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Teachers' metacognitive knowledge and the instruction of higher order thinking

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Abstract

The purpose of the present study was to investigate teachers' declarative metacognitive knowledge of higher order thinking skills. This was a qualitative study conducted within the educational setting of in-service science teachers' courses. The main finding is that teachers' intuitive (i.e., pre-instructional) knowledge of metacognition of thinking skills is unsatisfactory for the purpose of teaching higher order thinking in science classrooms. A general practical implication of this study is that courses which prepare teachers for instruction of higher order thinking should address extensively the issue of metacognition of thinking skills.

Keywords: Metacognition; Higher order skills; Teacher thinking; Science teachers; Teacher education

1. Introduction

The call for transforming schools from teaching "basic skills" towards "schools for thought" (Bruer, 1993) seems to reflect a growing consensus among educators. Researchers and educators worldwide have responded to that call, investing costly resources in projects whose primary goal is to enhance students' thinking. However, a serious impediment to wide and successful implementation of many such projects is the lack of adequate methods for pre-service and in-service staff development. A necessary condition for designing such methods is knowledge of teachers' cognition in relation to the teaching of higher order thinking. Therefore, we must first study teachers' cognition from the perspective of the special challenges they face while teaching for thinking. Gaining knowledge about teachers' intuitive knowledge regarding teaching for thinking could improve our ability to plan staff development programs.

Broadly speaking, the purpose of the present study was to investigate teachers' metacognitive knowledge regarding higher order thinking skills in the context of a specific project designed to foster higher order thinking in junior high school science classes. The following sections begin with a

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discussion of the concept "metacognition" in general, then go on to discuss metacognition in educational programs aimed at fostering students' higher order thinking skills. Following that, the educational setting in which the study took place will be described. Finally, some of the literature regarding teachers' thinking will be discussed from the perspective of the present study.

1.1. The concept "metacognition"

The concept of metacognition, which has become quite fashionable in contemporary cognitive psychology, refers to one's knowledge and control of one's own cognitive system. Although it is widely applied, the concept is used in two different senses, generating a considerable amount of tension and confusion. One sense of metacognition is knowledge about the cognitive system and its contents, and another sense is the effective regulation and control of that system (e.g., Braten, 1991). This knowledge/control distinction is reflected in several attempts to define metacognition. For example, Flavell (1976) defined the concept as follows:

> Metacognition refers to one's knowledge concerning one's own cognitive processes and products or anything related to them, e.g., the learning relevant properties of information and data. For example, I am engaging in metacognition … if I notice that I am having more trouble learning *A* than *B*; if it strikes me that I should double-check *C* before accepting it as a fact … " and "Metacognition refers among other things, to the active monitoring and consequent regulation and orchestration of these processes in relation to the cognitive objects or data on which they bear, usually in the service of some concrete goal or objective" (p. 232).

Brown (1987) includes in her definition of the concept the same central distinction:

> Metacognition refers to understanding of knowledge, an understanding that can be reflected in either effective use or overt description of the knowledge in question (p. 65).

Schraw and Moshman (1995) refer to the same basic distinction between metacognitive knowledge (i.e., what one knows about cognition) and metacognitive control processes (i.e., how one uses that knowledge to regulate cognition). They divide metacognitive knowledge (following others, e.g. Jacobs & Paris, 1987) into three kinds of metacognitive awareness, one of which is *Declarative knowledge*. The present paper will address primarily metacognitive declarative knowledge which refers to what is known in a statable, propositional manner, knowing "that" or knowing "about" things.

Although those definitions of metacognition may seem clear, it is important to note that there are many other definitions (e.g., Brown, Bransford, Ferrara & Campione, 1983; Brown, 1987). In addition, it is often difficult to decide about the boundaries between what is metacognitive and what is not and it is also hard to distinguish between the various components of metacognitive knowledge. The concept has numerous origins, meanings, and fuzzy borders. Wellmann (1981, cited by Brown (1987, p. 106)) was one of those who referred to the concept of metacognition as a "fuzzy" concept, writing that "agreement as to whether an activity is legitimately metacognitive breaks down; the definitional boundaries are truly fuzzy". Brown, Bransford, Ferrara & Campione) (1983) open their comprehensive review of metacognition by defining two primary problems with the term, the first of which is that "it is often difficult to distinguish between what is meta and what is cognitive". In addition to the general complexity of the concept, a specific difficulty in the present study is that a thorough analysis of metacognition in relation to instruction of higher order thinking has not yet been carried out. Some of the senses by which specific incidents of metacognitive thinking will be referred to below may therefore be debatable, because the thorough theoretical investigation required to sharpen the relevant definitions is beyond the scope of the present study.

1.2. Metacognition in higher order thinking educational programs

Despite the "fuzziness" of the concept, programs for enhancing students' higher order thinking often include metacognition as a significant component. In a comprehensive book, 'The Teaching of Thinking Skills' (Nickerson, Perkins & Smith, 1985), the authors write that "Many of the programs we have considered have metacognitive aspects … Some of the experimentation has involved trying instructional procedures [i.e., of metacognition, A.Z.] in the classroom and the results are clearly germane to the general topic of teaching thinking … A growing number of investigators believe that metacognitive skills are teachable and useful" (p. 294). The authors predict that "an emphasis on metacognitive skills may soon find its way into many instructional programs" (p. 302). Nickerson and his colleagues note that one especially prominent point in the teaching of metacognition is its relationship to transfer:

> Metacognition relates to the issue of transfer of training in at least two ways. First, there is some evidence that metacognitive skills are more likely to transfer spontaneously than are other types of skills. Second, there is the possibility of treating transfer itself as a metacognitive skill and attempting to train it directly …
> With respect to the second way in which metacognition relates to transfer, one sees evidence in the literature of a growing interest of the possibility of teaching generalization and transfer directly. That is to say, rather than viewing generalization and transfer as hoped-for by-products of teaching that focuses on something else, educational researchers are beginning to take the position that if what one wants a child to learn is how to apply a principle or a skill in a variety of contexts, that is what one should explicitly try to teach him to do … Two ways of facilitating transfer or generalization are especially worthy of attention, Brown … suggests. One is to give training in several different settings. This should preclude the possibility of the skill being "welded" to the single situation in which it was acquired. The other is to … (teach) transfer itself … as a metacognitive skill. Presumably the two methods complement each other, in as much as the ability to recognize situations for which a specific skill is appropriate should be enhanced by the practice of exposing one to a variety of tasks for which the skill is useful as well as some for which it is not (Nickerson, Perkins & Smith, 1985, pp. 300–302).

In reviewing programs designed for teaching higher order thinking, it can be seen that several meanings of metacognition play an important role in such programs. Many examples for the regulation/control meaning of metacognition can be found in the problem-solving literature. Flavell (1976) asks whether there is anything that children could be taught that would improve their problem -solving ability and suggests a set of several possible guidelines as candidates:

> Examine task features carefully. Is there a problem here? … Keep track of past solution efforts, their outcomes, and the information they yielded, using external records … Actively "remember" to remember, monitor and update information and actively bring this information to bear on the problem … .

Similarly, Brown and Campione (1978) suggest that problem- solving performance may be enhanced by teaching children an explicit set of metacognitive admonitions and questions to review before proceeding with the problem. Another example is found in Schoenfeld's (1985) work on mathematical problem-solving, where students learn to monitor and direct their own progress, asking questions such as: What am I doing now?, Is it getting me anywhere? or What else could I be doing instead?.

An example of applying metacogntitive declarative knowledge in a program designed to foster higher order thinking is found in CASE (Cognitive Acceleration through Science Education, Adey, Shayer & Yates, 1989; Adey & Shayer, 1990, 1993, 1994) where "Metacognition in the sense of conscious summary of strategies successfully applied, and naming of verbal tools used is one of the features of every CASE lesson" (Adey & Shayer, 1994). More elaborately, the role of metacognition in CASE is explained in the following way:

> In a Thinking Science lesson, the teacher asks pupils to talk both with the teacher and with each other about difficulties and successes they

> have with problems, not just saying "That was difficult," but also explaining "what was difficult about it, and how did I overcome the difficulty?" Students become accustomed to reflecting on the sort of thinking they have engaged in, to bringing it to the front of their consciousness, and to making of it an explicit tool that may then be available for use in a new context. Using words to describe reasoning patterns is another aspect of metacognition. The aim is for CASE students not only to be better equipped to recognize a proportionality problem, for example, when they see one but also to be able to say, "That's a proportionality problem!" and so open the door to a particular set of solution strategies. This is a special application of what Vygotsky (1978) described as the use of language as a mediator of learning. The language of reasoning mediates meta-learning (Adey & Shayer, 1993, pp. 9–10).

It is true that, according to some definitions of metacognition, the knowledge described above may be seen as knowledge of task variables and knowledge of strategy variables (e.g., Flavell, 1987), or as the monitoring function that is typically referred to as a component of the metacognitive control processes. But, nevertheless, a central feature of the knowledge described in the second part of the citation is definitely declarative and the CASE. A resolution of the conceptual debates (and perhaps elevation of the conceptual "fuzziness") must await future theoretical studies (e.g., Brown, 1987).

The present study defines metacognitive declarative knowledge in much the same way that the explicit aspects of metacoginition are referred to in CASE. In CASE, that knowledge includes an explicit awareness (that may be described in words) of one's reasoning patterns as well as the ability to think of (and talk about) reasoning patterns as distinct entities that may be related to specific tasks. This will also be the meaning of the concept when it is used in the following sections of this article in the context of a different educational project called Thinking in Science Classrooms.

1.3. Description of educational setting

The present study took place within the educational context of the Thinking in Science (TSC) project (Zohar, Weinberger & Tamir, 1994; Zohar, 1996). The project is designed according to the infusion approach to teaching higher order thinking (Ennis, 1989), i.e., instruction of higher order thinking is integrated into the science curriculum rather than taught as a separate subject. The project consists of a series of learning activities designed to foster higher order thinking and scientific argumentation. The contents of the learning activities match topics from the regular junior high school science syllabus, so that teachers may incorporate the learning activities in the course of instruction whenever they engage in a topic covered by one of these activities. The project's outcome is a set of opportunities calling for "thinking events" to take place in multiple science topics. The activities are designed to foster the growth of both scientific concepts and scientific reasoning skills. Learning theories derived from cognitive research were applied in designing the learning activities (e.g., conceptual change theories, creating a cognitive conflict as a means for meaningful learning, teaching for transfer, or towards metacognitive awareness).

In order to avoid fixed patterns of learning activities (which might eventually train students to deal with them in a merely algorithmic way), varied types of learning activities were designed (Zohar et al., 1994, Zohar, 1996):

a. inquiry and critical thinking skills learning activities;
b. investigation of microworlds;
c. learning activities designed to foster argumentation skills about bioethical dilemmas in genetics; and
d. open-ended inquiry learning activities.

It is particularly important to clarify the term "skill" in the context of the TSC project. In the higher order thinking literature, the term "thinking skills" often refers to factors which are disconnected from the rich conceptual frameworks of academic subjects. However, the emphasis on thinking skills in the TSC project does not mean that skills are taught as context-free entities. It is the science content and not a list of thinking skills that organizes the curriculum. From the students' point of view at each given time, they are studying a particular topic in science and not a list of thinking skills. The difference between the TSC lessons and "regular" science lessons is that in regular science lessons concepts are often taught applying a transmission of knowledge approach. In the TSC lessons instruction always begins with concrete problems (regarding specific scientific phenomena) which students are asked to solve. The cognitive demands for solving those problems include a set of thinking skills. Several examples of those skills are: identifying a research question, formulating hypotheses, planning experiments, controlling variables, drawing valid conclusions, differentiating between valid and invalid conclusions, identifying relevant and valid information for solving a problem and arguing in a sound way. It is important to note that students are active during the learning process. Much of their work takes place in small groups with rich scientific argumentation.

In what sense then, do students learn thinking skills? First, they employ various thinking skills while they are engaged with the TSC learning activities. The practice of those skills constitutes procedural knowledge (i.e., cognitive rather than metacognitive knowledge). However, after students have used the same reasoning skill in various concrete contexts (in the process of solving problems), they are encouraged (usually through class discussion) to engage in a metacognitive activity regarding that skill. The metacognitive activity may include several elements:

1. reflecting upon the thinking processes students have been engaged in;
2. looking for other examples of concrete problems (from other TSC activities they had encountered in previous lessons) in which students had employed the same thinking pattern;
3. analyzing the benefits of using that thinking pattern versus the disadvantages of not using it, leading to an understanding of the circumstances under which the strategy should be applied;
4. making generalizations and formulating rules regarding those thinking patterns; and
5. naming the thinking strategy.

Study of reasoning skills is therefore achieved through an inductive process that starts with concrete examples and moves towards generalizations and rules which are eventually made by the students themselves. Teachers are also advised to engage in far transfer activities, directing students to additional circumstances (both in school subjects and in everyday life) where the same thinking pattern (i.e. thinking skill) may be employed.

Therefore, although "skills" are not taught in a disconnected way, they still play an important role in the TSC project. One of the assumptions the project is based on is that teaching of higher order thinking must be systematic. Practicing a skill once or twice a year through problem solving may offer students an exceptionally interesting lesson, but will not be very useful in fostering their thinking. The methodology used in the TSC project is to repeat the same skill over and over again in different scientific contexts and in different types of problems. For example, in one junior high school subject—the role of water for living organisms, taught over approximately three months—seven skills were practiced in various TSC learning activities between six and nine times each (Zohar, Weinberger & Tamir, 1994). The repetition of the same thinking pattern in different contexts is considered essential for stable acquisition of thinking skills and for transfer. To conclude, the instructional means employed in the TSC project are based on the theoretical assumptions regarding direct teaching of transfer and metacognition (as summarized above in the citation from Nickerson, Perkins & Smith, 1985).

1.4. Teachers' thinking from the perspective of present study

Consideration of means for teachers' learning focuses attention on learning theories which are usually derived from studies on children's learning. When children's learning is addressed within the context of conceptual change theories, it is generally agreed that understanding children's prior knowledge is essential for designing instruction. In this sense, adults' learning is similar to children's learning. Therefore, in order to find out which learning experiences can be meaningful for teachers' professional development towards the role of teaching higher order thinking, it is necessary to first expose their prior knowledge in this domain. The main purpose of the present study may now be specified as examining teachers' intuitive knowledge regarding metacognition of thinking skills.

At this point, the following question must be addressed critically: Is it at all consequential for successful implementation of the TSC project whether or not teachers possess metacognitive knowledge of thinking skills? It is assumed that the response to that question is positive, because of three reasons:

1. Metacognitive knowledge of thinking skills is essential for introducing metacognitive activities in class.
2. Metacognitive knowledge of thinking skills is essential for the design of high quality new learning activities because the design process requires thinking about thinking skills as explicit goals of the learning activity.
3. Metacognitive knowledge of thinking skills is essential for systematic teaching of higher order thinking. The methodology of repeating the same skill over and over again in different scientific contexts requires that teachers be able to plan their teaching with an eye to both content goals and thinking goals. In order to be able to do so, teachers again must think of thinking skills as explicit goals of instruction.

Several researchers have proposed theoretical frameworks for the study of teachers' knowledge (e.g. Elbaz, 1983; Clark & Peterson 1986; Schon, 1983, 1987). Shulman (Shulman, 1986, 1987; Wilson, Shulman & Richert, 1987) suggested that the professional knowledge base for teaching consists of several components: *Subject-matter content knowledge*, *pedagogical content knowledge*, *knowledge of learners*, *knowledge of educational aims*, *knowledge of curriculum*, *and general pedagogical knowledge*. The present study accepts the general framework of Shulman's classification, adapting it to the special circumstances of teaching higher order thinking skills.

According to Shulman, subject matter content knowledge is composed of knowledge of the substantive and syntactic structures of a discipline (Shulman, 1986). Substantive knowledge refers to a variety of ways in which the basic concepts of the discipline are organized to incorporate its facts. Syntactic knowledge refers to the set of ways in which truth or falsehood, validity or invalidity are established. When there exist competing claims regarding a given phenomenon, the syntax of a discipline provides the rules for determining which claim has greater warrant. Therefore, syntactic knowledge of science teachers includes knowledge of scientific inquiry skills and many critical thinking skills (see examples in Sections 1.3 and 3.3).

Shulman's concept "subject matter content knowledge" requires adaptation for the present context where the TSC course focuses on higher order thinking skills rather than on a particular subject matter. Normally, this concept covers scientific inquiry skills and critical thinking skills, as well as knowledge facts. Although all of those are also relevant in the TSC context, there is an important difference in emphasis. Unlike programs that are subject-matter oriented, programs oriented toward higher order thinking place much greater emphasis on knowledge of thinking processes. Moreover, such programs contain an important component that does not appear at all in Shulman's definition, namely, metacognitive knowledge of thinking skills. Taken together, these differences justify a unique term for educational programs whose primary goal is to foster higher order thinking. The suggested concept "*knowledge of thinking processes*" therefore includes two specific types of knowledge: (a) procedural knowledge of how to apply thinking skills for problem solving and reasoning tasks; and, (b) metacognitive knowledge of thinking processes.

In the context of the TSC project Shulman's concept "knowledge of educational aims" consists of knowledge about the educational objective of fostering students' thinking skills in general and of teaching specific thinking skills in particular. The pertinent pedagogical content knowledge consists of instructional means for fostering students' higher order thinking. These means include knowledge of instructional theories referring to higher order thinking, knowledge of how to apply in class "ready made" learning activities designed to foster students' thinking, how to design new such learning activities, how to plan large units of instruction that will be rich in higher order thinking and how to address metacognition in class. These elements of pedagogical knowledge are specific to instruction of higher order thinking skills (as distinct from instruction of specific science topics), and will be referred to as *pedagogical knowledge of thinking skills*.

In order to comprehend the following sections it is imperative to note an important distinction between two perspectives. In the vast cognitive psychology literature that addresses human knowledge, the concepts "procedural knowledge" and "metacognitive declarative knowledge" usually refer to a person's own knowledge and learning processes. However, the present study is conducted from a different perspective in which these same terms are used to explore issues regarding pedagogical knowledge of thinking. In other words: although teachers are of course people whose thinking and problem solving skills may be investigated (just like other people's), the present study only refers to their cognition and knowledge in the context of their professional role as instructors of higher order thinking. The goal of this article is thus to explore the relationships between teachers' metacognitive declarative knowledge of thinking skills and their pedagogical knowledge of thinking skills.

2. Procedures

Background: This is a qualitative study conducted during in-service courses, preparing teachers to implement the TSC learning activities. The courses may vary in length from 24 to 56 hours (the length is usually determined by the organization which orders the course) that may spread over several months. The 24-hour course took place during eight after-school meetings that spread over three months. The longer courses took place during five to seven separate days in which teachers were released from their schools to participate in in-service training. The courses are modular to accommodate different requirements of length and special interests of particular groups of teachers. There is a basic core of approximately 24 hours, and a variety of additional activities. During the basic 24-hour course, teachers discuss instructional goals and learn some basic theoretical concepts related to instruction of higher order thinking (e.g. transfer and metacognition); become acquainted with specific examples of the TSC learning materials and analyze the instructional methodologies they consist of; and discuss various aspects of classroom implementation. The additional activities consist mainly of: (a) *Creative workshops* in which groups of teachers compose new learning activities to be used in their own classrooms; and (b) *Reflective workshops*. In the intervals between sessions of the course, teachers are asked to apply the TSC learning materials in their classrooms and to fill out structured written reports describing what happened in those lessons. Those reports are used for detection of problems generated during implementation. Detected problems are discussed through reflective workshops in subsequent meetings.

At the opening sessions of the courses considered in this study, the leader explained that an on-going assessment is a central component of the TSC project. The assessment is essential for continuous improvement of the TSC learning materials and teachers' courses. However, it was emphasized that we are interested in general processes and not in assessing individual teachers. It is important to note that data collection took place in circumstances where teaching (in the course) was seen as a primary goal, and research as a secondary goal. Procedures that could have improved research but were potentially hazardous for the relaxed and trusting atmosphere of the course were avoided. As part of this general policy it was decided not to ask for teachers' background information (e.g. ages or length of teaching) and not to look for patterns in individual teachers' behavior. In the two courses that were audio-taped teachers were informed that conversations would be recorded as part of the assessment. Teachers were also asked for consent to analyze their written work (anonymously).

The author is one of several course leaders. This role grants her natural participation in the group she investigates. She is intensively involved in teachers' learning. This fact may contribute to her ability to construct meaning from the data she collected, but may also limit her ability to see alternative meanings. In any case, this study represents her personal interpretation of the data.

Subjects: Subjects in this study were Israeli junior high school and/or high school science teachers who participated in the TSC courses. Teachers came to the courses either because they were sent by their principals, superintendents or department chairs or because they chose this particular course from a list of professional development courses offered to them each year. In both cases, participation grants professional credit. Accumulation of a certain amount of credits results in a significant raise in salary.

The subjects in this study did not constitute a random sample. As noted above, many of the teachers had chosen to participate in the TSC courses because they were interested in the topic and thought it important for their work. It can therefore be estimated that our subjects are a self-selected group which is probably more inclined towards an innovative educational experience such as the TSC project than a representative sample of science teachers would be.

Data collection: Data collection took place during teachers' courses by three means:

(a) All discussions from two courses (of 24 and 40 hours respectively) were audiotaped. A primary tape recorder was located in front of the room and a back-up tape recorder in the back. In addition, most conversations were also summarized by a research assistant. Thirty-seven teachers participated in the two courses that were audiotaped.

(b) During seven courses (including the two courses which were audiotaped), notes were taken by the leader, describing meaningful events. The total number of teachers who participated in those seven courses was 163.

(c) Two elements from teachers' written work that referred to metacognition were collected. The first element was an item from teachers' written reports about classroom instruction. A total of 83 reports were written by 39 teachers. The second element was a collection of lesson plans designed by 14 groups of teachers in two creative workshops which took place in two courses.

In each of the two courses teachers were divided into seven different groups of two to four teachers.

2.1. Data analysis

Tapes were transcribed by a research assistant. Sample transcripts were double checked for accuracy by the author. Transcription started with tapes from the primary tape-recorder. When the recording was incomprehensible, tapes from the back-up recorder were used. On the rare occasions that the back-up tape was not sufficient, the author consulted the written summaries of conversations produced by a research assistant to fill in.

The present study is part of a larger qualitative study, investigating teachers' cognition in implementing higher order thinking in science classrooms. At the beginning of the analysis the full transcripts and the leaders' journals were read three times by the author who jotted down ideas for codes as she read and re-read, leading to the development of a set of codes. Then, the full transcripts were read once more, and codes were written near relevant sections of the transcripts. Sections that were marked by the same codes were grouped together. All the evidence presented in the present study originated from the data that were classified by the code "metacognition".

It should be emphasized that investigating the issue of teachers' metacognitive knowledge of thinking skills was not among the larger study's initial objectives. Instead, it emerged from our data analysis. As is often typical of qualitative research, as the large body of data unfolded during its analysis, new perceptions regarding teachers' knowledge of thinking skills were crystallized. In this sense, the present study is an example of *grounded research*, in which concepts and theories are being constantly molded and consolidated in a circular process, which differs from the linear process that characterizes quantitative research (Glaser & Strauss, 1967; Spradley, 1980; Bogdan & Biklen, 1982; Sabar, 1990). The richness of the "metacognition" data and the complexity of the relevant theoretical issues brought about the decision to analyze them as an independent study.

3. Findings

3.1. Starting from the end: teachers' feelings regarding their gains from the course

Let us start by summarizing some trends in the responses of teachers when asked (in the courses' concluding session) to summarize what they saw as the most important things they had gained from the course. Since these comments presented below were made by teachers during a class discussion, the sentiments expressed may have been influenced by desire to please the instructor. However, please note that these quotations were not brought for the purpose of showing whether or not teachers liked the course (an issue that is likely to be influenced by social desirability) but in order to learn about what components of the course teachers saw as more valuable than others and about their perception of how the course had affected them (and not whether or not it had affected them). Teachers were not prompted to talk specifically about metacognition and most of what they had to say on the subject were not things that they may have heard during the course. In fact, some of what they had to say indicated considerable difficulties and even failures on their part. Therefore, apart from the issue of whether or not teachers liked the course (which is a side issue in these excerpts) it is hard to imagine why they would choose to say about metacognition precisely the things they have said unless it represented their genuine experiences.

Some teachers referred to metacognition as an exceptionally valuable thing they had learned:

- I've learnt a lot. Particularly about the issue of metacognition.
- The course was very good. The part about metacognition was important.

Other teachers responded by expressing the idea that before the course they were teaching for thinking in an "intuitive" way. The course made them conscious of teaching higher order thinking as a distinct educational goal, enabling them to deal with teaching thinking in a more structured and focused way. The following excerpts are examples of that idea:

- … Perhaps I was doing it intuitively … But now … things are more structured and well arranged for me.
- I think I went through a real process. I think that my awareness of things was sharpened a great deal. I think that part of what we got here – a large part of it we were all doing intuitively – but making it conscious – I think this is the greatest thing I gained. That … I will know what I am doing in a focused way … is what I see as the most meaningful thing. Because it is completely different. Because your work is planned in a completely different way. I think I tried to do it in the microbiology lessons I tried to teach [the reference is to a lesson in which this teacher had applied a special Learning by Inquiry method, A.Z.], but again – it was much more intuitive … I think today I could make it a lot more structured …
- Gaining experience with "thinking lessons" and the necessity to stop and think – one moment, what am I doing from the point of view of thinking? Am I doing it right? It boosts up my self-confidence and clearly also increases the level of … other lessons I teach.

As can be seen in the next excerpts, the consciousness of thinking as a distinct educational goal, and the ability to engage students with metacognitive activities of thinking skills, was seen by teachers as related to their newly-acquired metacognitive declarative knowledge of thinking skills.

- Other people have said most of what I had to say, but I would like to add a few sentences. I practically learned to teach differently. In a more creative way … For example, before the course I would let my students do an experiment exactly according to the instruction in the textbook. But now I would ask them to design their own experiment. In general, the focus on thinking … I used to do it in my lessons (before the course), but I never called thinking skills by their names, and I never expected my students to know that they were actually engaged in thinking. I found it interesting.
- This issue of metacognition- there is no doubt about it [i.e., that it is something valuable we learnt in the course,] because we usually don't

engage in it, no, there is no doubt about it. The concept [i.e. metacognition] was new for us and we never engaged in it at the same level as … and certainly not with our students. This was totally new for me and I plan to use it. Perhaps not in all my classes, I will start in one class … and … thinking skills, once more, it arranged their names that were very … [confusing]. Even now I must look them up in the book but more or less … part of them [i.e. part of the thinking skills that were learnt] I already master. That's it.

As is apparent from the latest two quotations, metacognitive declarative knowledge of thinking skills is seen by teachers as something that they were not familiar with prior to the course. The teacher who was quoted in the last excerpt, did not feel, even towards the end of the course, that she has mastered that knowledge. Indeed, data collected in earlier parts of the course confirm that before the course teachers usually did not refer to thinking skills in a declarative metacognitive way as is apparent from the next two excerpts:

- T1: … Even the skills we usually practice in class [e.g. the scientific inquiry thinking skills, A. Z.], we are not conscious about it in the same way. We don't call them by names
  T2: So we're not doing the metacognition
- Often we are not aware of which skill we would like [students to apply, A. Z.]. We want them to think and we … It's sitting somewhere in the back of our minds, but we ourselves are not really focused upon [saying things such as, A. Z.] … today I'm going to work on … critical thinking, etc.

However, more compelling evidence regarding the fact that prior to the course teachers usually did not refer to thinking skills in a declarative metacognitive way comes from analyzing teachers' discourse in creative workshops and from analyzing written projects which are the outcome of those workshops. During creative workshops, teachers were requested to articulate declarative knowledge of thinking skills. This request was often rather challenging for the teachers, indicating that such knowledge was not easily accessible. Some of the data referring to that phenomenon is described in the next section.

3.2. *Teachers' discourse in creative workshops*

Teachers' discourse in creative workshops was found to be a rich source of information regarding metacognitive knowledge. Creative workshops took place at advanced stages of the course. Therefore, when teachers first set out to design their own learning activities it was always after they had become familiar with several examples of the TSC learning activities and had discussed them extensively. It should be emphasized that parts of the extensive discussion of learning activities which took place in earlier sessions of the course focused on declarative knowledge. The thinking skills applied in each learning activity were labeled by names and were referred to as the thinking objectives of the learning activity. Also, it should be noted that creative workshops usually took place after teachers had implemented some of the TSC learning activities in their classrooms.

The main message that emerges from analyzing teachers' discourse in creative workshops is that teachers have difficulties with metacognitive declarative knowledge of thinking skills. The following scene (based on leader's journal) describes an event from an initial session of a creative workshop.

The leader opened the meeting by defining the task for the creative workshop. Each group of teachers was requested to choose a scientific topic applicable to their classroom instruction and to design a new learning activity addressing both science concepts and thinking objectives. To clarify the task, the leader asked for examples of thinking objectives. None of the teachers responded. After a few minutes of silence, the leader then explained that examples of thinking objectives are thinking skills which were discussed in various TSC learning activities introduced in previous sessions. The participating teachers seemed alert, but none of them responded. The room was quiet. The leader again asked for examples of thinking objectives, or of thinking skills. Finally one of the teacher suggested: "Let's open the book. There is a list of thinking skills on page … ". Then, that teacher located the correct page and started to read a list of thinking skills out loud. This event indicates that even towards the end of the course teachers were still unable to state a list of thinking skills: They still did not master the metacognitive declarative knowledge regarding those thinking skills they had been using successfully on previous occasions.

This scene was not unique. Similar scenes were replicated in other creative workshops with other groups of teachers. However, in all those creative workshops, once the list of thinking skills was spelled out and teachers started to design their own learning activities, they did extremely well. Teachers (working in small groups) designed activities which indeed addressed specific thinking objectives embedded in rich scientific topics (see detailed description in the next section). Additional data supporting similar findings is described in the next two sections.

3.3. A comparison of creative workshops' outcomes from two consecutive years

In this section the products of creative workshops from two different courses will be compared. Two particular creative workshops were chosen for this comparison because although the two courses in which they took place were generally similar, they differed in terms of the guidelines given at the creative workshop. The length of both courses was 40 hours, they took place in two consecutive years (1995 and 1996) in the same institution, the same course plan was repeated in the two consecutive courses and the background of the participating teachers was similar. In 1995 the guidelines for the creative workshop were given in somewhat general terms, asking teachers "to create learning materials which will apply the goals and instructional means of the TSC project to new science topics". However, based on the somewhat disappointing products of the 1995 creative workshop (see Table 1), two changes were introduced in the 1996 workshop: (a) an introductory phase was added to the creative workshop in which thinking skills applied in several TSC learning activities were reviewed (in a similar manner to what was described above in Section 3.2.); and (b) teachers were given a written page of guidelines including a request to define the thinking skills

Table 1
Specific thinking skills addressed by teachers in creative workshops

Thinking skill	Number of groups who addressed the skill in 1995 ($n = 7$)	Number of groups who addressed the skill in 1996 ($n = 7$)
Identify or formulate a problem	2	3
Identify or formulate hypotheses	—	5
Design an experiment	1	3
Describe experimental results	1	4
Draw conclusions from data/results	3	5
Differentiate between experimental results and conclusions	1	2
Translation from one form of representation to another (e.g. verbal to graphic)	—	4
Criticize conclusions based on a non representative or small sample	4	2
Control variables	—	2
Identify relevant information	2	2
Hypothetical deductive reasoning (if… then…)	1	3
Make comparisons	1	2
Avoid tautologies	2	2
Identify irregular data	—	1
Understand sound experimental design	—	1
Classify	1	—
Identify assumptions	1	—
Make a generalization		1
Identify causal relationship		1
Total	20	43
Mean number per group	2.86	6.29

addressed in each item they wrote. The purpose of those two changes was to focus teachers' attention on declarative knowledge of thinking skills, as they were creating their own learning activities.

An analysis of the learning materials designed by teachers in the two workshops showed that in each workshop there was one group of teachers who did not address any thinking skill in the learning activity they designed (i.e., their learning activity referred only to content knowledge objectives). The topics chosen by those two groups were blood types and the structure and function of the heart. In both workshops, six out of seven groups of teachers designed learning activities which addressed at least one specific thinking skill. The topics addressed by the 1995 teachers were: heat and temperature; enzymatic activity (katalaze); the origin of living organisms; measuring the amount of energy in peanuts; relationship between number of offspring, parental care and survival; blood groups; and ecological problems related to ozone. The topics addressed by the 1996 teachers were: the blood cycle; amount of energy invested in raising offspring relative to the number of offspring; osmosis; ratio between volume and surface area; relationship between heating and temperature; and adaptation of snails to their living environments. The number of thinking skills addressed in each of those 6 activities in the 1995 workshop ranged between 1 and 7 ($\bar{X} = 2.83$). The number of thinking skills addressed in each of those six learning activities in the 1996 workshop ranged between 4 and 12 ($\bar{x} = 6.29$). These results show that teachers in the 1996 course were more successful in designing learning activities which addressed specific thinking skills than teachers in the 1995 course (see Table 1).

How can the difference between the performance of the two groups of teachers be explained? Since the comparison between the two workshops does not constitute a controlled comparison, a sound causal relationship cannot be established between the changes in the introduction to the creative workshop and the increase in the number of thinking skills addressed in the 1996 workshops. However, given the general similarity between the 1995 and 1996 workshops, the data do suggest that the large difference between the products created by teachers in the two workshops may be attributed to the two changes introduced in the 1996 workshop, which addressed declarative metacognitive knowledge of thinking skills.

This suggestion supports the explanations given in the previous sections, referring to a deficiency in teachers' metacognitive declarative knowledge of thinking skills. Planning a learning activity which addresses a variety of thinking skills requires that the planners consciously address those thinking skills as distinct functions, referring to them as instructional objectives. Many of the items created by the 1995 teachers shared a surface similarity with the TSC project learning activities (i.e., individual and group work, class discussions and special worksheets) but they were lean in terms of higher order thinking. This finding indicates that the 1995 teachers were not applying much declarative metacognitive knowledge of thinking skills during the process of designing their learning activities. The transformed introduction to the 1996 creative workshop directed teachers' attention to the declarative metacognitive level of thinking skills and made it necessary to apply such knowledge in the design of learning activities. Assuming that the procedural knowledge of thinking skills was equal between teachers in the two courses (as is suggested by their similar background and by workshop leader's informal assessment during the workshop), this increased metacognitive awareness may be the reason for the improvement in teachers' performance in the 1996 workshop.

A specific incident from the 1996 workshop may illustrate how the request to define thinking skills applied during creative workshops affected teachers' thinking. A group of four teachers was working on a learning activity about the relationship between surface area and volume. When the leader approached the group one of the teachers reported that they felt "stuck" because what they were trying to do was not entirely clear to them. She added that she found it odd because all four members of the group had taught the topic before, and never had that feeling of confusion. The following conversation then took place:

L: Why do you think you "got stuck" now and not on previous occasions while you were teaching the same topic?

T_1: Because now we have to articulate what thinking skill we are using when we ask a certain question. In class we never do that.

T_2: Now I am thinking that before each lesson I must think what is my purpose in each question I intend to ask.

This short excerpt illustrates that the request to define the thinking skills applied in a learning activity indeed introduces a change from the way teachers commonly think about what they are teaching. Teachers are used to thinking about a network of scientific concepts but not about the thinking patterns employed in their science lessons. Transforming their own thinking to include thinking patterns employed during instruction is clearly a challenge for our teachers. However, the products of the 1996 creative workshop showed that struggling with that challenge by focusing on thinking goals as explicit objectives of a learning activity can bring about products which are indeed "rich in thinking".

3.4. Teachers' explicit request for help in defining thinking skills during reflective workshop

In another session that took place during a reflective workshop, a group of teachers were asked to share with the group "thinking events" that took place in their classrooms. One teacher started by describing something she felt was a recurrent problem: She reported that she often initiates in her classroom learning events that make her students think. However, she said that she finds it difficult to define what thinking skills she is practicing on such occasions. She concluded by requesting help in defining the thinking skills her students were required to carry out in various activities which took place in her classroom. Once she formulated this request, several other teachers confirmed that they too encountered a similar difficulty. The leader then suggested that they spend some time on this issue. Teachers took turns describing events which took place in their classrooms and the whole group set out to try and define whether those events indeed required higher order thinking, and if so what kind of thinking skills were required to accomplish the tasks presented to students. Among the events which teachers described was one case in which students were asked to define a research question, to plan an experiment and to control variables and another case in which students were asked to identify relevant information in two popular science journal articles, to compare pieces of information and to make generalizations.

Once classroom events were described, the task of defining the above thinking skills was not a trivial issue for that group of teachers. Teachers' descriptions of classroom events indicated that they were able to design learning activities that required varied thinking skills and to apply them in class. However, they still found it difficult to reflect upon those learning activities, analyze them and define the thinking skills they consisted of.

Taken together, the incidents described in the last four sections point in the same direction. It seems that despite instruction, teachers' declarative metacognitive knowledge of thinking skills remains intuitive (rather than "formal"). Many teachers who are able to apply thinking skills to solve problems, to design experiments, to draw conclusions, to evaluate experiments designed by others and even to design learning materials addressing these thinking skills and apply them in class, are unable to apply metacognitive declarative knowledge regarding those same skills, i.e., to discuss them in general terms using names, rules and definitions, and to think of them as explicit instructional objectives. All the examples mentioned in the last sentence as things teachers can do successfully, require (at least) procedural knowledge of thinking skills. What they cannot do requires metacognitive declarative knowledge. These findings thus indicate that there is a discrepancy between teachers' procedural knowledge and their metacognitive declarative knowledge of thinking skills. The findings also raise a serious question regarding the type of knowledge that is required for instruction. This issue will be addressed in the discussion.

3.5. Analysis of teachers' written reports about classroom instruction

Item number 11 in the questionnaire titled "A follow up of thinking lessons" was formulated in the following way: "Were any of the thinking skills used for problem solving discussed in your lesson in a general way? If the answer to that question is "yes", please elaborate by describing which thinking skills were discussed and by what means". Although this item refers to metacognition, the term metacognition was purposefully not included in the way the item was formulated.

While analyzing item #11, it became clear that some teachers answered the question in a positive way, although they did not really engage with their students in metacognitive discussions of thinking skills. Such answers were of two types. Seven answers clearly referred to a discussion of *contents* and not of thinking skills (e.g., "We discussed the relationship between the amount of water absorbed by the plant and the number of stomata. When the number of stomata is large, the plant evaporates a larger amount of water and therefore the level of water in the graduated cylinder decreases"). Three answers referred to concrete applications of thinking skills in specific problems and not to general, metacognitive aspects. Although teachers responded "yes" to the initial part of that item, those ten responses were coded as negative responses (i.e., as "not engaged in metacognitive discussions of thinking skills"). All other cases in which teachers responded "yes" were coded as positive answers (i.e., "engaged in metacognitive discussions of thinking skills"). Altogether, 33 out of a total of 84 answers to item 11 (42.3%) were coded as positive responses.

4. Conclusions and discussion

The main findings from this study are:

1. Teachers who had in fact been teaching higher order thinking before the TSC course describe this teaching as "intuitive" in the sense that they had not been aware of the fact that they were engaged in instruction of higher order thinking. Consequently, teaching for thinking had not played a conscious role in the way they planned their lessons and they obviously never engaged in metacognitive activities with their students.
2. A discrepancy was found between teachers' procedural knowledge and their metacognitive declarative knowledge of thinking skills. In previous research as well as in the present study, teachers were found to be highly proficient in solving TSC problems requiring procedural knowledge of some thinking skills. However, this study shows that they were often unable to verbalize the thinking patterns they had used during their problem solving. This finding is based upon three different sources of information: analysis of worksheets (in previous research), i.e., performance assessment of teachers' work during the course; reflective workshops where teachers were asking for help in defining the thinking skills they were practicing with their students; and, creative workshops where teachers were often unable to state specific thinking skills as goals of their learning activities.
3. The data support the theoretical assumption described in the introduction section, namely that direct consciousness of thinking skills as potential goals of learning activities is indeed necessary for designing learning activities that are rich in higher order thinking items (as was seen from the comparison of two creative workshops).
4. Towards the end of the course 42.3% of "thinking lessons" taught by teachers who participated in the TSC course included at least some discussions with students aimed at metacognition of thinking skills.

To conclude, the major finding from this study is that teachers' intuitive declarative metacognitive knowledge of thinking skills was found to be unsatisfactory for the purpose of teaching higher order thinking in science classrooms. A general practical implication from this finding is that courses which prepare teachers for instruction of higher order thinking should address extensively the issue of declarative metacognitive knowledge of thinking skills.

Several cases described in the results section seemed curious: How can one explain the fact that teachers could teach thinking "intuitively" (i.e., without being aware that they were engaged in teaching higher order thinking), that they could engage in instruction of thinking skills that they could not define, or that they could design a learning activity addressing some thinking skill that they could not describe in words? What type of knowledge can explain that sort of case? Let us try to explain this issue by using the theoretical framework outlined in the introduction.

What relevant knowledge did teachers have before the course? Previous research as well as evidence from the present study has shown that they had sound procedural knowledge of some thinking skills. In addition, before the course, teachers had sound general pedagogical knowledge. Two components of science teachers' general pedagogical knowledge are relevant for the present study. Teachers are familiar (through their pre-service studies) with Bloom's taxonomy (Bloom, 1954), and know that, in general, they should try to engage their students in tasks that are beyond comprehension. Teachers also know that teaching science by inquiry is a positive thing to do. Those two pieces of general pedagogical knowledge enable science teachers to engage in some instruction of higher order thinking and of inquiry skills even outside of a special project designed to foster thinking (Zohar, submitted). Procedural knowledge of thinking skills and general pedagogical knowledge may be enough to explain the instructional activities described above (i.e., engaging in some "intuitive" higher order thinking activities in class, or designing learning activities that address some thinking objectives). However, such general pedagogical knowledge is not enough for teaching higher order thinking in an extensive and systematic way, as aimed for in the TSC project. Declarative metacognitive knowledge is necessary for a comprehensive pedagogical knowledge of thinking skills.

The main objective of the TSC teachers' course is to teach pedagogical knowledge of thinking skills. However, it seems that by focusing our attention on pedagogical knowledge of thinking, we committed the same "sin" that Shulman (1986) describes as common to many educators:

> In their necessary simplification of the complexities of classroom teaching, investigators ignored one central aspect of classroom life: the subject matter … My colleagues and I refer to the absence of focus on subject matter among the various research paradigms for the study of teaching as the "missing paradigm" … Even those who studied teacher cognition, a decidedly non-process/product perspective, investigated teacher planning or interactive decision making with little concern for the organization of content knowledge in the minds of teachers'.

In the context of the TSC workshops, it seems that we had too little concern for our learners' relevant content knowledge, i.e., for their knowledge of thinking processes, and specifically, for their metacognitive declarative knowledge of thinking.

Informal assessment of the TSC teachers' courses from the perspective of teachers' metacognitive declarative knowledge, shows that the courses had begun to address this issue, inducing some progress in teachers' thinking. Teachers became aware of the need to explicitly consider thinking skills as goals of instruction, they improved in their metacognitive knowledge of thinking skills and started to engage in metacognitive activities with their students. However, our findings also show that the treatment of teachers' declarative metacognitive knowledge during the course was apparently insufficient. It should be noted that both reflective and creative workshops take place towards the end of the course, indicating that teachers still had difficulty with declarative metacognitive knowledge of thinking skills even at late stages of the course. In addition, finding number four above (see main findings at the beginning of conclusion section) shows that towards the end of the course most "thinking lessons" still did not consist of any discussions with students aimed at metacognition of thinking skills.

Before this study, the curriculum for the TSC teachers' course was designed from the perspective of the subject-matter to be taught. As part of the major issues in instruction of higher order thinking skills, the issue of metacognition was addressed in the TSC teachers' courses as one of several important topics to be covered. However, based on the findings of our research about teachers' cognition (Zohar, submitted) it is now clear that taking into account teachers' pre-instructional knowledge requires changes in the courses' curriculum. Specifically, the findings of the present study show that teachers' declarative metacognitive knowledge of thinking skills must be consolidated before they can use it effectively for instruction. The design of the TSC courses should be changed by allocating more time to this issue by the following means:

(a) More time may be assigned to consolidate teachers' declarative metacognitive knowledge of thinking skills applied in the TSC learning activities. This may be done by taking the teachers through the same instructional processes that are recommended in the TSC project for enhancing school children's declarative metacognitive knowledge of thinking skills (e.g. reflecting upon one's own thinking processes, analyzing what thinking skills are applied in the process of solving various problems, labeling thinking skills by names while discussing generalizations and rules regarding those skills). Such activities were conducted in the TSC courses described here, but on a very limited basis, because before this study it was not assumed that teachers' declarative metacognitive knowledge was deficient.
(b) Creative workshops may not only be a way to practice how to design new learning materials. The requirement to be active in the design process and to explicitly state reasoning objectives as goals of learning activities may be a means for sharpening the declarative metacognitive knowledge of the thinking skills that consist of the projects' objectives. Recently, an increased number of creative workshops with explicit guidelines were introduced into teachers' courses. Each creative workshop ended with a session in which small groups of teachers presented their newly-created learning materials before the whole group, followed by a critical discussion addressing the thinking objectives of those learning materials. Informal conversations with teachers indicated that they found these activities helpful in clarifying the project's objectives.
(c) Elaborate on the pedagogical aspects of metacognition. Specifically, this can be done by first eliciting teachers' intuitive knowledge on these issues and then bringing into the discussion some of the literature about metacognition, transfer and its role in instruction of higher order thinking in a way that will connect to teachers' pre-instructional knowledge.
(d) In addition, reflective workshops may be used for reflection and analysis of specific cases from lessons in which teachers did (or did not) address metacognitive issues with their students.

Interestingly, points (b)–(d) above represent an uncommon sequence of teachers' learning. Traditionally, it is assumed that subject-matter content knowledge is necessary for pedagogical content knowledge. The context of the TSC courses suggests an inverted sequence: instruction of pedagogical knowledge of thinking skills may serve as a means for consolidating metacognitive declarative knowledge (which is a component of knowledge of thinking processes). Perhaps the inverted sequence in our case may be appropriate due to the special nature of the body of knowledge we aim to teach, which is metacognitive knowledge of higher order thinking. In contemplating how to teach higher order thinking, teachers must consider thinking skills as explicit objects of thought and discussion, and therefore, activities geared towards instruction of pedagogical knowledge of thinking may also foster teachers' metacognitive declarative knowledge.

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