (1990) on problem solving in a LOGO environment. Many previous studies had shown that, left to themselves, children do not construct

the powerful mathematical ideas latent in the LOGO environment (Hoyles & Noss, 1992) and the so-called cognitive benefits hypothesis - that working with LOGO would improve general problem-solving and planning skills - were not fully realised.

From his experiments, De Corte (1990) identified the characteristics of what he calls “powerful learning environments” - learning experiences which promote higher order thinking and transfer of learning to new contexts. His basic view is that powerful learning environments are “characterised by a good balance between discovery learning and personal exploration on the one hand, and systematic instruction and guidance on the other....” (p.12).

In order to achieve this within a LOGO context, he initially modelled the whole programming strategy, then students were allowed to practice component parts with feedback and hints (coaching and scaffolding); and, then, the children practised the whole strategy in small groups (exploration). During these phases they were encouraged to articulate as clearly as possible the procedures which they used - for comparison with other children’s procedures, with the expert explanation and for the purposes of generalisation (teaching for transfer). In these studies, the experimental groups outperformed the control groups on post-intervention problem solving measures.

Reflecting on the successful features of these experiments, De Corte explains how learners move from apprenticeship status to become more competent practitioners or experts.

- ☐ Learners need an explicit explanation of the cognitive components of the task (a “thinking” vocabulary);
- ☐ Learners need to observe an expert performing the task (modelling);
- ☐ Learners need to be given hints and feedback on their own performance (coaching);
- ☐ Learners need to be given direct support in the early stages of learning a task (scaffolding) and to move gradually towards self-regulation and autonomy (teacher fading);
- ☐ Learners need the opportunity to articulate their cognitive and metacognitive strategies and to make comparisons with other learners (reflection);
- ☐ Learners need to explore, identify and define new problems in a domain and be shown how strategies acquired in one domain can be used to solve problems in another domain (transfer).

The characteristics of powerful learning environments can be created in different instructional settings - whole class instruction as well as small group and individual teaching. Traditional didactic teaching is often criticised because qualities of higher order thinking remain invisible to the learner. Thus, knowledge remains inert. Powerful learning environments may be powerful precisely because they require the “experts” to externalise the mental processes they are using to comprehend, to categorise and to problem solve. Students are thus given access not only to the conceptual and factual knowledge of a subject domain, but also to the tacit and implicit knowledge of the expert performer.

6.1.3 Realistic and Authentic Contexts for Problem-Solving.

A common theme in contemporary descriptions of school mathematics is the failure to relate school mathematics to the everyday experience of pupils. When doing mathematical word problems (which are supposed to be realistic), pupils often suspend rather than embrace reality. For example, Greer (1993) asked 13/14 year old students in Northern Ireland to do the following word problem: “A shop sells 312 Christmas cards in December. About how many do you think it will sell altogether in January, February and March?” About one quarter of the students answered by multiplying 312 by

3, without further comment (there are similar findings in other countries). Section 8 describes an example of a well-evaluated multi-media based approach - the Jasper series - which attempts to overcome these difficulties and to engage students in more authentic and generative mathematical problem solving.

6.2 Science.

Innovations within science teaching have been strongly associated with work in the Piagetian tradition (e.g., CASE) or on more general constructivist principles, notably the work of Rosalind Driver in the UK (Driver, 1989). Inquiry-based models of science education predominate. Two aspects of pupils' thinking have caused concern: misconceptions about scientific concepts and the failure to engage in scientific-type thinking such as reasoning from evidence, cause/effect reasoning, understanding probabilistic statements, generating models and so on (Linn, et al, 1996).

There is a highly productive "cottage industry" documenting students' misconceptions, naive models, or alternative frameworks in mathematics, physics, chemistry, biology and economics (Carey, 1986). The general finding is that students have naive conceptions of natural, and artefactual, phenomena which are highly resistant to change even after extensive formal instruction. For example, college students continue to have misconceptions about respiration, photosynthesis, and genetic mechanisms even after some years' instruction. Learners are not aware that their conceptions are at odds with the formal conceptions within the discipline and neither are teachers. Techniques which try to foster conceptual change are creating cognitive conflict (which CASE promotes), inquiry teaching and Socratic dialogue. The Nuffield Primary Science Project which grew out of the SPACE project (Science Process and Concept Exploration Project), uses classroom materials and techniques which help children develop a more "scientific" understanding of topics such as electricity, light, sound, energy (Russell & Osborne, 1993).

Other techniques which have been shown to help the development of science reasoning are - training in the use of analogies, using multiple representations, and collaborative problem solving on extended investigations (Halpern, 1992). The characteristics of powerful learning environments outlined in the context of mathematics by De Corte (1990) have been found to be equally effective for enhancing science reasoning. For example, CASE makes extensive use of metacognitive strategies - talking about thinking, evaluating problem-solving methods, teaching for transfer, etc. Again, considerable innovatory effort has gone into the design of software modelling tools and microworlds, such as Stella, Boxer and ThinkerTools (see Section 8). It should be noted that ThinkerTools (the example which is extensively treated in Section 8) targets both conceptual understanding (force and motion) as well as scientific enquiry processes.

6.3 History.

Research on history appeared for the first time in a recent review on acquiring intellectual skills in the *Annual Review of Psychology* (Voss, et al, 1995) alongside mathematics and physics; it was the only school subject (other than science and mathematics) to be given separate treatment in Berliner and Calfee's (1996) *Handbook of Educational Psychology* (Wineburg, 1996).

In the UK there is a tradition of research in historical reasoning following on Peel's work (Peel, 1967) in a Piagetian framework. Evaluation of the Schools' Council History 13-16 Project, where students were introduced to the nature of historical evidence, the nature of reasoning from evidence and problems of reconstruction from partial and mixed evidence, showed that substantial numbers of the project students achieved higher levels of understanding about the nature of historical enquiry

compared to controls (Shemilt, 1980). In a critique of the project, Wineburg (1996) points out that, although “History 13-16 Project yielded the most in-depth look at adolescent reasoning in history to date” the methodology was limited in that it failed to provide answers to questions such as “How did sophisticated notions of historical understanding get translated into classroom activities, explanations by teachers, or homework assignments for students? What were the key way stations, the cognitive bridges, along the path to higher understanding?” (p. 429) In other words, the instructional implications beyond curricular materials were not well laid out.

Wineburg identifies a number of lines of research which might fill this instructional gap. As with other school subjects, it is increasingly evident that children bring prior knowledge and beliefs into history classrooms. For example, children’s story-telling ability can be as much a hindrance as a help: a 10 year old, asked about early US history, spun tales about Pilgrims who sailed in a boat called the Mayflower and added “that’s how we got - April showers bring May flowers”. Nevertheless, Vansledright and Brophy (1992) concluded that children’s ability to construct imaginative stories are precursors to the more professional activities of historians who construct stories about the past.

In an attempt to study how historical interpretation develops, several studies have compared professional historians vs. students as they read primary and secondary sources (e.g., Wineburg, 1991). History-specific heuristics for making sense of documents have been identified: corroboration (details of one document checked against another), contextualisation (setting events in strict temporal and spatial order), and sourcing (constructing hypotheses about the authors’ intent before proceeding to main document). How such findings can support instruction and teaching have yet to be evaluated.

6.4 Geography.

Although cognitive instruction-based research in geography is not extensive (beyond work on mapping skills and map understanding), an innovative curriculum development project called Thinking through Geography has been produced by David Leat and his colleagues from the University of Newcastle, in partnership with geography teachers (Leat, 1998).

This programme is embedded in the constructivist learning tradition, and identifies the following list of “big concepts” which are important for geography teaching and learning - cause and effect, classification, planning, decision-making, location, inequality, development, systems. Twenty-four exemplar lessons have been developed, trialled and scripted by geography teachers working within the Thinking through Geography framework. Each lesson targets one or more of the big concepts and is designed around a “strategy” - odd one out, living graphs, story-telling, fact or opinion, mysteries, etc. For example, a lesson designed around mysteries presents students with a challenge to answer a question related to industrial change in South Wales (Why is Dai Williams involved in the building of a new Japanese restaurant in Bridgend?). They receive clues in the form of written statements in an envelope from which they must sort relevant from irrelevant information, make links between different pieces of information, speculate to form hypotheses, check and refine, then present an explanation.

Lessons are designed around principles which are very similar to De Corte’s characteristics of powerful learning environments - identifying the thinking objectives (big concepts), developing a vocabulary for talking about thinking, using talk and groupwork for generating and evaluating alternative methods, consciously teaching for transfer. Lessons can be used at Key Stages 3 and 4 as well as for GCSE, while some have been used with A-level classes (the focus of the lesson can change depending on the age/ability of the group).

Although no formal evaluation of the materials in terms of learning outcomes is yet available, Leat (1998) notes that the Thinking through Geography lessons provide teachers with leverage for working with students at National Curriculum levels 7/8 and the group have been responsible for designing the National Curriculum optional tasks and tests on earthquakes using the mysteries' strategy. The lessons thus provide not only tools for enhancing learning but important diagnostic opportunities for discovering what students are not yet able to do.

7. Infusion Approaches to Developing Thinking

An alternative method to adopting either a structured programme for generic thinking skills or confining efforts to a single subject domain is to design an across-the-curriculum strategy. Although this approach does have a generic character, it seeks to embed thinking skills within curricular areas and to exploit naturally occurring opportunities for developing thinking within the ordinary curriculum. The approach is often called infusion and is associated in the US with Robert Swartz, Sandra Parks and David Perkins (Swartz & Parks, 1994) although there are other versions (e.g., SPELT - Strategies Program for Effective Learning/Thinking, Mulcahy et. al., 1993). To infuse means to "introduce into one thing a second thing which gives it extra life, vigour and a new significance" (Webster's Dictionary). In the context of thinking skills instruction, it means that the teaching of curricular content is infused with the explicit instruction of thinking skills. Several approaches can be characterised as infusion. For example, Fisher's work in the UK on Philosophy for Children illustrates how it can be used across the curriculum (Fisher, 1998); Gardner's multiple intelligences require an across-the-curriculum approach (Gardner, 1993); and in the UK the work on accelerated learning clearly demands a high level of infusion (Smith, 1996).

Infusion is the teaching methodology adopted for the ACTS project (Activating Children's Thinking Skills) funded by Northern Ireland Council for Curriculum, Examinations and Assessment (McGuinness, et al, 1997) and the methodology will be described in that context.

7.1 ACTS - An Example of Infusion Methodology.

The purpose of ACTS was to promote the development of thinking skills in ordinary classrooms in Northern Ireland at Key Stage 2. More specifically, the second phase of the project worked in partnership with a small group of Key Stage 2 teachers to develop a Handbook for promoting thinking skills across the curriculum (similar to the strategy adopted by Leat for Thinking through Geography).

The benefits of infusion were seen as: thinking skills are matched directly with topics in the curriculum; content instruction is invigorated thus leading to deeper understanding; classroom time is used optimally; teaching for thoughtfulness is directly supported across the curriculum; and transfer of learning can be more easily promoted and reinforced at other stages. Moreover, the approach seemed particularly appropriate for Key Stage 2 where the teacher is in charge of the whole curriculum for a classroom. (The method has since been successfully adopted by another group of teachers working in subject areas at Key Stage 3).

A version of Swartz and Parks' (1994) taxonomy of thinking skills was adopted as the cognitive framework (see Section 3.3) and initial analytical work was completed which identified contexts within the Key Stage 2 Northern Ireland Curriculum programmes of study for developing different kinds of thinking. This attempt at mapping thinking skills across the curriculum was merely illustrative and simply served to show teachers that the curriculum already provided contexts for the work.

ACTS used thinking diagrams (or graphic organisers as they are called in the US) as an aid for making the steps in a thinking process explicit. For example, a thinking diagram for decision-making invites the students to first consider and write down all the options related to the decision (suspending judgement at this stage), then each option is taken in turn, pros and cons are listed and then weighed up, before an action is decided upon. Both students' own decisions and the decision-making of literary or historical figures can be evaluated in this way. Diagrams are useful in this context because they make the steps in the thinking more explicit for both teachers and pupils, they slow down the thinking process giving students time to grasp what is involved, and an external record of the thinking steps is kept, permitting students and teachers to look back and reflect on earlier stages and the whole process.

ACTS methodology also adopted the teaching strategies which were identified in previous studies as characteristic of successful learning environments and subscribed to the development of a thinking classroom. For example, the methodology put thinking as an explicit learning objective; developed a thinking vocabulary through talking about thinking; encouraged teachers to give students time to think; pointed to the importance of discussion and reflection on thinking strategies as a way to increase competence; encouraged the development of teachers' questioning techniques; and deliberately built in teaching for transfer (which proved to be the most difficult).

Seventeen teachers participated in the project. They attended 6 training days, distributed over 6 months, and scripted some of their own lessons for the handbook. After an initial 2-day induction to the methodology (which included modelling infusion lessons), each teacher experimented in their own classrooms, recorded their results and returned the following month to discuss achievements and difficulties and to exchange good practice. On these review days, additional thinking skills were introduced, teachers were given feedback, and more advanced questioning and teaching for transfer skills were discussed. By the end of 8 months, over 100 hundred infusion lessons had been taught to some 300 pupils. The Handbook was completed (and is now in press) and includes 24 lessons illustrating how infusion lessons can be designed and taught over nine areas of the NI Curriculum and demonstrating 10 different thinking strategies (e.g., compare and contrast, classification, sequencing, prediction, problem-solving, decision-making).

The primary purpose of the project was to develop the methodology, produce the Handbook and to gauge initial reactions of teachers and students. Children's learning gains were not monitored at this stage. However, teachers' evaluations of the impact of ACTS on the pupils and themselves were very positive. For example, all teachers identified benefits for children's thinking. They referred to children's greater reasoning powers and increased creativity, their ability to clarify their thinking processes, to see links between different subject areas, and to be more structured and focused in their approach to thinking. With regard to themselves, teachers noted that the approach has sharpened their own concept of thinking skills; enabled them to review their schemes of work and encouraged more effective planning. Some teachers emphasised the across-the-curriculum effects and noted changes in the nature of classroom interaction, that there was an increased level of interaction, that group work was more structured, there was more open discussion and sharing of ideas and that children expected to be "pushed" more.

Time was identified as the main constraint. Much of the problem was attributed to relative inexperience with the approach which required more planning and pre-class preparation. The requirement to design lessons which matched topics with appropriate thinking skills was not easy. Teachers also commented that thinking skills lessons often went on for longer than initially planned, and that they had to be careful to allow time for thinking and not jump in with ready-made answers. Children's main difficulty was the absence of an adequate language for talking about thinking.

All teachers commented positively on how useful the ACTS methodology had been for their continuing professional development. All were very experienced teachers yet they commented that “it was a refreshing focus on the nature of learning”, “it made me rethink the way that we, as teachers, teach”, “I was delighted to find something new”, “it encouraged self-evaluation of my own teaching style”.

As is clear from the above, teachers were very satisfied overall with the ACTS methodology. They quickly adapted the method to their own teaching style and needs (one of the strengths of the approach). Even within a short time they could see benefits for the children’s thinking, for their own teaching, and for the classroom in general.

Notwithstanding these positive comments, the limitations of this type of evaluation should not be forgotten. The data are teachers’ impressions and opinions and are not related to learning outcomes in the classrooms. Comparisons were not made with alternative methodologies and the evaluations were collected immediately at the end of the training days (when spirits were high). However, 11 of the ACTS teachers met for discussion one year later and evaluation remained positive though many expressed the wish for continuing support.

From a training point of view, one of the primary difficulties with the infusion methodology was enabling teachers to sharpen their understanding of thinking skills, to keep the twin perspectives of thinking skills and content objectives simultaneously in view, and to develop and sustain the metacognitive perspective.

7.2 Thinking Classrooms.

In the context of developing the infusion methodology, it became increasingly clear that developing children’s thinking goes far beyond an understanding of how children learn. Issues to do with curricular design, availability of curricular materials, the nature of pedagogy, teachers’ beliefs about learning and teaching as well as their professional development came to the fore. Perhaps it is not surprising that the emphasis has shifted from thinking-as-a-skill to concepts such as thinking curriculum, thinking classrooms and schools for thought.

Several schools in the UK have embraced the whole-school concept by adopting a range of structured thinking skills programmes - Instrumental Enrichment, Somerset Thinking Skills and CASE - for different purposes and age/ability levels. More radical examples can be seen in some US school projects which have transformed classrooms from a cognitive intervention research perspective. One example is led by a team of researchers and teachers from the University of California at Berkeley in an inner city primary school (Brown et al, 1993; Brown & Campione, 1994); another example, CSILE - more dependent on information technologies for collaborative learning, is described in the next section.

7.3 Guided Discovery in a Community of Learners.

This project draws on a long tradition of research into metacognition, self-regulated and strategic learning conducted by Ann Brown and her colleagues since the 1970s. Currently it draws on ideas about reciprocal teaching and on the jigsaw method for co-operative learning.

Reciprocal teaching was developed in the context of teaching reading comprehension strategies to low achieving 11 year olds. Palinscar and Brown (1984) reported a series of experiments describing and evaluating the method. Reciprocal teaching takes place in a co-operative learning group and

consists of guided practice in using the specific strategies for text comprehension of questioning, clarifying, summarising and prediction. The teacher initially leads the group, actively models the desired comprehension strategies and makes them overt, explicit and concrete; then (after some practice) each student takes a turn at modelling the strategies and leading the discussion. Gradually, the responsibility for the comprehension activities is transferred to the group and the teachers' role fades into the background. In reciprocal teaching, the teacher acts as a mediator or guide in two ways - as a model of expert performance as well as a scaffold or social support for the underdeveloped attempts of the novice (the method is very similar to De Corte's analysis of powerful learning environments). Brown (1987) reported that reciprocal teaching produces better results than either direct instruction in the desired strategies or even teacher modelling alone.

What was initially developed in the context of reading comprehension now provides a more general model for class organisation and instruction - guided discovery, coaching, peer tutoring, self-regulated learning, distributed expertise (Brown et al, 1993; Brown & Campione, 1994). Students learn through working in research groups. For example, in a biology cycle on changing populations, students are assigned responsibility for one of five or so subtopics (extinct, endangered, artificial, assisted and urbanised populations). The research groups prepare teaching materials (from computers, multi-media and written materials) and regroup into reciprocal teaching seminars where each is an "expert" on the subtopic. The burden of teaching from expertise is real because all children in the group must teach their subtopic and prepare questions for a test of mastery as well as learn about the other subtopics themselves.

Clearly, managing a curriculum in such a classroom requires very specific pedagogical skills and places a high demand on teacher competence as "official guide". Brown and Campione's monitoring of the classroom processes provide fascinating reading on the classroom rituals which are required, how subcultures of expertise develop among students and are acknowledged by others, and how misconceptions and classroom discourse are managed. Compared to controls, evaluations show that children taught in this way show learning gains across a variety of measures: they perform better on standard biological knowledge quizzes, on transfer tasks requiring "what if" thinking, on reading comprehension scores and show evidence of better argumentative skills in discussion and dialogues.

Extensions of the idea of a community of learners includes using older children as discussion leaders, inviting guest speakers on specialist topics, extending the community beyond the classroom walls through email and databases for browsing.

8. The Role of ICT in Developing Thinking

Since the arrival of computer technology and computer programming into classrooms and teaching, there is a widespread belief that interactions with computers, or more specifically - learning to programme - can provide opportunities for enhancing thinking which had been attributed in previous generations to learning mathematics and the classics. Not only has the specific hypothesis been put to the test in recent years (e.g., LOGO), but there is now a substantial and growing research literature on the impact of computer-mediated learning in classrooms and beyond. The term "computer-mediated" learning encompasses a range of technologies - computers (stand-alone and networked), multimedia, hypermedia and telecommunications (Internet, World Wide Web), hence the shift from using the acronym IT for information technology to ICT for information and communications technology. The specific focus for this review is the impact of these technologies on the development of thinking skills.

There are substantial reviews and edited volumes which comprehensively survey the current state of research and practice. For example, the Cognition and Technology Group at Vanderbilt (CTGV,

1996) developed a framework for understanding technology and education research and reviewed over 500 studies and commentaries (largely US). A more international perspective is provided in the edited volume by Vosniadou and De Corte et al (1996) which covers examples of research from Britain, Europe and the US. The Vanderbilt group make the point strongly that the way in which technology-based applications are used and assessed in classrooms is mediated by advances in learning theory. As theories have shifted from transmission models to constructivism to social constructivism, so too have the images of computers in classrooms. For example, the image of the isolated and autonomous computer learner who passively receives information has been largely replaced by the opportunities for interaction, interdependence and collaboration which the new technologies have afforded.

In early examples of computer-assisted instruction, the pedagogy was largely drill and practice of skills such as arithmetic facts, word recognition and spelling. The computer provided opportunities for rehearsal, some degree of self-pacing and feedback. The learning gains which were made with this type of instruction were attributed largely to time spent on-task and motivational effects (CTGV, 1996, pp 811-814 for a fuller critique). Recent innovations are more consistent with a thinking skills approach.

8.1 Exploratory Environments.

In the more recent software innovations, there is a shift towards computer-based instruction to enhance students' reasoning, to deepen their understanding of specific concepts and/or to diagnose misconceptions rather than solely memorising facts. Many of these developments are related to teaching science and mathematics, mainly because students' failures in understanding, "naïve" theories and misconceptions have long been documented in these areas (e.g., Carey, 1986). Such software presents an exploratory environment or microworld which allow students to direct their own learning through discovery and guided discovery processes. The environments are designed to permit students to construct their own knowledge in the context of complex problems and situations. Software applications are available such as Geometry Sketchpad which is a tool to construct and investigate geometric relationships, a general application tool for exploring systems thinking (STELLA), economics microworld (Smithtown), physics (BOXER and ThinkerTools), chemistry (4MChem), see CTGV (1996) and Vosniadou et al (1996) for a fuller review.

A particularly well developed research, implementation and evaluation programme is associated with the microworld, ThinkerTools, for teaching Newtonian laws of force and motion as well as the scientific processes of inquiry (White & Frederiksen, 1998). ThinkerTools will be used to illustrate the scope of computer-mediated learning within a thinking skills framework. The design, implementation and evaluation of ThinkerTools is embedded in modern cognitive science theory and research. It draws on inquiry-based models of science education and deliberately supports (or scaffolds) students and teachers in the early stages of the inquiry process. Reflection assessment is designed into the software in order to maximise the metacognitive influences on learning enhancement. This term refers to a set of prompts which require students to check the extent to which they are "being inventive", "being systematic", "making connections", "reasoning carefully" and so on.

The software enables students to interact with Newtonian models of force and motion and lets them create their own models and experiments, by using drawing tools and running simulations. For example, students can experiment in ways which would not be possible in the real world by varying the amount of friction or gravity or even turning them off! The software includes measurement tools which allow accurate observations, graphical and tabular representations, as well as analytic tools which allow simulations to slow down or to pause. The pedagogy requires the student to go

through five steps of the inquiry cycle - formulating a question, making a prediction, experimenting, modelling and application. The cycle is repeated for each of the seven modules in the ThinkerTools curriculum which begin with a simplified world of one-dimensional motion. The ThinkerTools software is thus used to test predictions and to model in the context of other teacher-led activities and collaborative work with students.

The inquiry-based curriculum was trialled with a small group of teachers in 12 classes of 11, 12 and 13 year olds in two urban schools in California. Compared to a control group, the ThinkerTools inquiry group not only showed better understanding of the science concepts, they were more able to apply their knowledge to new situations (thus showing that they had gained mastery over the inquiry process) and they had more positive attitudes towards science in general (e.g., less likely to view scientific theories as immutable, less likely to attribute scientific aptitude to inborn ability). These effects were particularly evident in the lower achieving pupils.

In common with other innovatory software, ThinkerTools has a number of features which contribute to the development of thinking. It helps to make the thinking process more visible by deliberately designing in the inquiry process and requiring some metacognitive reflection and assessment. It enables students to generate "what if" scenarios and to test predictions quickly and get feedback. It permits multiple representations of data by allowing students to shift between graphs, tables and formulae. Such dynamic interactive simulations can make it easier for students to change from their intuitive ways of reasoning about the world to the more formal abstract theorising which scientists use.

8.2 Multimedia Technology.

Video and multi-media technology are also used to create exploratory environments. One example is in the area of mathematical problem solving. Mathematics educators have long been concerned about students' failure to transfer their mathematical knowledge to real world problems and situations - the problem of inert knowledge. The Computers and Technology Group at Vanderbilt have addressed this problem through "anchored instruction" - anchored in realistic problem scenarios which are captured in interactive video disks (Van Haneghan, et al, 1992; CTGV, 1994; Vye, et al, 1997).

The Jasper series of videodisks describes the adventures of a character called Jasper as material for complex and authentic problem solving. For example, in the first of the series Jasper takes a river trip and buys a boat whose running lights are not working. He must decide if he can get the boat to his home dock before sunset. Jasper has to answer two questions - does he have enough time to return before sunset and does he have enough fuel? What will Jasper do? The students have to solve the problems Jasper had to solve to make his decision. As they work through the problems, students discover that this apparently simple decision involves a great deal of thinking. They have to seek more information which is embedded in the design of the disk (e.g., find a map to calculate distances, estimate the time of sunset) and to engage in prolonged and complex problem solving of more than 15 interrelated steps or subproblems. Jasper's adventures can be solved as a whole class, in small groups, or individually. Even college students find Jasper's adventures challenging.

Evaluations of the impact of working with Jasper videodisks indicate that, compared to control groups, Jasper students adopt more planful approaches to solving problems, they set higher order goals and work through sub-goals more systematically. These learning benefits transfer to problems with a similar structure and to "what if" variations (what if everything about Jasper's trip remained constant except that his boat travelled at a speed of 9 rather than 8 miles per hour?). Working in

pairs on the problems and discussing alternative solution paths were particularly beneficial and increased solution coherence (Vye et al., 1997).

The design features of the Jasper series provide a particularly rich “anchor” for problem-solving; the stories are realistic, the problems are complex (multi-step, multiple solutions possible), students must set goals, generate and solve subproblems, and data are embedded in the videodisk which must be sifted and sorted. Compared to text-based scenarios, the advantages of the multimedia presentation are that they allow students to form rich images or mental models of the problem situation which can be particularly helpful for those with reading difficulties; they give practice in developing pattern recognition skills, and they provide random access capabilities which allow teachers to instantly access information for discussion as well as to prompt alternative perspectives.

The accessibility of complex data in multiple modalities through CD-ROMS offers enormous scope for open-ended investigatory and interpretational work in the social and human sciences. The multimodality of such resources echoes the different modes of intelligence proposed by Gardner (1991, 1993).

8.3 Collaborative Learning and Technology.

Increasingly, the importance of talk, discussion and students’ collaboration is recognised in the context of computer-mediated learning. The benefits to be gained and the reasons why such learning gains might accrue are similar to those described earlier in the context of computer-free thinking skills initiatives. Talk enables students to articulate their thinking and makes it more visible; students and teachers discussing and exchanging views can reveal misconceptions and conflict between ideas thus paving the way for conceptual change; and peer collaboration can help students construct knowledge, generate and refine hypotheses and solutions. But Crooks (1994, 1995, 1998) points out that the new technologies provide a unique opportunity for peer collaboration to serve cognitive development. He advances the general argument that “interaction with some set of material objects furnishes a strong referential anchor for the business of developing shared knowledge” (Crooks, 1995, p. 545). Computers can resource children’s collaboration and talk because they externalise problems, allow for concrete manipulation and experimentation where a child’s interaction with a problem can be witnessed by peers who can then enter into the joint activity. Technology, therefore, acts as a powerful vehicle for the construction of shared knowledge and mutual understanding - a far cry from the image of an autonomous learner.

8.4 Technology and Thinking Classrooms.

The power of technology to build shared knowledge can be seen in several innovative studies and projects which aim to create and support individual and collaborative learning in classrooms within schools as well as creating learning communities through networked classrooms. The projects are variously called communities for learning, schools for thought, smart schools, technology-intensive learning environments (TILES).

One well developed example is CSILE which stands for Computer Supported Intentional Learning Environments (Scardamalia, et al, 1994). CSILE consists of a number of networked computers in a classroom (about 8) where a communal database is maintained. The database consists of text and graphical notes, all produced by students and accessible through database search procedures. Teachers work CSILE activities into the curriculum in many different ways and it has been used in history, social studies, science, literature and geography. Information brought into CSILE comes from any source - books, experiments, observations, interviews, other electronic media. The main

strategy is that students are presented with a question or a topic for study, they have to find information, and record it via notes in the database. Other students can then comment on the notes and add new notes, thus creating a dialogue.

For example, the authors describe an example of 11-12 year olds in a biology class who were researching the characteristics of different animals. One child chose to study sponges and posed questions about how they might reproduce. The note entered into the database reported three ways of reproducing. The news about sponges' reproduction spread by other children browsing the database which led in turn to questions as to why sponges should be so favoured, what were the advantages of three ways or reproducing compared to one, etc. The dialogue followed a sophisticated line of reasoning. Other examples show how working with a communal database provides opportunities for integrating across curricular areas. In a project on medieval history, questions about aspects of medieval life led to an examination about castle defence systems which in turn led to two children creating a working model of a portcullis and describing how it worked in a CSILE note. The note was widely read and several alternative models began appearing in the database.

Many of the learning objectives in the CSILE classroom are consistent with more traditional project work and extended investigations. The added value of the communal database is that all children are required to participate, the questions/answers can be tracked in a systematic way, and students' dialogue is advanced without the intervention of the teacher. Of course the explosion of information creates its own problems and designers of CSILE have seen the need to add additional "tools" to manage the database such as the "group note" (as an aid to dialogue for students working on the same question) and the "summary note" to help students synthesise information. Teachers also need to be able to correct misconceptions.

Evaluations of learning outcomes in CSILE classrooms are so far encouraging. Compared to control groups, CSILE students performed better on standard measures of language, showed greater depth of explanation in essay type writing, showed higher levels of competence in using diagrams (an unanticipated effect), showed greater ability to extract complex information from text, and had more mastery-oriented beliefs about learning.

There are now several projects (including CSILE) that began as within-class learning communities and are taking advantage of telecommunications opportunities to network with other classrooms, to access national "educational" databases, and to email directly to subject matter experts. It should be emphasised that, beyond the small-scale research studies cited above, this is all largely uncharted territory in terms of evaluation (Bruce et al., 1993). Indeed, reviews of the area point out that questions are raised about how to organise and search the knowledge in this kind of environment, how to support users' understanding and to update. As CTGV (1996) comment "When students are free to put in their thoughts and to co-construct knowledge, misconceptions often appear in the database. What happens to such misconceptions is an important issue for research" (p.823). It is clearly important not only for research but for learning as well!

8.5 Comment

Although the examples of computer-mediated learning cited in this section all point to the positive effects which ICT can have on the enhancement of thinking and learning, several cautionary notes need to be struck.

- ☐ Computers alone do not mediate thinking and learning. Good software design and an appropriate pedagogy are crucial. Delivering information via computers is not sufficient for learning; knowledge needs to be designed.

- ❑ Many of the evaluations are from small scale studies which have been highly supported by research teams and/or involved teachers which were well attuned to the required pedagogy. Transporting the effects to ordinary classrooms may require a new set of considerations (see Section 9 for a fuller discussion).
- ❑ If students are to learn in a technology intensive learning environment, then infrastructure is important - not just hardware and software, but classroom furniture, phone-lines, power points, technical support and maintenance, etc.

9. Teacher Development and Support

Although the primary focus of the review is on pupils' thinking and learning, a theme emerges from evaluations of successful cognitive interventions which is strongly related to teacher development and more general issues about curriculum/pedagogical innovation and change. (A full treatment is beyond the scope of this review.)

Many writers comment on the importance of teacher preparation and teacher support for successful implementation of thinking skills approaches. For example, Blagg (1991), in his well conducted evaluation of the impact of Feuerstein's Instrumental Enrichment in four schools in Somerset, attributed its partial failure to the "non-optimal conditions of training for teachers". The success of CASE is due in no small measure to the well developed teacher training and support which accompanies that programme. Indeed, subsequent work on CASE has concentrated precisely on the factors which influence the uptake of a large scale curricular innovation (Adey, 1997). Some teachers' responses to ACTS indicated the degree of change in practice and thinking which was needed to successfully implement the methodology.

Teaching thinking (by whatever approach) demands that teachers, pupils and technologies interact with one another in certain ways. Classrooms are likely to be characterised by talk and discussion, by questions and questioning, and require smooth transitions between activities. Such classrooms need to be managed and orchestrated yet remain clearly focussed on learning objectives. Some of this may not sit comfortably with all teachers (or all pupils) and will challenge existing beliefs and practices.

There is a substantial research base on teachers' cognitions and beliefs and how they are related to classroom practice (see Calderhead, 1996 for a full review). These cognitions have been characterised in terms of knowledge (subject knowledge, pedagogical content knowledge, craft knowledge) and beliefs/image (about content, the nature of teaching and the nature of children's learning). Just like pupils, teachers bring conceptions to the classroom about their discipline, images about themselves as teachers and about how children learn. These conceptions are largely implicit but increasingly are acknowledged in teacher education as providing important levers for professional development both with novices and more experienced teachers.

Leat (in press), in a penetrating analysis called "rolling the stone uphill", pointed to a number of reasons why thinking skills approaches may not deliver on their initial promise. From interviews with a substantial number of post-primary teachers who have used or at least tried one of the existing programmes, he pessimistically concludes that "in few of these schools would the innovation survive the departure of the key members of staff, whose number rarely exceeds three". He points to a number of forces in teachers, pupils and schools which act as barriers to innovation and explains how these are likely to impact on the implementation of thinking skills approaches. For example, teachers can discourage one another with comments like "our pupils couldn't do that" or "we tried that in 1984" while pupils, who may be accustomed to a more passive style of

learning, can 'passively' resist getting involved. Teachers' existing craft knowledge can be threatened as they struggle to implement a more constructivist learning environment through co-operative groups and so on. Additionally, teachers do not readily construe their disciplinary knowledge in terms of pupils' reasoning patterns and even experienced teachers can be reduced to novice status. Leat concludes that, if the drag effects of these forces are to be overcome, in-service education and teacher support need to include consortia or networks of teachers, peer coaching and a thorough exploration of evidence in relation to children's learning.

While Leat's analysis pinpoints primarily the barriers for individual teachers, other researchers who have been involved in small-scale teaching experiments and/or so called hothouse schools have identified the problems of scaling-up and moving into ordinary classrooms. They have discovered that their programmes motivate students only when they are special events and not when they are part of everyday practices; that they work well in small teacher/researcher-to-student ratios but not in classes with one teacher and 25+ students; that they require levels of professional development that were unanticipated, do not always fit well into typical school timetables and produce learning gains that are not assessed or valued in high stakes examinations (CTGV, 1996).

From this analysis it is clear that demonstrating the efficacy of thinking skills approaches in optimal conditions is not sufficient. Transplanting the effects into ordinary classrooms needs careful monitoring and support.

10. Conclusions

10.1 Current attempts to teach thinking are part of a more general thrust in educational reform which emphasises the quality of thinking processes and thinking skills as a means for raising educational standards and in preparing children and young people for life-long learning. **Raising standards** requires that attention is directed not only on **what is to be learned** but on **how children learn** and **how teachers intervene** to achieve this.

10.2 Sufficient research and practice has accumulated to identify core concepts in a **framework for developing thinking skills**. Although theoretical emphases can differ, the general framework now includes; the need to make thinking skills explicit in a curriculum; teaching through a form of coaching; taking a metacognitive perspective; collaborative learning (including computer-mediated learning); creating dispositions and habits of good thinking; generalising the framework to thinking curricula, thinking classrooms and thinking schools.

10.3 Considerable **evaluation** work remains to be done in order to link the critical features of the framework to learning outcomes in different contexts.

10.4 For comparative purposes in this review, **three models for delivering thinking skills** were identified. Interventions can be directed towards general thinking skills (e.g., Instrumental Enrichment), they can target subject-specific learning such as science (CASE), mathematics (CAME) and geography (Thinking through Geography), or they can be infused across the curriculum (ACTS). Whatever approach is adopted, the methodology must maximise **transfer**, that is, adopt teaching strategies (e.g., bridging, deliberate teaching for transfer) which ensure that the learning transfers beyond the context in which it occurs.

10.5 A successful **prototype for developing curricular materials** was identified: strong theoretical underpinning, well-designed and contextualised materials, explicit pedagogy, teaching support and programme evaluation. Curricular materials alone are not sufficient. These requirements can be applied equally to computer mediated curricular materials.

10.6 Several large-scale **classroom evaluation studies** have successfully linked teaching thinking methodologies with **learning outcomes** both in the short term and the longer term although not all interventions are equally successful. CASE, for example, succeeded in raising pupils' grades in GCSE public examinations (on average 1 grade) two to three years after the programme had been completed. Philosophy for Children has an impact across a wide variety of cognitive and social development measures. On the other hand, Blagg's evaluation of Instrumental Enrichment showed no direct learning gains but did impact positively on attitudes and behaviour.

10.7 Research evidence from **smaller scale teaching experiments** show that, for example, mathematical problem solving, science reasoning, reading comprehension, argumentative skills and dialogue can be enhanced through cognitive coaching strategies.

10.8 Despite differences in emphases among the various approaches, the common features of **successful cognitive methodologies** can be characterised as powerful or high quality learning environments. These are: identifying high quality thinking as a classroom priority; developing a vocabulary for talking about thinking; making thought processes explicit through exploration, discussion, reflection and sharing; teacher modelling of thought processes followed by hints and feedback to students on their performance (coaching and scaffolding); co-operative and collaborative learning permitting students to become self-regulated; deliberate teaching for transfer.

10.9 **Information and communication technologies** can be linked to the **thinking skills** framework in several ways. Interactive exploratory environments help make thinking more explicit, they enable pupils to hypothesise and experiment with immediate feedback and facilitate discussion and reflection with peers. Multi-media technology permits students to form rich images of problem situations in multiple modalities and prompts alternative perspectives. Local and networked communication (databases, email, WWW, National Grids) provide unique opportunities for collaborative learning. Although several well-researched examples which link computer mediated learning and thinking skills have been reported in the literature, additional evaluation linked with learning outcomes is needed, particularly for whole class (rather than individual) learning.

10.10 Making **thinking skills** explicit **within subject domains** has led to a deeper understanding of how thinking works in different subject areas pointing to the importance of depth of subject knowledge for both teachers and learners. Domain specific interventions within a thinking skills framework are particularly evident in the sciences and mathematics and, increasingly so, in history and geography. There is scope for considerably more systematic work in this area in order to link together existing research which is not so readily identified as "thinking skills" (e.g., creative arts, moral and social development) as well as to examine commonalities and differences between thinking skills as they are exercised in disciplinary contexts (e.g., the extent to which problem solving refers to the same mental process in mathematics as it does in science, the extent to which evidence-based reasoning is the same or different in science as in history).

10.11 Subject specific and infusion approaches present opportunities for **embedding thinking skills within and across the curriculum** and there are clear arguments in favour of doing this. Nevertheless, the challenges of adopting an infusion approach should not be underestimated, especially the risk that the thinking skills framework may become trivialised or "watered down". Evidence suggests (e.g., ACTS) that teachers experience difficulty keeping the twin perspectives of thinking skills and topic content simultaneously in view (together with the other aspects of classroom management and practice).

10.12 Much of the research on the efficacy of teaching thinking was conducted under optimal learning conditions and **problems with scaling up** and transferring the effects to everyday classrooms have been identified. In particular, the most successful interventions have been

characterised by explicit models of **teacher development and teacher support** (e.g., CASE, Thinking through Geography, ACTS).

10.13 The shift from **thinking skills to thinking classrooms** can be clearly seen through within-the-curriculum and across-the-curriculum approaches. Currently, there are only a few well-documented examples in the literature where thinking classrooms have been established, managed and evaluated within a research-led social constructivist framework. In these examples, information and communication technologies play a significant role. The idea of thinking classrooms, and schools as thinking communities, requires further articulation and interpretation, and the research base is in its infancy. Nevertheless, the idea of a thinking classroom brings the thinking skills analysis the full circle and links with emerging research on school ethos. What began as a highly individualistic - and some might say reductionist - analysis about the nature of thinking has found its way into the heart of discussions about the aims and purposes of learning and teaching.

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