Improving thinking
through the content of teaching

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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

suggest improving thinking within the context of teaching subject matter knowledge.

The recognition of the importance of knowledge in relationship to thinking gained a new impetus in the 1980s. This view was well formulated in several books and papers. For example, Glaser (1984, p. 97) states: "Much recent work emphasises a new dimension of difference between individuals who display more or less ability in thinking and problem solving. This dimension is the possession and utilisation of an organised body of conceptual and procedural knowledge, and a major component of thinking is seen to be the possession of accessible and usable knowledge." A few years later, Resnick (1987) argued for the benefits of embedding the fostering of thinking skills in academic disciplines.

By the end of the 1980s, the expectations concerning the development of thinking within the framework of regular instruction became apparent and perhaps were stated in the clearest terms by Perkins and Salomon (1989, p. 24) in the conclusion of their paper discussing the degree to which cognitive skills are context-bound: "We forecast that wider scale efforts to join subject-matter instruction and the teaching of thinking will be one of the exciting stories of the next decade of research and educational innovation." In the same year, Resnick and Klopfer (1989) collected related cognitive research under the title 'Toward the thinking curriculum', and a few years later, Nisbet (1993, p. 281) began his paper by stating: "The argument of this paper was that the concept of 'the thinking curriculum' is winning long-overdue recognition in education."

A large number of studies examined and highlighted several aspects of teaching thinking as they relate to subject matter instruction. Perkins (1987) proposed elaborate classroom activities for teaching thinking through the content. Swartz (1987) emphasised the importance of critical thinking and also proposed the infusion of thinking skills into mainstream instruction. Nickerson (1988) reviewed a large number of studies aimed at improving thinking through instruction. Canfield and Ceci (1992) related learning to intellectual development.

As these trends indicate, teaching thinking skills in the framework of subject matter instruction has received a growing attention. However, this focused interest resulted in a still growing diversity of programmes and approaches rather than in a firm and consistent theoretical foundation. Although a large body of theoretical considerations and empirical results have been accumulated and certain convergent tendencies can be observed, practitioners still lack guidelines to develop such programmes.

For ease of expression, the approach described here will be called 'content-based methods'. In short, content-based methods is a way of improving general thinking skills while teaching subject matter knowledge. Another practical simplification will also be applied: instead of the long expression 'teaching thinking skills' the term 'training' will be utilised. In the experimental phase this training may take the form of an intervention in the traditional sense, but as I propose here, content-based methods should be so seamlessly integrated into the

regular school instruction that ultimately the regular school instruction itself should be functioning as such 'training'.

This chapter collects the relevant information on this issue. First, the primary practical needs and theoretical considerations that support the integration of teaching thinking with subject matter instruction will be presented. Then some general principles for using the discussed procedures in real life school instruction will be introduced; and examples will be used to describe how such training exercises can be constructed and how they can be integrated into the mainstream curriculum. Finally, the difficulties and perspectives of the content-based approaches will be examined.

A framework for teaching thinking through the content

Why content: Practical considerations and arguments

When we develop a subject matter course or a curriculum that contains 'infused' or 'embedded' opportunities for training thinking skills, we face the difficulties posed by the constraints of the content which we are supposed to use. We may ask the question: 'Why should we put forth so much effort to include the training in the established curricular disciplines, when there would be fewer constraints if we devised a separate course?' The first and most trivial answer to this question is: because the subject matter knowledge is there and the students are required to deal with it and finally to master it anyway. Students spend thousands of hours studying the contents of several subjects. Why not better utilise this time by also improving thinking?

Thinking always needs a content; we think about something. The 'empty thinking' or 'thinking about nothing' does not exist. Separate courses for teaching thinking often use exercises with abstract content without any concrete meaning in the hope that the thinking processes acquired in this way do not stick to some specific concrete situations so they transfer well to any other domain of thinking. However, there is little evidence that these programmes have long-term effects on intellectual development. If the training of thinking is integrated into the curriculum, the information given there can be used to process, by the skills to be practised. In this way, as Resnick (1987, p. 49) notes, "It is ensured that there is something solid to reason about."

In most educational systems, school curricula already contain a huge amount of subject matter knowledge that students are expected to acquire. Pressure is exerted on the schools to accommodate their curricula to the new developments of sciences, newly emerging fields of social studies or activities of creative arts. Describing this knowledge and operationalising the goals of teaching are easy. Subject matter knowledge appears in a concrete form and it traditionally finds its way easily into the curricula. On the other hand, the goals of improving thinking abilities are harder to define and operationalise. They are much less articulated and

their position is rather weak when competing for instructional time. Thus, methods must be found for transmitting subject matter knowledge and improving thinking that do not compete but rather cooperate.

Thinking is not only a goal of instruction, a desired outcome that finally appears as a result of specific training, but it is a means of learning that has to be practised throughout the entire learning process. One of the most common experiences of researchers and practitioners alike is that learning is possible without intensive thinking, but if students spare thinking, simple memorisation or rote learning results in inert knowledge that can be used for little. Some main problems frequently mentioned in this context are:

- Since students are not able to mobilise their knowledge in contexts other than in which they learned, their knowledge cannot provide a firm basis for further learning. Thus students' knowledge falls into separated, isolated segments.
- Students are not able to apply their knowledge in real life situations.
- School learning does not affect students' naive theories and misconceptions, even if they learn the content of the subject matter and are able to recite it. Therefore their misconceptions are more likely to influence them then is their science knowledge when they make decisions.

In contrast, meaningful learning results in coherent understanding of content. Understanding requires active processing of the material, following the inherent logic of the subject matter, organising the concepts and facts, drawing conclusions from the information given, and building relationships between already existing knowledge and newly acquired information. In summary, practising thinking in the framework of teaching the subject matter knowledge is necessary not only for improving the quality of thinking but also for improving the quality, accessibility and applicability of knowledge as well.

Several innovations and reforms in education indicate that significant improvements cannot be expected without significant additional efforts. This is so with improving thinking as well; no short-cuts or quick fixes exist. Although not requiring much less effort, modification of already existing courses, practices, and teaching methods in order to foster thinking is more conceivable than introducing new courses and producing totally new materials. Furthermore, school curricula are already full and new programmes can be added only if others are eliminated. In most educational systems, stand-alone programmes would have little chance in competing for the limited educational time against the well-established science, humanities, language and social studies programmes.

Theoretical sources: From Piaget to information processing models of cognition

Among the leading paradigms of psychology that attempted to explain the development and functioning of thinking, at least two must be considered when discussing theoretical backgrounds for using subject matter knowledge to improve thinking. Piaget's theory, despite the controversies and the modifications and

alterations that have been proposed since its original formulation, is still one of the most consistent models for explaining the origin and accumulation of knowledge. The organising principle of the other paradigm that consists of a set of models is that it describes cognition as information processing.

Piaget, influenced by the structuralist approaches of his time and his background in biology, described cognitive development as an adaptation process. Adaptation takes place through two different processes. Assimilation is the process by which a child integrates new information into already existing structures. Accommodation is the modification and reorganisation of the existing structures. The latter takes place when the new information cannot be assimilated into the old structures. In this theory, development is discontinuous; it goes through different qualitative stages and finds its equilibrium or its end stage by reaching the stage of formal operations. From the point of view of teaching thinking, one of the most interesting aspects of the theory is Piaget's epistemological consideration of the origin of thinking skills, or in his terms, operations. The internalisation process starts with concrete operations, the physical manipulation of real objects. Then, when the same operational structures are used on different objects of the environments, the structures became detached from the concrete contents of the operations. The operational structures become internal and the child becomes able to carry out the operations not only with concrete physical objects but also with their symbols, including abstract concepts and verbal propositions. Thus, according this theoretical framework, ready-made knowledge is not acquired, but instead, new knowledge is actively constructed.

Besides this constructivist approach, another important feature of Piaget's work is that he and his co-workers always studied children's reasoning in real situations, in 'semantically rich' contexts, and not in solving content-free puzzle-like problems. The Piagetian tradition emphasises the operational side and the universal features of cognition and pays less attention to the differences. Neither the problem of differences between the individuals nor the differences between the specific contents or domains of thinking are elaborated in the theory.

The information processing paradigm emerged after a series of changes in psychology often referred to as the cognitive revolution. The information processing paradigm drew several of its concepts, ideas and models from computer science, especially from artificial intelligence research. The main research areas of cognitive psychology are concerned with detecting, perceiving and coding information; and with the questions of how meaning is attributed to the information, how knowledge is represented in the mind and how it is organised into schemes and mental models.

The results of the research carried out in this framework have changed our view of the role which knowledge plays in human cognition. Consistent findings showed that productive thinking more likely means mobilising previous experiences and existing knowledge rather than pure, computation-like reasoning. Human cognition is much less rational than was generally believed in the past. Content of the

problems often plays a more important role than its structure. Learning certain skills in a specific domain provides little chance to use these skills in a new, unfamiliar context. In other words, we have little natural ability to decontextualize our thinking skills which are acquired in a specific context.

Models of the semantic representations of information in memory reinterpreted and reinforced of long held views. Specifically, these models suggest that independent pieces of information (e.g. meaningless words, names, dates - in general stand-alone facts and figures) are harder to learn, less accessible and sooner forgotten than information which is organised into coherent units or schemes (coherent texts, stories, descriptions, theories). Organised knowledge and interrelated sets of information are better maintained and more easily recalled, although, more effort is required to reveal the internal relationships of such schemes; in other words, to understand them.

The Piagetian theory and the results of recent cognitive research seem to contradict each other at first glance. However, several researchers have attempted to further develop Piagetian theory and find a balance or a synthesis of the advantages of the two approaches. Some of these researchers are labelled 'neo-Piagetians'. They offer fruitful frameworks for developing programmes for training students' thinking (e.g., Demetriou, Shayer, & Efklides, 1992). Despite the differences in the two approaches, they provide a consistent message: to ensure that students will access previously acquired knowledge, learning must be an active, constructive process.

Certain terms must now be introduced and an explanation of how they will be used in this chapter will be provided here. 'Domain-specific skills' are the procedural components of competence in a certain domain. They comprise the main body of a specialized domain knowledge. An expert of a particular domain is more likely to possess them than a novice. Doing well in school subjects, as well as in professions requires mastering a number of domain-specific skills. The student who skilfully solves algebraic equations or who is able to carry out chemical experiments; the civil engineer who designs homes for her clients; and the lawyer who is able to select, organise and present the arguments, all possess several domain-specific skills. Domain-specific skills are context-bound and are closely attached to the particular content knowledge of the domain. Such skills are relatively easy to identify and describe.

Domain-free, domain-general, or simply 'general skills' are those that contribute to efficient reasoning in a number of different domains. Higher order thinking skills, inductive, deductive and critical reasoning skills, problem solving skills as well as their sub-skills surely belong to this group. These skills may well be candidates for inclusion in general intelligence models. To define and identify them is more difficult. As used in this chapter, the term 'general skills' is not necessarily very complex. Simpler skills, like those that are often called 'Piagetian reasoning skills' (seriation, class inclusion, logical and combinatorial operations, etc.) may also belong to this domain-free set of skills. Carroll (1993) also considers them as

belonging to the factors of intelligence. The structure (operational schemes, patterns of actions, rules) of general skills rather than their content characterise them. General skills may also be context-bound and attached to certain contents, but because of their common structural features, they have the potential to be freed from the particular contents in which they were mastered and then be generalised across the domains.

What the acquired thinking skills are for: The problem of transfer

The most crucial question concerning the programmes that aim to improve thinking is how general the acquired skills are. Are the newly acquired skills strictly context bound or can they be used in a broader area? This is again the question of transferability of thinking skills. To discuss the issue of transfer in general is not the aim of this chapter, but as every training programme needs to explain how the training may have an effect on domains or contexts other than the ones in which trained occurred (see for example Klauer, 1990), the problem of transfer must be dealt with here. Only those aspects that are relevant for the content-based approaches will be addressed here.

The research regarding transfer remains inconclusive. Thus far (as Resnick, 1987, also concluded) for teaching there have been few convincing reports of training programmes which have facilitated truly broad transfer. The way one defines transfer depends largely on one's theoretical position. Those who are closer to the Piagetian paradigm may rely on the larger effects of transfer. Beyond the results of several experiments, practical everyday experiences support this view; after all, to learn everything in every new situation is not necessary. Other views maintain that transfer does not exist or that it occurs very little. Those who are closer to the information processing approach may be more likely to share this view. If transfer does not exist, then the same structures must be relearned in each novel situation.

Depending on how the role of transfer is considered, two types of content-based teaching of thinking must be distinguished here. (a) For those proponents of content-based teaching of thinking who either do not believe in transfer, consider it very limited, or do not think it is important, most of the thinking skills are context-bound and domain-specific. Therefore, they do not care about transfer. They argue for the content-based training of thinking because, in their view, this is the only way to foster thinking. In this framework, thinking skills must be taught in every particular context and domain, because only this can ensure that students become competent thinkers in every possible domain. (b) Other proponents of the content-based methods who recognise the possibility of transfer and aim to teach transferable skills: skills that are learned within one domain, but can be used in others, possibly many different domains. In this model, almost any content area is suitable, because skills can be transferred from anywhere to almost any other content area. If this works, teaching thinking skills in one or in a few domains is sufficient.

In this chapter, another theoretical position is proposed that draws from both above described views and pursue a balance between them. The view argued in this chapter suggests that transfer does exist, although limited, and occurs only in certain circumstances. In some conditions the degree of transfer approaches zero while in other conditions it is significant. Thus, the task is to find those conditions in which transfer works fairly well, and to design training tasks to ensure the best transfer. Thus, the purpose of the research is to find those methods that result in transferable skills.

In the context of content-based methods, transfer should not be considered a yes-or-no, an all-or-nothing phenomenon. Rather, it should be thought of as a measurable, continuous variable, ranging from zero to full transfer. The degree of the transfer may be different for each skill and for every possible pair of domains. Furthermore, the transferability of a skill depends on the conditions under which it was mastered.

Based on the results of a large number of experiments, as well as the theoretical arguments presented in the current cognitive psychology literature, I suggest a somewhat pessimistic view of transfer, that is, it is more productive to hypothese a low level of transfer. Thus, caution and awareness of the limitations of transfer should be taken into account when designing content-based methods for training thinking. Three main plausible limitations should be considered. (a) Even if a skill that is potentially transferable is mastered within one domain, transferability is not a feature that comes automatically with the skill. Thinking skills, especially in the early phase of their development are bound to the content in which they are practised. To make them transferable, further specific training is required. (b) The type and content of the training determines how broad the transfer can be. Skills can be more easily transferred into close, familiar content areas than into distant and unknown fields. (c) The skill itself cannot be transferred into another domain; rather, transfer means an improved ability to learn a skill (with the same or similar structure) in new content areas. The consequence of these constraints for content-based training is that the training exercises must be embedded into every relevant academic subject.

While the very essence of teaching thinking by using the content of learning materials is the transferability of the skills, a more elaborate conception of improving transfer is needed. For this, the sub-domains should be considered as basic units of subject matter that use a consistent set of concepts, facts and domain-specific thinking skills. Within such a unit, transfer is not questionable, because a skill is considered to be acquired if it works for the whole of such a unit. However, the content of the sub-domains is different and transfer between them is not automatic. The topics of the traditional school subjects are such sub-domains. For example, the content of geometry obviously differs from the content of algebra, although both are fields of mathematics. Similarly, mechanics has a content different from optics. In order to make a skill transferable, training in the content of more than one sub-domain is required. This makes it possible to generalise the

skill, and to detach the structure of the skill from its actual content. If a skill is trained with materials from only two different sub-domains, then its transfer into any other area cannot be expected. However, the presumption that the skill will work in at least these two content areas is plausible. Furthermore, another plausible assumption is that after the skill is mastered in two different fields, it will be learned in a third field more easily. Extending this reasoning, the more content areas a skill is trained in the easier it can be learned in a new domain.

Several experiments propose an active and conscious decontextualisation to facilitate the transfer of a skill. Metacognitive effects may be used to improve the transferability. Despite these efforts, the skills usually cannot be universally applied; there are always unfamiliar contexts where application (without further training) fails. If the skill was practised in several different content areas, the training should result in a skill which is applicable in several domains. Thus, from a practical point of view, the content-based method is much less risky to suggest since the training will have certain benefits, even if the transfer is not very broad.

Designing teaching thinking materials in the content areas

General principles of teaching thinking through the content

Since Resnick and Klopfer (1989) introduced the term 'thinking curriculum', a new view about teaching thinking has gradually become more and more dominant. The assumption that cultivating the mind should be the primary goal of school instruction is unquestionable. Accordingly, the task of teaching thinking cannot be completed in one or even a few separate courses. Improving thinking has to be a continuous goal for the entire period of compulsory schooling from the very first day to the final years or even further, until the completion of higher education. The question is not whether thinking can be improved at school; but how it can best be accomplished; how every single lesson can contribute to the development of thinking.

Although the type of training discussed in this chapter is different from both the one that teaches domain-specific skills and the one that teaches general skills in separate courses with abstract, domain-free materials; it does manifest elements of both approaches. Such a synthetic approach has already been proposed by Glaser (1984). Glaser first described the advantages of the domain-free methods on the one hand and the training in the context of specific domains on the other hand, and he cited a method that combines these two. But then he goes on to describe a further possibility, a deeper integration of these approaches: "But rather than switching between general and specific, I would also examine a fourth possibility: teaching specific knowledge domains in interactive, interrogative ways so that general self regulatory skills are exercised in the course of acquiring domain-related knowledge" (Glaser, 1984, p.102) .

The content-based method is similar to the training of domain-specific skills in

that it uses learning materials to train thinking. It is also similar to many stand-alone programmes because the skills to be trained are analysed carefully and described in detail. Furthermore, it is a more or less direct method because the targeted skills are directly practised. It differs from the direct approaches in two ways. In the content based method, instead of abstract contents, the elements of the teaching materials are used, and the training is not limited to a short period of time.

One of the main characteristics of a domain-independent method is the precise analysis of the structure of the skills to be trained. One example of this precise description of the skills is Klauer's (1993a, 1993b) system which is the basis of a stand-alone programme for developing inductive reasoning. Such descriptions, as will be illustrated later, can be utilised for the content-based methods as well. However, the development of content-based programmes requires further work. The main steps of this process to be illustrated in the next section of this chapter are: (a) defining the goals of the training; (b) identifying and defining the skills to be developed; (c) selecting the teaching materials to be used for the training; (d) analysing the subject matter knowledge and searching for places where specific exercises can be embedded; (e) designing the training exercises; and (f) integrating the exercises into the teaching-learning processes.

The next sections describe a process for a possible implementation of teaching thinking in the content areas. The description of this approach will be given through examples from experimental programmes. Since 1985, in the framework of several research projects, we have been experimenting with modified teaching materials and the examples presented here are from these projects (Csapó, 1990, 1992, 1995).

As it is a principle of the content-based method, the subject matter is the concrete material for the training of thinking skills. Accordingly, the examples presented here are from the subject matters of chemistry, physics and grammar. The purpose of these examples is only to illustrate the possibilities of this method, and the examples quoted here should be comprehensible to those who are not experts in the given disciplines. Thus, both with respect to the given skill and the content in which they are practised, the simplest possible examples are presented. However, I must emphasise, that the described method is not limited to such simple skills or well-known contents. It can be used practically anywhere if (a) the particular skills to be developed can be defined and described and (b) the learning material is complex enough to accommodate well structured problems and exercises. When designing a content-based training programme, the first phases of the work are the same as those for the stand-alone programmes. Therefore, the experiences of the stand-alone programmes can be utilised. The other phases of the work, developing and using the exercises, are different.

Defining the goals of training

The purpose of training: The outcome and the aimed group

To conceptualise the goals of the training, two related aspects must be examined: (a) What do we consider to be the outcome of the training? and (b) Which group should be targeted? As for the first aspect, the changes that can be expected in students' cognition must be clarified as to the ways in which these changes are to be measured. In other words, what are the specific criteria for claiming that training has improved students' thinking? Criteria often mentioned are: (a) Can students use their skills in the same domain in which those skills were acquired (does the training have any effect at all)? (b) Can students use their new skills in other domains (is there any transfer)? (c) Do students perform better on general intelligence tests (is there a broad transfer)? and (d) Have students become better learners (does the training affect their learning abilities)?

In the content-based approach all of these goals and levels of evaluation may be relevant but a new way of evaluating the effects of training can also be proposed. Have the students become more intelligent users of the knowledge they have mastered during their training? As a result of the modified ways of teaching, students can be expected to become more competent users of their knowledge; develop a deeper understanding; become better able to mobilise their knowledge in other contexts when it is appropriate, apply it to new situations, apply their abstract knowledge to everyday situations, and make decisions on the basis of their scientific knowledge instead of their naive theories or misconceptions.

The second aspect regarding the goals of training is determination of the targeted group. In general, three groups can be targeted: those whose skills or abilities are below average, around average and above average. However, the methods are not equally beneficial for each of the three sub-populations. (a) Those who are below average may require remediation. They may have learning difficulties or certain problems of understanding that must be corrected in order to catch up with the average students. If the aim of teaching the subject matter is to achieve a deeper insight and understanding, and the students - because of the lack of understanding - cannot do more than simply memorise the material, the proposed content-based methods are typically for them. The proposed method that stimulates thinking about the material to be mastered may be especially helpful for this group. (b) For those students who are average, the training may enhance development beyond that which would be reached with regular instruction. The average students may be the primary targets of the content-based methods. (c) Those who are above average already excel in acquiring and understanding the learning materials and these methods offer little extra benefit. For them more challenging learning materials should be offered instead of the regular materials with more intensive thinking.

Selecting the skills to be trained

To design a programme for teaching thinking, a taxonomy, or at least an inventory of the thinking skills, is needed. A list of the skills to be developed is also required and several attributes of these skills must be specified.

A universally accepted model or a methodical description of thinking for a system or inventory of thinking skills is still a long way off. However, several inventories or taxonomies can be used as an initial model for designing the training. It is not my intention to collect the available training models nor to list the skills that may be developed through the content of teaching. Instead, in this chapter I will address the attributes of the skills which are imperative to succesful training. At least four attributes of skills should be considered before designing the training: (a) relevance, (b) development, (c) structure, and (d) modifiability of the skills.

As for relevance, only thinking skills of broad relevance should be considered. However, for designing training in certain domains, one must examine whether specific skills have relevant function in the reasoning within the given content domain.

Knowledge of the general 'developmental tendencies' of the given thinking skills is necessary. A theoretical model for the development of the given skills would be helpful. Furthermore, empirical data regarding the development of the skills under natural circumstances is needed. Developmental curves may indicate in what period the changes are fastest under natural circumstances and what is the developmental level that the students reach in average without the intervention. Examining individual differences may also help to make decisions about the goals of training.

'Modifiability' is a crucial feature of the given skill. Experiments, even the results of experiments carried out under other conditions, may be helpful in deciding whether an attempt to improve a skill for certain age groups is worthwhile. Modifiability may also be age dependent, so results of experiments with children of certain ages may not be generalisable to children of other ages without further consideration. It is also important to determine whether there are specific ages during which a skill is especially sensitive to developmental influences and, whether there are 'imprinting like' periods during which fast improvements can occur.

The characteristics listed above are helpful in designing training programmes. A massive body of research data is available for this purpose, but there are only a few skills that are described more or less completely in the terms proposed here. In general, the more we know about a skill, the better our chances are of designing an efficient training programme. Without such detailed information some chance may still exist to design successful training, but such detailed information is indispensable in one aspect, namely one has to know to the structure of the given skills.

From the point of view of designing content-based programmes, the 'structure'

is the most important characteristic of the skills. This is the feature by which the skills can be described and identified. Only if the structure of a certain skill is known, can the same skill be embodied in different contents and the same skill (the skill with the same structure) developed in different content areas. The structure of the skills may be described verbally, but formal models are the best representations of the structure of the skills.

Knowing the structure is a necessary condition for designing training programmes and it is the structure which poses the strictest limitations on the content-based methods. The structure of simple thinking skills can be easily described, but the structure of those skills that are often referred to as higher order thinking skills are difficult to describe. Nevertheless, successful attempts to describe the structure of such skills have been made.

Preparing the training materials: Some examples

One of the main differences between the American and the European educational systems is that in most of the European countries the content of teaching is more strictly defined and a larger proportion of teaching materials are centrally or locally prescribed. In some European countries the content of teaching is defined in national core curricula, while in other countries it is prescribed by local governments or educational authorities. Nevertheless, the discussion in this chapter considers the content of teaching as given, defined and organised by disciplinary experts. Accordingly, only minor modifications can be made when teaching content.

In the first step of preparing training exercises, the learning materials (curricula, textbooks, other instructional materials) must be analysed to identify where the skills can be exercised or where such exercises can be placed. This requires that the elements of knowledge (concepts, propositions, etc.) which can be used as materials for constructing training tasks be identified.

The working hypothesis to begin this analysis is as follows: if general thinking skills that can be applied to several activities in several content domains actually do exist; and if such thinking skills are general and relevant; then they must be found in (almost) any larger units of (almost) any content area. That is to say that general thinking skills are already present or they can be incorporated without abandoning the original goals of teaching. Such skills may even foster better acquisition of subject matter knowledge.

Constructing training exercises requires unifying the already prepared structures of skills with the given elements of teaching materials, or in other words, to fill the 'empty structures' with the actual content in order to give the abstract or formal description of the structure a concrete meaning. Three examples will serve to illustrate the design of training materials.

Deductive reasoning

The development, role and place of logical operations in thinking is one of the most controversial issues in cognitive psychology. This is also the field where the Piagetian theory most sharply clashes with the information processing paradigm. On the one hand, formal thinkers - in Piagetian terms - are supposed to solve certain logical tasks whatever the content of the tasks; on the other hand, children solve logical tasks with familiar contents, yet often fail to solve tasks with the same structure but unfamiliar content. How do these problems appear in school learning, and can student's logical reasoning skills be improved? Experiments indicate that teaching formal logic is of little help. Can such skills be developed by using the content of teaching?

Primary school science textbooks are full of propositions of complex logical structures and children are able to learn these correctly. They reproduce the statements when they are asked in the same context and usually they are able to interpret accurately what they have learned in the context of the given content. But even if they know the actual meaning of the complex statements, they are rarely able to generalise the logical structure of the statements and use the same logic in other cases.

For formal descriptions of reasoning skills, binary operations of propositional logic are the best examples. These operations form the central part of the Piagetian logico-mathematical structures, and the system of the sixteen operations is well elaborated and easy to represent formally. In the textbooks, propositions are often connected with such operations (AND, OR, IF ... THEN, etc.), and, especially in science texts, understanding of the exact meaning of these complex statements is crucial.

An example for such an operational structure is: IF (p OR q) THEN r (where p, q, and r are simple propositions).This structure can be embodied in several contents if p, q, and r are substituted with real, meaningful statements. For example, if p = 'the milk is pasteurised', q = 'the milk is boiled', and r = 'the harmful bacteria are destroyed', then the actual content of the operational structure is: If the milk is pasteurised or boiled, then the harmful bacteria are destroyed.

This is a real statement that can be found in a real school textbook. How can a training exercise for logical reasoning be built around this complex statement? First, the logical nature of this statement must be emphasised. Several ways for doing this are available.

One way is the systematic evaluation of the logical truth-table of the complex proposition. We may systematically consider what happens to the bacteria when the milk is: neither pasteurised nor boiled, pasteurised but not boiled, not pasteurised but boiled, both pasteurised and boiled. Then the difference between the actual status of the bacteria and the truth of the whole complex statement can be discussed, as well as, whether the statement itself is true when the p, q, and r propositions are respectively: true-true-true, true-true-false, true-false-true, and so on. Of course, the whole discussion should be about the actual problem, in the

terms of pasteurisation, boiling and bacteria. The very essence of the exercise is to prompt the students to think in an organised, structured way about the material to be learned.

Another possibility is to ask students to tell the same thing in different ways. Whether the different wordings mean exactly the same thing can be discussed. The students can be asked how they can prove that this complex statement is true. What experiments should be carried out? What kind of possibilities should be examined to ensure that the statement is true? Why do the students think that the statement could be proved in a certain way? How could the statement be falsified? What would be the facts that could contradict the statement?

These exercises should be organised in a realistic and meaningful way. For example, students may discuss where boiling milk is still practised, where pasteurisation is practised, and what are the advantages of pasteurisation. Then the students could be asked, what happens to the bacteria if pasteurised milk is boiled.

Another way to emphasise the logical nature of a statement is to help students to decontextualise the structure of the skill with some further practise. The students may be asked if they have ever dealt with a statement that is similar to the one under discussion. If they respond with an example, it can be analysed to determine if it is really similar. Students can be asked why they believe it is similar, what similarity in this case means, whether the rules discussed previously apply to this statement, and, whether they can construct similar statements?

A principle of this method of improving thinking is to use neither technical terms nor formalisations. Everything should be expressed in terms of the actual content of learning. Long-lasting results may not be expected from one or even a few exercises. Many such exercises should be carried out during an academic year and the skills should be practised over several years until students reach the optimum level in the given skill.

Of course, deductive reasoning cannot be limited to the logic of propositions. Exercises may be constructed for other types of deductive reasoning as well, in a way similar to the process presented here.

Combinatorial reasoning
According to Piaget's theory of cognitive development, combinatorial reasoning is an integral part of formal thinking (Inhelder & Piaget, 1955). Since the operational structures examined by Piaget and his co-workers (Piaget & Inhelder, 1951) can also be formally represented and organised into a more complete system, the development and structure of combinatorial reasoning can be empirically studied and described (Csapó, 1985). Combinatorial reasoning plays an important role both in school learning and everyday thinking. It is performed when different elements are combined into larger units or constructions and several, usually all possible constructions, are looked for or enumerated and examined. Well-developed combinatorial skills may improve the fluency of thinking when considering different solutions for a problem; finding unusual relationships

between certain elements, concepts, propositions; or generating a large variety of patterns from given units.

The example presented here for the training of combinatorial reasoning is from a set of exercises devised from the contents of seventh-grade chemistry. This example illustrates how such exercises may help students to find unusual relationships between given concepts. In this way the ability to make remote associations may be developed as well. In this example, the aimed thinking structure may be formally described as enumerating all possible combinations of two elements of a given set. Let's consider a set of five elements: {A, B, C, D, E}. The combinations may be enumerated in this way: AB, AC, AD, AE, BC, BD, BE, CD, CE, DE.

The textbook, an existing and broadly used chemistry book, that provides the content for devising the training tasks, lists some possible groupings of materials in an introductory section. The groups of materials introduced there are: sources of energy (A), inflammable materials (B), nutritive materials (C), metals (D), and minerals (E). Students could be asked to combine these aspects in every possible way (combinatorial reasoning) and then to discuss the connections between the various concepts in pairs (making the exercise relevant in terms of the given content).

The possible pairs of the five groupings are:
- Source of energy - inflammable material.
- Source of energy - nutritive material.
- Source of energy - metal.
- Source of energy - mineral.
- Inflammable material - nutritive material.
- Inflammable material - metal.
- Inflammable material - mineral.
- Nutritive material - metal.
- Nutritive material - mineral.
- Metal - mineral.

After enumerating the possible pairs, students could be asked what they can say about these relationships. This allows for the collection of many known facts, for example, numerous sources of energy are inflammable; certain nutritive materials are sources of energy for living organisms; salts of certain metals are vital, whereas others are poisonous for living organisms; most of the metals can be found in the form of minerals in Nature, and so on. The unusual combinations of the groupings of materials inspire students to reason in a way that is different from the usual pattern of a given discipline but may be practised across disciplines. These operations offer a new possibility for increasing the consistency of knowledge because they highlight relationships which might otherwise never appear in the teaching-learning processes (Csapó, 1990).

This specific exercise was placed at the beginning of the study of a new topic and used for mobilising students' preliminary knowledge. These types of activities

are especially helpful for embedding a new body of knowledge into the students' existing experiences. They allow the students to relate their previous everyday experiences with the framework of knowledge to be acquired. Such an exercise may also be used at the end of a topic. After summarising and organising the newly mastered knowledge according to its internal logic, it may then be viewed from a different perspective. These kinds of exercises may help students cope with the isolation of the knowledge of a specific topic by building a large number of associations with other fields.

In several cases, the combinatorial structures are given in the learning materials and students carry out enumerations with great accuracy by using the given contents. However, the skills of enumerating the possible combinations are strongly attached to the given content and students are unable to decontextualise the operational structure of the skill and are unable to use it outside of the given context. Such examples can be found in grammar or foreign language learning. To form pairs from two sets of elements, for example {S, P} and {1, 2, 3}, such that the first component of the pairs should be chosen from the first set, while the second component from the second set, the enumeration of the possible pairs (the Cartesian product of the sets) is: S1, S2, S3, P1, P2, P3.

If S stands for singular, P for plural, and 1, 2, and 3 for the first, second and third person, this abstract structure becomes the well known pattern for the conjugation of verbs. Students do these enumerations when learning grammar, especially in languages where the cases have different endings. This structure must be reproduced when learning the formal grammar of another language. Students often have to compare the similarities and differences between their first and second (third, etc.) languages. In German, for example, some of the cases are not different but in French the verb 'être' is different in every case. In Hungarian every regular verb has different endings in the different cases. Thus, the above enumerated formal structure can be embodied by the conjugation of verbs of different languages, as the following example illustrates:

Formal structure		German		French		Hungarian	
S1	P1	lerne	lernen	suis	sommes	tanulok	tanulunk
S2	P2	lernst	lernt	es	êtes	tanulsz	tanultok
S3	P3	lernt	lernen	est	sont	tanul	tanulnak

Within the framework of language learning, students usually learn these skills for enumerating such lists and they are even able to recognise the pattern of correspondence, similarities and differences between them. However, students are usually not able to extend the scope of these skills, the operational scheme of the enumeration, beyond the context of grammatical structures. The decontextualisation process may be facilitated by 'translating' the structures into another content

that is obviously outside the context of natural languages. For example, if singular is 'translated' into 'square' and plural into 'circle', and then the first, second and third persons are 'translated' into blue, yellow and red colours, students can be asked to construct a pictorial representation of conjugation. They would draw a blue square, a yellow square, ..., and a red circle.

Transferring the skill into a remote domain cannot take place without further efforts. In order to develop a skill with the same structure in physics, students must practice the skill with contents taken from physics. Such an exercise can be created when students are experimenting with the pendulum. In an exercise with the same '2x3' structure, students are provided with a heavy (H) and a light (L) ball that can be put at the end of a short (S), medium (M) or long (L) string. If students are to observe how the time of the pendulum swing depends upon the weight of the ball and the length of the string, the best strategy is to construct every possible variation of the pendulum from these materials. Accordingly, pendulums of HS, HM, HL, LS, LM, and LL should be constructed and then students can perform the necessary measurements and comparisons. Then, the structure can also be extended within the context of physics by designing experiments with more elements (4x5 measurements and so on) and by introducing new dimensions (sets, variables).

Much can be done to extend these combinatorial structures within grammar as well. For example, a new dimension can be introduced by using different tenses. Students usually have difficulties considering more than two dimensions at the same time, and enumerating grammatical structures in unusual order may help to overcome this difficulty.

Latin grammar was taught for centuries in the belief that it cultivated the mind. Maybe it really did, at least to some extent, otherwise it could not have been a practice lasting for centuries. But the benefit of those rigid exercises could hardly have been proportional to the sufferings and boredom of the students. Of course, when examining the possible utilisation of grammatical structures in the training of thinking, I do not intend to revitalise those old practices. On the contrary, I would like to show, that some easy and playful exercises may help to decontextualise the skills that children acquire with almost an imprinting-like ease.

Following the well-structured rules of enumerating combinations and variations does not necessarily mean limitations, rather, it may be the starting point for creation and construction. This was observed in an experiment when combinatorial operations were developed in art education. After some examples of systematic enumeration were presented, children produced a great number of variations of shapes, figures and colours in their drawings (Zombori, 1992).

The above examples show that not only transmitting disciplinary knowledge and fostering cognitive skills can be linked but also the processes and exercises of improving different types of thinking skills. In these examples, students were supposed to compare things, recognise similarities and differences, and eventually find analogies. These are the processes of a more complex skill, inductive reasoning.

Inductive reasoning

Inductive reasoning is different from the other two types of reasoning examined in the previous sections. While the previous two reasoning skills are examples of skills that are rather simple and easy to describe, inductive reasoning is a type of thinking that is often referred to as a higher-order cognitive skill. Its central role in thinking and its relationship to general intelligence is broadly studied in several relationships and contexts; several intelligence tests contain inductive reasoning tasks. Inductive reasoning has been studied as a central component of critical thinking (Ennis, 1987); as one of the mechanisms of hypothesis generating and hypothesis testing (Gilhooly, 1982) and concept development (Egan & Greeno, 1974; Gelman & Markman, 1987; Markman, 1989); and as one of the basic learning abilities (Pellegrino & Glaser, 1982) or learning skills (Ropo, 1987); while current works use inductive tasks to measure learning potential (Resing, 1993; Tissink, Hamers, & Van Luit, 1993).

Holland, Holyoak, Nisbett, and Thagard (1986) presented a comprehensive theoretical analysis of inductive reasoning. Klauer (1993a, 1993b) developed a formal description that is used for defining the structures of the tasks in his training programmes. In terms of Klauer's definition, the essence of inductive reasoning can be identified by comparison processes: attributes of objects and relations between the objects are compared to detect similarities and differences.

Since inductive reasoning is a rather complex cognitive skill, in order to develop it within the framework of teaching subject matter knowledge, inductive reasoning must be dealt with at a higher and more complex level, where larger units and more advanced thinking processes can be identified. In this way, inductive processes can be described at two levels. (a) Formal descriptions, like Klauer's, allow identification of certain forms of inductive reasoning by their structures and embodiment of the same structure in different contents. Here, these contents are the elements of teaching materials. (b) The extensive previous research into induction resulted in a large amount of theoretical and empirical knowledge that can be mobilised to identify larger units of inductive reasoning. These larger units should also be identified in the learning processes, and training exercises should bear the relevant attributes of these larger units of thinking.

At this higher level, for example, such processes can be identified, and trained across several topics within a domain or across several school subjects (Csapó, 1995):

- Generalising rules from measurement results, observations, and everyday experiences; hypothesis formation and hypothesis testing.
- Analogies, where the relationship can be element-set, part-whole, cause-effect, contrast, function, transformation, origin or functional part-whole.
- Series to continue, where the members of a series are connected to each other by the relationship of element-set, part-whole, time, cause-effect or transformation.
- Grouping, organising facts and figures, creating two or more dimensional tables,

system formation.
- Concept formation and concept development, concepts as sets and subsets, comparing everyday and scientific concepts.
- Complex analogies, analogue series, analogue systems, parallel developments, isomorphic phenomena, rules and laws.

Inductive approaches are well known in educational practice; teaching by examples, among others, is an old method. However, a closer look at existing educational practice reveals that students usually are provided with ready-made knowledge, even if the knowledge presented to them is the result of inductive processes. Students are not expected or forced to think actively. In order to advance beyond this practice, teachers have to receive more theoretical support and be provided with applicable methods. The teaching material must be modified and enriched with exercises that require active thinking.

This will be illustrated with an example taken from the chemistry curriculum. (since the exercise must be presented here in a simplified way, the details of the chemical aspects will be omitted). From two related parts of the textbook, two phenomena can be brought together and presented as an analogy: the battery and the corrosion. In this exercise, a pictorial representation of these two chemical phenomena is presented (a battery on the one side and a corroding piece of iron with water and atmospheric oxygen on the other side). Then the students are asked to analyse the two phenomena. At first, they are asked to list the similarities and differences they can observe. At this step they may collect both relevant and irrelevant features. In the next step students have to express their observations in chemical terms (electrolyte, positive electrode, negative electrode, and so on). In this way, they realise that the two phenomena can be described with common terms and they can recognise similarities again, in a more explicit way. They may be asked to find corresponding parts of the two sides of the figure (part-whole analogies). Then they should find the scientific term that names the essence of the common features of the two phenomena (electric cell - concept formation and concept development). When students are asked what makes the two cells work (chemical energy - similarity), a functional analogy can be shown. To return to the differences, the concrete materials may be examined and the chemical reactions in the two cases may be compared, as well as the different voltages, energies, and reaction speeds. Practical applications may also be discussed by collecting the similarities and differences, and comparing beneficial and harmful aspects.

The exercise built on the above scheme can serve several functions in the teaching process, depending upon its place in the curriculum: (a) one of the phenomenon is already known and the other phenomenon can be explained by using the analogy; (b) both phenomena are already known, but the common features can be generalised and a higher concept can be taught; (c) two or more phenomena may be introduced in parallel, to generalise common features.

These suggestions are not strange and are not even new in the context of current science education reforms. Activities like these have frequently been proposed,

sometimes under other terms (for example analysis-synthesis). Scientific reasoning skills are considered main components of general intellectual skills (see Voss, Wiley, & Carretero, 1995), and inductive reasoning, especially hypothesis generating and hypothesis testing, is supposed to be best trained in the context of science education. However, in order to teach transferable skills and make the skills usable beyond the context of dealing with sciences, the same type (structurally identical) reasoning skills should be trained in history, grammar, and other subjects. These skills can be used beyond one or a few given contexts.

Here the ideas that thinking skills cannot be separated and that different types of thinking abilities should be practised within the teaching of every particular topic of each subject matter must be emphasised. To show a possible relationship between the types of thinking used in these examples, another exercise can be considered. Students are given six different materials: A, B, C, D, E, F. Among these are materials that can be used as electrodes and electrolytes. The students are asked to construct the best battery (electric cell) from these materials. One strategy is to compose every possible combination of three materials (ABC, ABD, ..., DEF), and then exclude those that cannot form an electric cell. Then the students determine (by theoretical or experimental methods) which cell would produce the best result. Another strategy utilises analogical reasoning, especially finding structural analogies which may be helpful in the decontextualisation processes. Improving the transfer of a given skill from one domain to another may be accomplished through collecting analogous exercises from the different domains.

Integrating the exercises into the instructional process

During the design phase, for analysis, the structure of the exercises designed to practice a given thinking skill must be clearly identified. But for practical use, the exercises must be integrated into the teaching-learning processes. The training exercises must not be artificial or unusual in the given context; otherwise they would become somewhat independent from the given context and they would do no more than the context-free exercises. The exercises must be embedded in the process of acquiring the subject matter knowledge and they must contain real functions in it. The practice of thinking skills has to be consistent with the original goals of teaching and must facilitate better acquisition and understanding.

Thinking exercises can be used to improve knowledge acquisition in several typical ways:
- Thinking exercises can establish relationships between old and new knowledge, in order to integrate new information into the context of the existing body of knowledge.
- Practising thinking skills may be used to build relationships between the different areas of the existing knowledge. It can promote the integration of the knowledge of different sub-domains of a discipline or of several disciplines.

- Training exercises can be used to enrich the connections between the students' previous everyday experiences and their scientific knowledge. Training may facilitate the substitution of naive generalisations, theories, and misconceptions with more appropriate scientific knowledge.
- Training thinking skills may facilitate the use of newly acquired knowledge by connecting it to practical applications through reasoning processes.

The exercises can be integrated into the teaching-learning process in several different ways. The best approach is probably a combination of the different possibilities in order to avoid monotonous, schematic and boring training. The optimal proportion of the different applications largely depends on the age of the students and the type of domain. Some possible ways to integrate the exercises are: (a) interactive classroom work with teacher guidance; (b) group work utilising co-operative learning; (c) student experiments in the laboratory; (d) individual work with worksheets, workbooks; (e) individual projects that require performing several structured exercises; and (f) several forms of homework.

The training exercises can be embedded into the teaching processes at several levels. Since such embedding requires competence in at least two domains (in the given school discipline and in the thinking skills), it can be best accomplished by specially trained experts and working groups. However, the required expertise can be acquired by practising teachers as well. Thinking exercises can be designed for one or more lessons spanning one or more weeks of study. However, more enduring effects can be expected only from longer periods of training, i.e., training which lasts at least a semester if not a whole school year. Such training program-mes can usually be developed by groups of teachers and other experts. Depending on the curriculum policy of a given country, such training programmes could be designed at national as well as at local (school district or school) levels.

In an ideal case, training thinking would be consistently designed for a variety of cognitive skills, carried out in several school subjects, and continued for several years or for the whole schooling period. Despite conscious efforts, a curriculum that places as much emphasis on teaching general thinking skills as on teaching subject matter knowledge is still far from reality. Maybe Nisbet was too optimistic when he predicted: "... 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, p. 290) However, sooner or later this prophecy will be fulfilled.

Concluding remarks: Problems and promises

The idea of training thinking through the content of teaching is not new at all, but as current literature shows, only in the last decade has it attracted attention and inspired comprehensive research projects. Since large-scale experiments and the implementation of these ideas in practice require more time, it is too early to

determine whether it can be used in everyday practice and whether the benefits of modified instruction are worth the extra efforts invested in designing training exercises and modifying instructional practices. Even though the time is too short and the number of large-scale experiments are too few to draw strict scientific conclusions about the practical applicability of these approaches; and despite the enthusiasm observable since the 1980s, theoretical analyses and propositions still outnumber the real experiments.

Although the conceptual framework for evaluating large-scale experiments has improved a great deal, and not only well-founded theories exist but also empirical studies, (see, for example, Adey & Shayer, 1994; Shayer, 1992) the evaluation of content-based developmental programmes needs further refinement. New approaches are necessary; for example, to find better assessments of the quality and accessibility of knowledge.

A further problem concerns the replicability of content-based intervention studies. While the content of the regular curriculum is used to design training exercises, these exercises must be produced again and again if the conception of the training is to be transferred from one educational system in another or even from one subject matter to another subject matter. Similarly, successful training programmes cannot be directly exported from one system into another. Consequently, ensuring standard conditions for experiments is difficult, and measurement and comparison of the effects of the training are not possible with the same accuracy as are possible with the stand-alone curriculum-independent training programmes.

From the content-based methods one cannot expect great results in the short run. These methods work better if applied in several school subjects over several years. So, short term effects may hardly be detectable. The efforts invested in devising better curricula may offer a higher return at the societal level; small changes accumulate over the years and, if the improved curricula is taught to large masses of students, the small effects accumulate again.

The examples presented in this chapter are simple. The principles of the training may be generalised and can apply whenever the structure of the targeted skills can be determined. But how far can we go in describing the structure of higher order skills? Whether the growing attention to content-related methods of fostering thinking indicates that the pendulum is now swinging from the general abilities to the direction of content knowledge or whether this recent emphasis on the integrated methods indicates a final or at least a temporary balance between the two sides of the dilemma remains to be seen.

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