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Teaching thinking

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Introduction

In the history of education there has never been so much interest in the teaching of thinking and problem solving as there is today. This interest is not new. There have always been educators who see the cultivation of the thinking ability of students as important objectives. In particular, mathematics (Nelissen; Van Luit; Verschaffel, this volume) and science courses (Adey; Csapó, this volume) have traditionally paid much attention to the teaching of problem solving in these specific domains. Dewey (1910/1991) was among the first to focus attention on the enhancement of thinking ability. Largely due to his influence, considerable energy was and is today devoted to the development of thinking.

Other important impulses in the past came from the Würzburger School (Külpe, Selz) and Gestalt psychology (Wertheimer, Duncker, Maier). In 1930 Kohnstamm wrote about Selz: "Originally he was only interested in discovering the problem solving methods for himself but in the course of time he started to inquire into the learnability of these methods" (p. 28). Selz (1935) conducted research into inductive reasoning amongst other topics. He assumed, as a starting point, that the thinking process consists of applying means of ordering, thinking schemes, which determine

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the course of the thinking process by their character of anticipating the solution. According to Selz, who assumed this to hold, it must be possible to raise the functioning of human intelligence to a higher level by providing the necessary thinking tools. He thought it must be possible to learn problem solving methods. In his experiments 'Versuche zur Hebung des Intelligenzniveaus' he worked according to the principle of the 'kleinstmögliche Hilfe', now known as the heuristic solution method.

According to Resnick (1987), today's need for teaching thinking is created by the rapid changes taking place in society. Knowledge and information are becoming ever more complex and soon may become dated. Children, therefore, have to be equipped with the skills of evaluating choices, and identifying and solving problems using logical reasoning. Thus, it is not enough to have a considerable amount of knowledge at one's disposal (declarative knowledge), but the questions of how to acquire knowledge, and how to apply this knowledge are also important (procedural knowledge). It is also claimed (e.g., Halpern, 1992; Resnick & Klopfer, 1989) that having only a limited command of thinking skills is one of the reasons for falling behind in school. This can be seen in mathematics, reading, and writing, where all sorts of activities come to the fore in which thinking skills play a central role. Examples are the ability to describe and to compare objects, to group objects, to associate one thing with another, to form concepts, and to generalize. Thus, mental processes which are normally associated with the concept of 'thinking' are not limited to some kind of 'higher order' of mental development. On the contrary, thinking processes play a role in a broad range of learning activities in school. This means that these thinking processes should form an integral part of the school curriculum.

This issue of adjustment or innovation of educational aims is an actual topic of study in education. However, the realization of these aims is not simple. The reason is that too many questions are still not, or insufficiently, answered. For instance: What is thinking? Are we able to teach children to think? Which thinking skills can be assessed? Thinking is partly the result of an autonomous process in the development of children. The question that arises from this fact is: What is left to be taught? Which part of the behavioural changes in children can be attributed to spontaneous 'development' and which part to 'learning'? Generally, in education no attention is paid to the explicit stimulation of thinking skills and there is no such thing as a school subject called 'thinking' or 'stimulation of thinking' (Presseisen, 1987). Usually teachers assume that thinking skills develop spontaneously as a by-product of the teaching of regular school subjects. Nowadays, the current view is that this assumption is only partly true (Resnick, 1987). Deprived children, and children with learning difficulties, can benefit from explicit stimulation of thinking, and children who do not belong to such groups can also learn to think more efficiently.

In the United States there have been many proposals to explicitly stimulate thinking and a variety of general and specific programmes have been developed and

described (e.g., Baron & Sternberg, 1987; Costa, 1991a; Idol & Jones, 1991; Jones & Idol, 1990). Variations of general and specific programmes have been designed and collected (e.g., Chipman, Segal, & Glaser, 1985; Costa, 1991b; Nickerson, Perkins, & Smith, 1985). In Europe much attention is also paid to this subject (e.g., Adey & Shayer, 1994; Demetriou, Shayer, & Efklides, 1992). Coles and Robinson (1991), Fisher (1990), McGuinness and Nisbet (1991) and Nisbet and Davies (1990) have published reviews, mainly of British programmes. Hamers and Overtoom (1997) have published an inventory of programmes as well, and extended the field of research by including a greater part of Europe in their inventory.

These programmes and methods appear to be of diverging theoretical orientation: Vygotskyan, neo-Piagetian and along the direction of information processing. Furthermore, the range of themes is wide: programmes for training general reasoning skills, critical thinking, problem solving, memory, comprehensive reading, composition, arithmetic, and secondary school subjects such as science. Terms or concepts are used in a variety of ways, sometimes interchangeably, sometimes synonymously: e.g., thinking, problem solving, reasoning, decision making. Other terms such as analysing, imaging, inferring, inventing, and reflecting are used with greater specificity. It is not our aim to precisely define any of these terms precisely here. In the chapters of this volume, thinking (the most general term) is broadly conceived and it includes much of what is discussed under the other, more specific terms. The chapters in this volume will show that not everyone focuses on the same aspects of the multifaceted activities of thinking.

In this chapter, we will describe some theoretical and practical trends in the research on the stimulation of thinking and pay attention to the impact of these theories on educational research and practice, as demonstrated in several chapters in this volume. In addition, we will describe some of the main issues in the research on the development of thinking and teaching thinking. Finally, we will draw conclusions and give an introduction to the following chapters.

Theories on thinking

Thinking is a broad and relatively abstract concept that is discussed and defined in many variations. Several disciplines consider it as a central concept, and a number of research paradigms examine it using a broad range of approaches and applying a variety of research methods. The list of adjectives used in conjunction with thinking (e.g., from convergent thinking to critical thinking) is virtually endless, and - from the works of Greek philosophers to today's psychologists' publications - many attempts have been made to classify types of thinking or at least to enumerate the relevant forms of thinking (e.g., Chipman et al., 1985; Segal, Chipman, & Glaser, 1985) or to just create a working taxonomy of thinking skills (e.g., Ennis, 1987). However, there are two main fields of research into human thinking that have especially important implications concerning the subject of the present book: (a) the

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perspective of developmental psychology that identifies types and forms of thinking and describes how the states of these forms are changing over the individuals' life span in a qualitative or quantitative sense; and (b) the educational, cognitive and learning-psychological perspective that deal with the problem of how the development of thinking can best be stimulated by organizing the most influential learning environments for the developing individuals. Both perspectives have lead to the rise of theories emphasizing development (Piaget) or development and learning (Vygotsky, Bruner and neo-Piagetian theories). Those learning theories that aimed at explaining the cognitive processes which take place between the input and output of information, deeply influenced by the conceptual framework of computer science, have evolved towards the information processing approach. The processes involved in perceiving, storing, memorizing and applying information are being studied. Figure 1 shows a global division of the most important theories. In this section we will briefly introduce these theories and some others.

One of the most well-known theories of cognitive development, Piaget's theory, is rooted in the rationalist tradition and has several traits of constructivism as well. According to this theory, the development of thinking in children progresses according to successive, discrete stadia. Thinking in a certain stadium is qualitatively different from the thinking in the previous or the next stadium. Piaget sees development as the emergence of new structures of knowledge or schemas, and as the transformation and refinement of these schemas. The result is equilibration, the attainment of balance between the schemas and the environment. Piaget's classification into stadia of development is based on this principle. The four stadia he distinguished (the senso-motor, the pre-operational, the concrete-operational and the formal-operational) are always passed through in the same order and they are considered to be universal.

In the neo-Piagetian option, the issue of universality of developmental stadia is dropped. Partly as a consequence of learning theory, the possibility of stimulating thinking is being studied, as well as breaking through the stadia and establishing larger individual differences in cognitive schemas. Case (1985) integrated Piaget's theory with information processing theory. By learning or training, children will

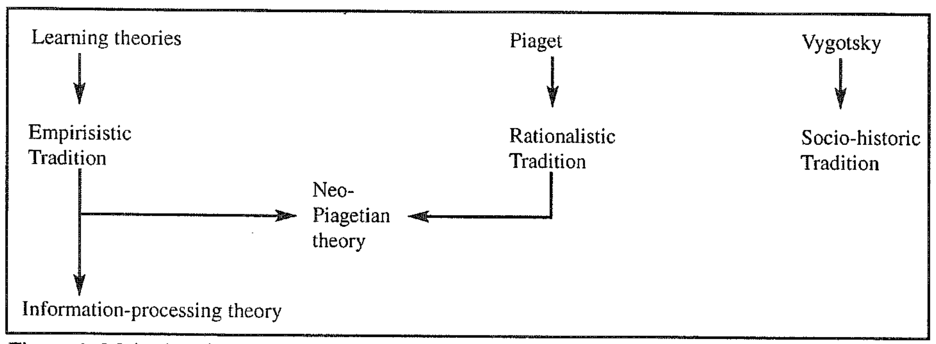

Figure 1 Main theories on thinking

become more skilled in the processing of information. This means that they are increasingly able, and sooner than Piaget assumed, to perform cognitive operations. In this way, the learning environment plays a more balanced part in development. It makes children's development more heterogeneous.

Bruner, Goodnow, and Austin (1956) conducted some of the first research on learning viewed as a product of thinking. What made their work 'A Study of Thinking' distinctive was that it studied learning as an outcome of thinking, using methods that made thinking amenable to objective study. The kind of learning they studied was 'concept attainment'. One can think of concept acquisition as analogous to learning a set of rules for classifying objects, e.g., 'If x has warm blood and fur, then it is a mammal'. This is an important kind of learning because classifying objects is essential to thinking. Bruner and his colleagues thought of the processes of learning as similar to hypothesis testing. A learner uses some strategy to generate possible rules for defining a concept and then tests these hypotheses against actual instances until one is found to survive the tests. In this way, Bruner et al. (1956) found strategies which where well-adapted to the practical difficulties of the situation, such as its complexity. Thus, learning involved thinking (generating and testing hypotheses on the basis of their implications) and it depended on the particular strategy being used (rather than being determined by the environment alone). Bruner's (1990) work is widely accepted, in part, because it made the study of thinking 'tough-minded'.

Vygotsky's socio-historic theory is primarily a learning theory and, from this point of view, applies to learning to think (Case, 1996). Vygotsky values the interaction between parents and children throughout their development. A central concept in his theory is the 'Zone of Proximal Development' (ZPD). This zone refers to the difference in what a child can accomplish on its own and what it might be able to perform with the help of competent others. With such help the child can reach a higher level of development. Language plays an important role in this process. A child's first words are communicative actions that shape its interactions with others. According to Vygotsky, during the first two years of life the development of language and thinking occur along more or less parallel, but relatively separate lines. Around the age of two, a fundamental change takes place in the child's relation between language and thinking. Thinking becomes verbal. Language originates by way of thinking, but subsequently language fosters the further development of thinking.

Characteristic learning processes that occur between the input and output of information processing are determined in learning theory, and on the same lines, in information processing theory. Research is carried out on cognitive processes involved in the perception, storing, memorizing and application of information. Duijker (1977) described the concept of thinking as follows: "Thinking denotes for psychology a coherent complex of specific theoretical problems, dealing with the complexity of the information processing activities (what do they consist of and how are they controlled?) and with the roles these representations of information play

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(how are they established, what is their nature and structure?). Cognitive psychology mainly occupies itself with problem solving, which means that activity of information processing in which the subject tries to find an answer to a question that is difficult for him" (p. 89). The central concepts in this quotation are: information processing, representations and problem solving. In today's cognitive psychology these concepts are crucial. In information processing theory much attention is paid to incorrect and inefficient thinking. These evaluations of the thinking processes are considered essential, and are useful in improving thinking. In particular, differences in the use of control mechanisms or metacognition and in the speed of information processing account for differences in the development of information processing activities. One of the central questions is how metacognition can be guided or influenced (Boekaerts & Simons, 1993).

Constructivism is another theoretical orientation that nowadays receives growing attention (see Philips, 1997). It has many faces and several sub-branches or sub-theories, so today it can be considered a broad paradigm rather than a specific or consistent theory. Both 'realistic' and 'radical' constructivists are active on a number of fields of instruction, especially in reforming mathematics education (Cobb, 1996). The 'new math' movement traces its origin back to the Piagetian framework while the more recent realistic mathematics education (see also Nelissen, this volume) is influenced by the information processing approach and Vygotsky's social constructivism as well. Although constructivism is not a sophisticated theory yet, it may be a good candidate for integrating several aspects of some competing theories of development (Piaget, Vygotsky and information processing). Constructivists emphasize more strongly that learning is an active, constructive process. Learning is productive, useful, achieves results only if the students are actively involved in the subject matter. The art of learning is to connect new information to existing knowledge. This active connecting process consists of involving all kinds of prior knowledge in the construction of new representations of information. Because each person has individual experiences and different foreknowledge to build on, these new representations are unique. Possibilities are sought to facilitate the active, constructive learning in 'rich learning environments' by involving modern technologies, for instance.

Another important theory is that of psychometry. The psychometric tradition has had a long-term impact on the research of thinking in at least two significant ways: (a) by making psychological traits measurable and in doing so opening the way for quantitative analyses (e.g., factor analysis) and (b) by launching the concept of intelligence (see Carroll, 1993). Galton (1822-1911) is considered to be the founder of this theory of the individual differences in human faculties, while Binet was the first to develop an intelligence test. Binet was already well known for his work on the development of thinking in children who achieved very different levels of attainment. He took it upon himself to develop a tool which could be used to select those children who need special educational help. Binet and Simon's test has been translated and adapted into many languages. In the US this led to the Stanford-Binet

Intelligence Scale, which in its current version is one of the most widely used IQ tests. Later, other influential tests such as the Wechsler Scales followed.

Following on from Binet's work, and from the results of factor analysis, intelligence was described in terms of a collection of latent variables called factors. Individual differences in test achievements, the manifest behaviour, were derived from individual differences in these factors. Typical intelligence theories which can be considered as belonging to this perspective are Spearman's two-factor theories, Thurstone's primary mental abilities theory, Guilford's structure of intellect theory and Cattell-Vernon's hierarchical theory. These factor analytical traditions differ from each other in the number of skills mastered and their inter-relationships. The ones most known today are a few modern variants of intelligence structures (Gustaffson, 1984; Snow, Kyllonen, & Marshalek, 1984). Efklides (this volume) based her research on Gustaffson's intelligence structure.

Binet and Wechsler were both interested in the development of a theory about intelligence. Both had an opinion about intelligence that was instrumental in the choice of tasks and for the cognitive processes which underlie tasks and the development of these processes (Sternberg, 1985). The designers of the factor theories thought they should get a better grip on the cognitive process of the operation which enables an individual to reach an answer during the solving of a problem (Kail & Pellegrino, 1985). This is the reason that in intelligence research a cognitive-psychological approach appears in which analyses of processes have to offer an explanation for the solving of a problem, whether successful or not. Thus the Russian researchers, such as Gal'perin and Zaporozec (in Van Parreren & Van Loon-Vervoorn, 1975) conducted studies of Thurstone's factors 'numeric' and 'space', respectively, from an active learning perspective. De Groot (1965) partly laid the basis for the studies of the novice-expert perspective. These studies investigated how novices differ from experts in their solving of complex problems, for example, in chess problems. Schoenfeld (1985) adapted this idea to educational problems occurring in physics and mathematics. The research used introspection and protocol analysis to gain access to human cognitive processes (see also Elshout, 1988).

Although intelligence and its measurement proved to be a useful concept for several practical purposes, improving its identifiable components (e.g., inductive reasoning, see several chapters in this volume) seems to be a more fruitful and realistic enterprise for education. Sternberg (1985) was one of those theorists who renewed intelligence research by applying the framework of the information processing approach. Sternberg (1985) attempted to answer three questions. The first concerned which elementary cognitive operations (components) were involved in solving a certain type of problem. The second was about the amount of time an individual needed to solve a problem and how accurately the individual worked. The third question concerned the inter-individual differences in the speed and accuracy of the processes. Sternberg (1985) distinguished three types of thinking skills in his component subtheory: (a) executive processes which are used to plan, monitor and

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evaluate one's own thinking (meta-cognition); (b) performance processes which are used to actually carry out that thinking; and (c) learning processes which are used to learn how to think in the first place. Examples of executive processes include identifying and formulating a question, keeping the situation in mind and organizing one's thoughts. Examples of performance processes include seeing similarities and differences, deducing, and making value judgements. Asking and answering questions of clarification such as 'What do you mean by that?', and listening carefully to other people's ideas, are examples of learning processes. De Koning and Hamers (this volume) give examples of Sternberg's performance processes applied to inductive reasoning (encoding, inference, mapping, application, comparison, response).

The learning and thinking theories discussed here emphasize the development of thinking (Piaget), the development of thinking and education (Bruner; Vygotsky), learning (information processing, constructivism) and measuring individual differences in mental capacities (psychometry). It is primarily the opinions of Piaget, Vygotsky and Bruner which are often compared to each other. In general, we can say that they agreed on the sequence in which thinking developed: from concrete actions via increasing reflection to abstraction. In fact, Vygotsky and Bruner assume much more strongly than Piaget that education has an essential function with respect to a child's development of thinking. The cognitive approach to thinking and intelligence is significant because it can offer an explanation for the way in which achievement in all sorts of tasks is accomplished.

Many curricula for the teaching of thinking are influenced by one or more of these approaches (see Hamers & Overtoom, 1997; Nickerson et al., 1985). The latter proposed five approaches:

(a) In the cognitive operations approach, it is assumed that thinking problems are caused by an insufficient mastering of basic operations like classification and seriation. The training programmes in this approach could be particularly suitable for weaker students who have not yet mastered these operations (emphasis on neo-Piagetian and information processing theory).

(b) In the heuristic approach all kinds of problem solving operations are taught, like problem analyses, planning, representation and verification. The essence of this approach is the task analysis, in which a task is split up into manageable parts or subtasks. After the analysis, attempts are made to improve a person's performance in the subtasks by training in the problem solving strategies and by involving metacognitive skills (emphasis on Vygotskyan and information processing theory).

(c) In the formal thinking approach, the starting point is the neo-Piagetian or Piagetian theory. The programmes aim at effecting the transitions between the different stadia, for example, between the concrete-operational and the formal-operational stadia. A characteristic of this approach is the integration of thinking operations into school subjects like science (emphasis on

neo-Piagetian theory).

(d) In thinking as manipulation with language and other symbols, teachers stimulate the use of thinking skills by means of the regular school subjects (emphasis on Vygotskyan theory).

(e) In thinking about thinking (metacognition), it is assumed that a better understanding of the nature of one's own thinking process will improve one's competence in thinking. Students are encouraged to think about thinking in general, and to become more aware of their own thinking processes (emphasis on Vygotskian and information processing theory).

There is some overlap between these five approaches. For instance, in the last approach, heuristics are being used, and thinking through the curriculum content includes various elements of the other approaches. Besides, none of these approaches is superior to any other. All aspects of these approaches are also discussed in chapters in this volume. In 'teaching thinking' the various theories mentioned are brought together; they are seen as compatible and complementary (Sternberg & Berg, 1992). They all contribute in their own specific way to understanding and optimizing learning conditions for the teaching of thinking.

Teaching thinking

Most educators agree on at least one general point, namely that a central aim of education is to take the knowledge that has been acquired by one generation and to create conditions such that this knowledge can be acquired and extended by the next generation. This point does not require any particular view on educational aims and methods. One reason for this diversity is that there is no agreement as to the nature of knowledge itself since there are several different theories of knowledge (Case, 1996). These views have their roots in British empiricism (Watson, Thorndike, Hull), in continental rationalism (Piaget), and in the socio-historic theory (Vygotsky) (see Figure 1). The theories of knowledge deal with the issue of the relationship between man and knowledge. For a long time, philosophical schools such as empiricism and rationalism, for example, formed the foundation for two distinct paradigms in which psychologists formulated their research on the relationship between man and knowledge. This originally led to contrasting views on how people use knowledge, how they reason, and how education can best take advantage of this. De Koning and Hamers (this volume) describe how so-called pragmatic deductive- and inductive reasoning schemes have brought about a synthesis between both paradigms. These context-free schemes ensure the orderly processing and application of knowledge and the organization, reorganization and storing of knowledge.

Views of knowledge (Case, 1996) and knowledge acquisition or learning are inextricably linked. Learning comprises many processes which a person can work through. On the one hand, these learning processes have several common features.

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For example, each process will provoke a number of changes in people which are relatively enduring. On the other hand, all types of learning show a great variety of processes. Examples of types of learning include: learning that aims at insight (learning to think), learning facts, memorizing, and learning automatisms. It is the differences which make it difficult to consider or describe learning as an unambiguous concept.

Thinking occurs in a situation when a person is presented with a problem, i.e., a task for which there is no immediate solution. In the most favorable case, the person will allow himself to assess the problem, look at the different aspects, and find a suitable solution by way of insight. The psychology of thinking concerns the issue of how someone acquires that insight. In school we encounter many forms of learning that encourage insight, as in comprehensive reading, arithmetic, and text production in which thought relations must be adapted (e.g., agreement - difference; cause - effect). The essence of this sort of learning processes is primarily the learning of accurate concepts and general rules with which children can tackle new tasks (Van Parreren, 1990), for example, in order to solve a problem involving areas children must be familiar with the concepts of area, right angle, length, width and circumference. The formula for solving this problem provides a rule linking these concepts.

As well as acquiring concepts and general rules, learning which encourages insight also requires mastering the actual methods for solving a problem (Van Parreren, 1990). Research into methods or processes for solving problems has always been an important issue in thinking psychology (Piaget, Wertheimer, Duncker, De Groot, Bruner; for overviews see Dumont, 1966; Frijda & Elshout, 1976). A standard Anglo-Saxon work in this field was written by Newell, Shaw, and Simon (1958). But East European researchers, such as Kuljutkin, Ponomarev and Puskin, also studied solution methods (see Van Parreren & Van Loon- Vervoorn, 1975).

Puskin (1975) distinguished three phases in solution processes. The first phase leads awareness of the problem as such. If all attempts at applying known concepts and rules fail to solve the problem then one is compelled to look for new solution methods. The second phase is closely connected to looking for new solution methods. The actual solution process takes place in this phase. The person must find those operations which, when applied, lead to the desired target situation. This process can be considered the application of transformation methods. In the third phase there is a check on these and the results are integrated into the personal motives structure. In general, three such methods can be distinguished:

(a) The algorithm method: the problem is transformed according to fixed, always valid steps until the solution is reached. The solution is guaranteed. Strictly speaking, this is not about problem solving.

(b) Blind exploration (trial and error): different possible solutions are tried out, without using information about the possibilities themselves (Frijda & Elshout, 1976). This can also be called trials (Podd'jakov, 1979) or guess exploration (De Corte & Verschaffel, 1980).

(c) The heuristic method: in this method sensible ways of operating are selected without having to search every possibility. This method only provides a greater chance of finding a solution, but no guarantee of finding it. In addition, various heuristic principles can be distinguished (Duncker, 1935; Frijda & Elshout, 1976), such as target-means analyses, material and conflict analyses, and splitting the main problem into subproblems.

Learning in all its forms can also be self-taught, one can 'learn to learn' (Van Parreren, 1990). An important starting point here is that learning progresses as the students become more aware of their own activity: learning as a conscious activity or metacognition. In that framework it is important that students orient themselves well to the task, make a plan of how to tackle the task so that they work systematically, analyse mistakes and analyse successful attempts retrospectively, i.e., reflect on the mental steps taken in order to achieve integration of the knowledge. Thus, a goal that the developers of mental stimulation methodologies aim to achieve is that children start thinking more efficiently, partly by acquiring insight into their own mental processes and partly by actively directing these processes. An important means for achieving this aim is reflection, which means stimulating thinking about one's own thoughts or metacognition (Boekaerts & Simons, 1993): "People have knowledge to a greater or lesser degree about their own cognitive system and how it works. The knowledge can concern their own thinking, memory, fantasy, reasoning, etc. and that of other people ..." (pp. 88-89). It is generally accepted that people who have a relatively greater metacognitive knowledge are better able to direct and improve their thinking.

In the process of designing programmes for teaching thinking, the choice of tasks is of great importance. There are many kinds of tasks: some demand primarily motor activity, others demand more mental or thinking activity, as in analogies (e.g., client = doctor : ....), completing series (e.g., 2, 6, 11, 17 ...) and classification (e.g., What does not belong here?: cat, dog, elephant, guinea pig). Cognitive psychologists have tried to describe and analyse the characteristic difficulties and processes of these and other thinking tasks. The most well-known classification of tasks or problem types is that designed by Guilford (1956). He constructed a division of tasks from three starting points: (a) the contents of the thinking task or the nature of the material that has to be worked with; (b) the actions or operations that have to be performed; (c) the result or product of the actions. In his option, a problem of analogy like leg : knee = arm : ... could be characterized as convergent thinking (operation), as semantic (concerning the contents) and as relation (product). Particularly in the field of inductive reasoning many new tasks have been added and investigated (Jacobs & Vandeventer, 1972). Jacobs and Vandeventer taught subjects to solve so-called double classification tasks. These tasks consisted of a 2 x 2 or a 3 x 3 matrix, which presented figures that varied horizontally and vertically and in which the figure in the lower right corner was omitted. The tasks belong to what Guilford (1956) calls the 'cognition of figural relations' in his Structure of Intellect (SI) model. Guilford's

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SI model recently has been strongly criticized by several psychometricians (see Carroll, 1993). During the last few decades many new tasks have been developed and examined (e.g., Csapó, this volume; Sternberg, 1985; Vosniadou & Ortony, 1989).

Some relevant issues in teaching thinking

As already stated, thinking is approached theoretically in different ways. Theoretical starting points have implications for the construction of a programme. A logical conclusion is that there is no such thing as one kind of stimulation of thinking. In this section we will describe some widely discussed themes with respect to the teaching of thinking.

Skills versus infusion approach

There is discussion on whether thinking skills apply to all domains of the school curriculum (domain-general) or whether they are specific to the school subjects (domain-specific). And, if the thinking skills are general, are they best taught via discrete programmes or should they be fused into subject areas? This discussion has resulted in two approaches (Maclure & Davies, 1991): (a) the general approach with separate courses for teaching thinking; and (b) the specific approach with integrated courses, which means that the thinking skills are embedded in the school subjects.

In the first approach the basic assumption is that thinking skills can be taught explicitly and independently of the regular school curriculum (the 'skills' or 'across-the-curriculum' approach). In this view there are certain more or less universal thinking skills that can be generalized in the school subjects. A prerequisite for the occurrence of a positive effect on, for instance, reading, writing and arithmetic is that, during the training, a 'bridge' is built between both. These general thinking skills are mostly trained with 'content-poor' tasks (see Figure 2). The question in this case is: In which of the four squares would the figure on the right fit best?

The second approach assumes that thinking skills can best be taught embedded in the school subjects (the 'infusion' or 'within-the-curriculum' approach). Thinking skills are being taught in specific or 'content-rich' domains like reading, writing and science. The following text is an example of this approach.

The zoo

The teacher visited the zoo with the third grade pupils. The children were very pleased. The crocodiles attracted most attention in this wonderful zoo. How big they were! The elephants were funny. They sprayed each other with their long trunks. And those beautiful birds in all kinds of colours ..., etc.

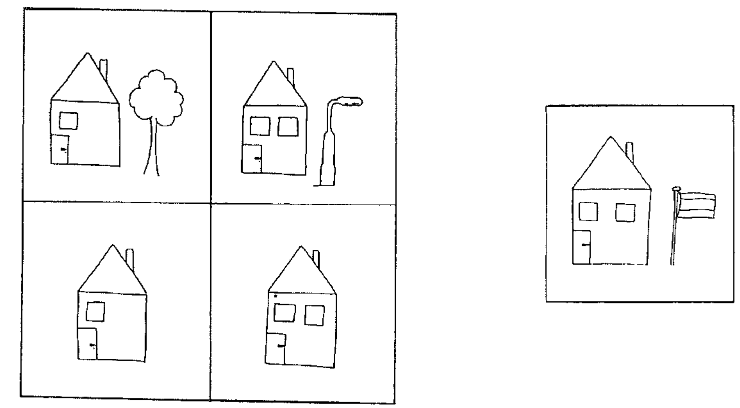

Figure 2 Example of a 'content-poor' item (test item from De Koning, Hamers, & Sijtsma, 1996)

At the end of this reading lesson the teacher will categorize the animals from the story into, for instance, land animals, winged animals and water animals. This text involves the same processes as those required for the item shown in Figure 2.

This integrated mode of operation requires fundamental changes in content and presentation of the subject matter (Csapó, 1990, this volume). Examples of this approach can be found in arithmetic (Nelissen; Verschaffel, this volume), in comprehensive reading (De Koning & Hamers; Oostendorp & Elshout-Mohr, this volume) and in text composition (Chanquoy, this volume). For example, De Koning and Hamers' programme (1995) uses texts which demand thinking operations like classification (grouping on the basis of attributes of objects in the text) and seriation (the formation of a logical sequence on the basis of, for instance, cause-effect relations in the text).

Advocates of the second approach hold the view that teaching thinking programmes should be embedded in the school subjects because a great number of these skills are content-specific and are not easily transferred to other content domains. We are of the opinion that content-relative programmes are preferable to general programmes, unless the students have great difficulty with the domain contents.

Transfer

Transfer of thinking processes can be considered an end-target of learning. The belief in the possibility of transfer can be traced to the institution of school itself and in the assumption that what one learns at school can also be useful in life outside school. Different types of transfer can be distinguished (Salomon & Perkins, 1989; Simons & Verschaffel, 1992). One of the most well-known distinctions is between the so-called near and far transfer. Near transfer is when a

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skill is learned in a certain context and applied in an almost identical situation. The features of the transfer task are largely similar to the original task, e.g., using the alphabet for looking up a word in a dictionary. Far transfer concerns applying a skill in a completely different context.

One generalization about transfer is that it requires explicit focus in any approach to the teaching of thinking. Whether thinking skills or problem solving strategies are taught in the context of subject areas or in separate courses, students need to be aware of the applicability of what they are learning to contexts other than that in which they are learning it. One problem is that most of the research on thinking has been done in classrooms and psychological laboratories and relatively little is know about the transfer effects to performances in everyday situations. So how reliable are the predictions of demanding tasks used in an academic setting to demanding tasks encountered in everyday life? In this volume the chapters on so-called realistic mathematics (Nelissen; Verschaffel) describe research focused on the kinds of thinking and problem solving taught in schools and outside academic contexts.

Process paradigm

Research (Hamers, De Koning, & Sijtsma, 1998) aimed at studying the interaction between teacher and students during the implementation of programmes to encourage thinking shows that education generally can be characterized as product-oriented. This 'product paradigm' is widely held by teachers and teacher-trainers. Education is primarily thought of as the reproduction of knowledge from particular subject areas. This knowledge is the product of a scientific research process and it consequently has an absolute value, which can best be transferred by an expert in the relevant discipline.

At present a new paradigm has gradually been formulated in which the principal temporary nature of openness of scientific knowledge is emphasized and in which the status and expertise of the teacher is put into perspective. Furthermore - and this is essential -, in this paradigm it is not only the end-result (of the thinking) that is emphasized but also and primarily the preceding process. One of the fundamental premises of this 'process paradigm' is that education must not involve reproduction of knowledge as much as the development of skills and capacities which can be applied to knowledge. In other words, it is more important that a person knows what he can do with certain information or how to acquire it (procedural knowledge) than that he should only have such knowledge, available in his memory (declarative knowledge). In this opinion knowledge functions more as a means than an end in itself.

The shift from factual knowledge to knowledge of procedures of how to acquire knowledge and to organize it assumes a more open, dynamic concept of knowledge. The development or stimulation of thinking assumes teaching-learning situations which primarily run according to the problem-process-solution paradigms. The problems which are offered to children should therefore be organized so that they show a discrepancy between the desired end-situation and the undesired starting situation. And the solution process can be changed by varying the complexity, the scope and the degree of structure of the knowledge.

Concluding remarks

Encouraging thinking has been an important subject since the criticisms of and reinterpretation of Piaget's theory on the development of thinking (e.g., Brown & Desforges, 1979; Donaldson, 1978). These criticisms have pointed to the supposed limits in children's capacity for reasoning and abstract thinking. Thinking can be trained or remedied (Sternberg, 1984) and it has been claimed that children with an apparently limited capacity have a greater potential (Hamers, Sijtsma, & Ruijssenaars, 1993). It has been asked whether that potential can in fact be exploited or achieved with suitable training; opinions are divided about this. We refer to the nature-nurture debate on thinking where the arguments for intelligence as an inherited or acquired feature have been detailed. Intelligence could be defined as a person's 'rough' intellectual power, and thinking as the 'skilled' use of that power. In other words, thinking deals with how people use their intelligence and what they do with it. Thinking could therefore be encouraged 'to a certain level' (the potential). For lack of experience it may underperform. The methodologies for encouraging thinking are used to compensate for the lack of experience or to remedy (or in any case improve) how a person thinks.

The division into general and specific programmes and the preference for one or the other is a subject for discussion. Which of these programmes do we most need in schools? The answer to this question determines to a great extent how thinking will be taught. If thinking is taught in an 'across-the-curriculum' course, objectives for thinking skills and strategies will be the basis of the programme. If thinking is taught in the context of a school subject, content objectives will be the basis. There is considerable debate as to which context is more effective for teaching at-risk students (Resnick, 1987). Proponents of the first approach argue that low-achieving students may experience overload if they have to learn both content and skills simultaneously. For instance, Feuerstein (1980) developed content-free programmes using geometric shapes and pictures. Most other programmes for teaching thinking, however, use a combination of content-free and daily life formats (e.g., Klauer, this volume). Proponents of the second approach argue that programmes should be content-related because a substantial part of skills and strategies is content-specific and these skills and strategies cannot be easily transferred to other areas (Resnick, 1987). We agree with Presseisen's (1987) compromise that content-related programmes, in which skills are learned as a means to learning how to solve problems, are generally preferable, unless students have great difficulty with the content. In which case, an 'across-the-curriculum' course might be the best choice, provided that transfer is built into the programme

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and that the substance of the programme is well coordinated with the school content courses.

Difficulties encountered in most intervention studies are more complex than is often suggested in the literature. It is widely accepted that the effectiveness of cognitive programmes depends highly upon the degree of transfer from the present task to other tasks. Transfer is extremely difficult to achieve in practice. Many programmes (see e.g., Hamers & Overtoom, 1997) do not provide sufficient guidelines on how to facilitate transfer although many authors acknowledge that transfer is an area which requires further work. Experiences in many studies suggest that curriculum-independent materials (see Figure 2), while having the advantage of being novel to the children, make the 'bridging' task even more arduous. Less abstract and more curriculum-based materials may be required for effecting transfer to other academic areas (assuming that the aim of the intervention is transfer to other school domains).

The teacher plays a crucial role in implementing a programme to encourage thinking skills. The programmes keep provoking new views on instruction. The interactions described between students and teacher must encourage students to be more active participants in the learning process, e.g., by creating new ways of working together and by role changes between teacher and students. It has also been our experience (Hamers et al., 1998) that implementing these programmes demands a thorough reorganization of the way in which the teacher teaches the students. The teacher must master and use a greater variety of didactic strategies (process-directed versus product-directed teaching, encouraging thinking aloud, the dialogue form, guiding versus leading the way, algorithm versus heuristic, mutual learning and teaching, stimulating reflection about own thinking, etc.).

If we want to teach children to think then we are aiming to improve their problem solving ability. We can aim to achieve this by putting children to work systematically and methodically on different types of problems. In this book we take a look at thinking processes and how to encourage them from different points of view. Sometimes there is more emphasis on the development of thinking or on the identification of thinking skills and sometimes on encouraging thinking with the aid of training programmes. The chapters also deal with some special themes such as thinking and mathematics, reading comprehension or text production. In addition, in the different chapters we can recognize combinations of theoretical view points and training goals. The book is completed with a contribution about the methodology of improving thinking and, finally, several general and provisional conclusions are given in Chapter 14.

Introduction to the chapters

Csapó (Chapter 2) discusses cognitive research, which has revealed a broad range of approaches to teaching thinking; several of these can be applied to mainstream school instruction. The chapter reviews the current literature that proposes integrating teaching thinking with subject-matter instruction and then summarizes those theoretical considerations which provide resources for designing teaching materials that foster thinking. Two paradigms, the Piagetian cognitive theory and the information processing approach, are discussed. The chapter then examines how some aspects of these two paradigms can be integrated into a consistent framework for improving thinking through the teaching of subject-matter in regular school classes. Then, based on this framework, a method is presented for analysing teaching materials, designing structured exercises and embedding them into the regular instructional processes. The model presented in this chapter can be applied: (a) to thinking skills that can be identified by their structure, and (b) when teaching materials are given (e.g., as defined by a prescribed curriculum). The process of identifying the suitable content of teaching materials, designing exercises and placing them into the regular instruction is illustrated by examples of: (a) several thinking skills from the domains of deductive, combinatorial and inductive reasoning for which exercises are devised and then embedded in teaching material, and (b) several school subjects, e.g., chemistry, physics and grammar.

Adey (Chapter 3) proposes a programme called Thinking Science, designed for use in schools with students aged 11 - 14 years. He describes the basic Piagetian and Vygotskyan theories and the ways in which these theories are worked out into practical activities. In particular, the ideas of cognitive conflict, metacognition, and bridging are called on in the design of the activities and in the method of teaching. Students who experience Thinking Science activities once every two weeks for two years show significant gains in levels of cognitive development compared with controls and with national norms, and they subsequently show enhanced performance in national tests of science, mathematics, and English. These long-term far transfer results are presented as evidence of the effectiveness of the intervention programme for increasing students' general cognitive processing mechanisms. Conclusions are drawn for the design of programmes for promoting thinking, and also for the methodology of evaluating programmes intended to promote thinking skills.

Scheinin's and Mehtäläinen's (Chapter 4) Formal Aims of Cognitive Education (FACE) is a school intervention project based on a philosophical theory of knowledge. In this project the teaching of skilful thinking was integrated into instruction in most of the subjects in the school curriculum. The project was implemented over a period of three years with students in a junior high school. The evaluation of the effectiveness of the project included both process evaluation of the implementation as well as examination of the effects on students' cognitive abilities, formal cognitive skills, cognitive self-concept, and self-esteem. When interviewed, the teachers claimed that their teaching had changed and that this was influencing the students. Test results show no significant broad transfer effects in cognitive abilities, but clear improvement was found specifically in formal cognitive skills. The change was well beyond the age-typical development of the

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control group. There were significant positive changes in the cognitive self-concept of the students but no change in their self-esteem.

Efklides (Chapter 5) presents two studies which aimed to investigate the possible acceleration of domain-specific abilities. The theoretical assumptions underlying the two studies were derived from experiential structuralism, a theory of cognitive development, which postulates general and domain-specific abilities, including the quantitative-relational (QR) and the causal-experimental (CE) abilities. The studies involved three sets of tasks: QR tasks, CE tasks, and general intelligence (G) tasks. There were three treatment groups: the first was trained in QR abilities, the second in CE abilities and the third was a control group with no training at all. The results showed that the mechanism of cognitive change involves either both G and domain-specific abilities or only the latter. There was also evidence of transfer from QR to CE abilities but not vice versa. The constraints to change and cognitive acceleration were related to the cognitive level and age of the subjects. Finally, the various methods of training imposed different cognitive demands that influenced their effectiveness. These results imply that the teaching of thinking cannot be reduced to skills' acquisition but is a more complex mechanism which may take different forms depending on the teaching method we use and the ability trained.

Klauer (Chapter 6) presents a theory of inductive reasoning, specifying both processes which enable one to solve inductive problems and the various kinds of problems which are inductive in nature and solvable by the defined procedure. Following this, three hypotheses are derived in order to test the theory. Such tests were possible since training programmes based upon the theory have been developed, programmes which address children and youths of different ages and different ability levels. Moreover, a rather large number of training experiments have previously been run where a training group was contrasted to a non-training control group or to a control group which participated in a non-inductive training. Using meta-analytic methods, the existing body of training experiments is synthesized. Based on the meta-analyses it is concluded (a) that inductive reasoning is amenable to training, (b) that training to reason inductively transfers to tests of fluid intelligence, (c) that the training effects last for at least some months, and (d) that the training transfers to and fosters acquisition of declarative knowledge. Unexpectedly, the effect on learning in school are even higher than that on fluid intelligence. One can assume that the theory of inductive processes has proved to be useful, particular if it is taken as an objective for educational measures.

De Koning and Hamers' (Chapter 7) projects are based on Klauer's theory of inductive reasoning. Firstly, the authors discuss the philosophical schools such as empiricism and rationalism in which research is conducted regarding the relationship between man and knowledge. In addition, attention is paid to how people deal with knowledge, how they reason and how education can best take advantage of this. They also describe how research in each of these schools has led to a new synthesis which can be put into practice by means of so-called pragmatic

deductive- and inductive reasoning schemes. These context-free schemes appear to represent the abstract level of man's reasoning. They ensure the orderly processing and application of knowledge and the (re-)organization of stored knowledge. Secondly, the importance of induction for young children is considered. The probabilistic character of induction requires the application of so-called intuitive statistical schemes which monitor the balance between acquired knowledge and the adaptation of knowledge organization on the basis of new knowledge. Adults use inductive pragmatic schemes of the law of large numbers and regression to do this. It is assumed that young children must first form an image of group- and row structures. Thirdly, the authors discuss research regarding the training of children using visual, numeric and verbal inductive reasoning tasks which illustrate the general character of the reasoning schemes. The results show the importance that group- and row structures can have in the relation between man and knowledge.

Nelissen's (Chapter 8) Thinking skills in realistic mathematics focuses on an important approach to mathematics instruction, the so-called realistic approach or realistic school. This approach has brought about far-reaching changes in mathematics instruction. Two factors have had a significant influence on the development of the realistic school: firstly, the mathematicians who developed a different view of mathematics and, secondly, a new conception of how children learn mathematics, which draws both from cognitive psychology and from the cultural-historical tradition. This chapter concentrates on mathematics learning and instruction in primary schools, using three key concepts: construction, interaction, and reflection or metacognition. The chapter then proceeds to explore which cognitive processes are fundamental to solving mathematics problems and, finally, to discuss developments within the field of educational psychology which may be relevant to mathematics instruction. Although the theoretical basis for construction, interaction and reflection is quite solid and there is a high level of agreement about the three concepts, more research is needed at all levels of mathematics instruction to increase our understanding of these cognitive processes and the role they play in mathematics learning and instruction.

Verschaffel (Chapter 9) addresses the issue of teaching and learning how to solve application problems in upper elementary school children. He presents a model of expertise in the solution of mathematical application problems, involving the integration and interactive application of different categories of aptitudes during the distinct phases of the problem solving process. This model is then used to describe and analyse some well-documented research findings about elementary school students' difficulties with modelling and solving application problems, and about the characteristics of the current practice and culture of elementary school mathematics that are (partially) responsible for these difficulties in students. A subsequent review describes three recent experiments in the domain of elementary mathematics education that have been explicitly set up to answer the question of how mathematical modelling and problem solving can be successfully taught to

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(upper) elementary school children. A critical discussion of some problematic elements in designing these experiments leads to some suggestions for further research and development work.

Van Luit (Chapter 10) argues that more than ten percent of all children in primary education cope with learning difficulties. Most of them need special methods of instruction either in special schools or in remedial classes in regular primary schools, in order to learn adequate problem solving strategies and to practice using them. Many children who are labeled as learning-disabled or as educable mentally retarded do have a lack of knowledge and capacity to understand problem solving strategies in mathematics. Easy strategies for addition can be taught. However, in the domain of multiplication and division it is often too hard for them to learn and select adequate strategies. There are too many diverse strategies and they do not understand why they should use one strategy for one problem and a different, more suitable strategy for another problem, or how to choose which strategy to use. This chapter discusses the effect of a strategy instruction training for teaching multiplication and division problems to 30 children in schools for educable mentally retarded and 30 children in schools for learning-disabled. All these children had severe mathematics disabilities. The effectiveness of this training can be explained in terms of its successful integration into parts of the mathematics curriculum, the thinking about different ways of problem solving and the self-instruction. The results show that teaching these children to think mathematically, based on a programme that includes self-instruction for strategy use, was significantly more effective than teaching them in control groups based on a regular mathematics programme. They developed a capacity to think about the best problem solving strategy for doing a specific mathematics task. Furthermore, the results suggest that most of the experimental children with learning disabilities were far better able to deal with generalization tasks after the experimental training. The results are consistent with previous findings, suggesting the importance of implementing strategy instruction in mathematics training programmes.

Chanquoy (Chapter 11) aims at analysing the variations in connectives used in three textual genres, in relation to the development of writing abilities and thinking processes. To reach this objective, connectives are investigated in texts written by 10 and 13 year olds. Connectives have been considered as appropriate surface indicators of deep writing processes. Eighteen fifth-graders and eighteen eight-graders (French native speakers) successively wrote a narrative, a description and an argumentation concerning similar topics. An analysis of the mean proportion of interclausal connectives was conducted to study the children's ability to use specific connectives according to specific genres. Results showed that both 5th- and 8th-graders used similar proportions of connectives, and that these proportions varied according to textual genres. Connectives were more numerous in argumentations and in descriptions than in narratives. The analysis of linearity markers and textual structuring markers revealed that 5th-graders used more linearity markers than 8th-graders, who used more textual structuring markers. Descriptive texts had more linearity markers than argumentative and narrative texts, respectively. Conversely, argumentative texts exhibited more structuring connectives than narrative and descriptive texts. A descriptive analysis of different categories of connectives indicated a high degree of specialization in the use of the different categories of connectives (and spatial, temporal, non temporal and argumentative connectives) for different types of text. These results were globally in agreement with other works. Connectives were not randomly used, but varied according to the text, and their diversification was accompanied by a relative specialization, and by a reorganization of their functions. Finally, the findings of this experiment should prove particularly interesting for those concerned with instruction. These results highlight the variable and adaptable nature of young writers' composing processes, and also the types of text as an important and influential factor in these processes and in the acquisition of writing skills.

Van Oostendorp and Elshout-Mohr's Chapter 12 on thinking skills in reading and text studying, deals with the complicated activities and the thinking skills which are involved in comprehending the meaning of texts and in processing text information according to the situation and purposes at hand. Relevant thinking skills are identified at various levels. They distinguish and discuss the basic level, the strategic level and the higher order level. Furthermore, they focus on a sample of difficulties that frequently occur in reading and studying informative texts, and on thinking skills that might be helpful in dealing with those difficulties. Three categories of difficulties are discussed. The authors describe how these difficulties have been highlighted from the perspective of experimental reading research by manipulation of text materials, reading tasks, and reading abilities of subjects. Subsequently they discuss these difficulties from the perspective of thinking skills. It has been indicated that reading can be viewed as a higher order skill, because research on reading revealed that complex thinking skills, like inductive reasoning and problem solving, are required throughout the reading process. Increasing the specificity of the links between difficulties and thinking skills will not only enhance insight into the required skills; but it can also facilitate accurate description of lower order skills that help readers to reach automaticity and higher order skills that are needed to organize and monitor appropriate appliance of the necessary skills. The authors also discuss how the difficulties which were selected for elaboration in this chapter are related to the broader reading process.

Hager's (Chapter 13) methodological issues primarily deal with the application of concepts of evaluation research to evaluation of cognitive programmes. After defining 'cognitive programmes', Hager considers the connections between these programmes and basic theories interpreting the programmes as 'systems of technological rules'. This interpretation makes it necessary to empirically evaluate the effectiveness of any programme independent of the status of the basic theory that 'inspired' it. Subsequently, two categories of goals or objectives for such programmes are identified, proximal or near, and distal or far goals. It is argued

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that different criteria are appropriate with respect to these two categories of goals and that the criteria actually chosen should consider the goals to be assessed. There is further discussion on the sizes of statistical effects associated with the programmes and some basic types of evaluation research are reviewed. Some of the most important consequences of the distinction between comparative and non-comparative evaluations are discussed in greater detail, with special attention given to the most plausible effectiveness hypotheses and the sizes of the statistical effects to be expected. Non-comparative evaluations aim at the programme's effectiveness as such, and no statement can be made on the effectiveness of the control programme. In comparative evaluations, the effectiveness of two or more programmes with the same objectives are compared. The problem of appropriate comparison groups in order to control for different nuisance effects is also addressed. Some general criteria for a programme's effectiveness are proposed and the hypothesis-oriented view underlying the chapter is considered.

Csapó and Hamers (Chapter 14) draw some final conclusions on the work presented in this book. They attempt to outline a strategy for managing the diversity found in the chapters. Furthermore, they address some general issues related to present and future research regarding teaching thinking. They discuss the dilemmas that will influence the next few years of research and how a fruitful balance can be found between the benefits and drawbacks of diversity and consistency in theories, programmes and methodological issues.

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2

Improving thinking through the content of teaching

B. Csapó

Introduction

Throughout the history of education, there has been a dilemma between the teaching of declarative knowledge ('knowing what': e.g. facts, figures, verbal information) and procedural knowledge ('knowing how': e.g. skills of doing something, thinking). One side of this dilemma received periodically greater emphasis than the other. In the last century, for example, formal systems like mathematics or Latin grammar were considered the best means for cultivating the mind. In this century, the dilemma reoccurred in a refined and more sophisticated form when the methods of teaching thinking (or even improving intelligence) were considered: should thinking be taught directly in separate courses using specific materials (the so-called stand-alone courses) or should it be taught within the framework of the established school disciplines by integrating these efforts into the regular school curricula (the 'infusion' or 'embedding' approaches)?

In recent years, the number of publications discussing theoretical aspects of content-based development of thinking skills has been increasing as well as the variety of experiments, programmes and research projects focusing on fostering thinking in the context of mastering subject matter knowledge. Many arguments in the current literature support the content-related approaches and several authors

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