Chapter 6

Higher Order Thinking in Science Teacher Education in Israel

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Abstract: This chapter describes a course called Thinking in Science that is part of a junior high school teacher preparation program in an Israeli college. The purpose of the course is to prepare prospective teachers to integrate instruction of higher order thinking skills into science topics. A qualitative evaluation study of the course examined processes that took place, documented in a portfolio. The findings show a developmental trend in four different aspects 1) students' ideas about instruction of higher order thinking; 2) students' opinions and attitudes regarding the course; 3) students' experiences in developing higher order thinking as learners; and 4) experiences developing higher order thinking as teachers. Learning processes during the course took place on both a cognitive and an affective level. Students' development went through a stage of cognitive imbalance, indicating meaningful learning. We also discuss the implications regarding the introduction of higher order thinking into science teacher preparation programs.

Although schools have been trying to teach higher order thinking for decades (Resnick, 1987), numerous studies indicate that they have not been very successful in achieving this goal (Dossey, Mullis, Lindquist, and Chamber, 1988; Mullis & Jenkins, 1988; 1990). An overview of science curricula and learning materials from various countries reveals predominant occupation with facts and little occupation with ways of producing knowledge (Duschl, 1990). Scientific processes that bring about new knowledge do not receive proper attention in school. A similar picture emerges from the examination of instruction in many science classrooms (Friedler & Tamir, 1984; Mendelowitz, 1996). Instruction focused on dispensing information produces students who are not proficient in higher order thinking skills in general or in scientific inquiry skills in particular.

S.K. Abell (ed.), Science Teacher Education, 95–119.

However, recent educational endeavors show that when interventions are explicitly directed towards fostering students' thinlung, they can bring about significant improvement (Brown & Campione, 1994; Bruer, 1993; Feurstein, Rand, Hoffman, and Miller, 1980; Lipman, 1985; Shayer & Adey, 1992a; 1992b; Zohar, Weinberger, and Tamir, 1994). As more and more "thinking" projects are being implemented in schools worldwide, it becomes clear that a serious impediment to broad and successful implementation is the lack of adequate methods for preservice and inservice staff development in this particular area.

We have every reason to assume that the instructional model that was experienced by most preservice teachers when they were school children did not emphasize learning of higher order thinking. Based on the common saying that teachers teach in a way that reflects the ways they were taught as school children, this situation does not predict that preservice teachers will apply instruction of higher order thinking without specific preparation. In addition, several studies show that science content courses within preservice programs are often based upon lectures and transmission of knowledge (De Rose, Lockard, and Paldy, 197% Donnellan, 1982; Yakoby & Sharan, 1985). Therefore, preservice teachers may get the undesirable message that a transmission-of-knowledge approach is appropriate for instruction. The need to correct this undesired message requires a course that will highlight ways to integrate higher order thinlung skills into instruction (Casey & Howson, 1993). This chapter describes a course called *Thinking in Science* that is part of a preservice program for prospective junior high school science teachers in Israel. The goal of the course is to prepare the preservice teachers for implementation of a project designed to enhance higher order thinlung in science classrooms.

Integrating the development of higher order thinlung into science teacher education is based on two assumptions: a) preservice teachers need to improve their own thinking abilities (Brownell, Jadallah, and Brownell, 1993); and b) exercising thinlung skills will contribute to the prospective teachers' ability to advance their students' thinking skills (Bransky, Hadass, and Lubezky, 1992; Krombey, 1991; Sesow, 1991).

Several researchers have proposed theoretical frameworks for the study of teachers' cognition (Clark & Peterson, 1986; Schön, 1983; 1987). Shulman's (1986) categorization of teacher knowledge, including subject matter knowledge and pedagogical content knowledge, illuminated the relationship between various categories of teacher knowledge and teaching. Shulman's initial categories have been further developed and refined in later studies (e.g., Adams & Krockover, 1997; Grossman, Wilson, and Shulman 1989; Zohar, no date). The present study accepts the general framework of Shulman's classification of teacher knowledge, adapting it to the special circumstances of teaching higher order thinking skills. Subject matter knowledge in this context is knowledge of thinking processes, and the pertinent pedagogical content knowledge includes instructional means for teaching higher order thinking. We will address these two types of knowledge, documenting their development in the *Thinking in Science* course.

In the next sections, the cultural context and national policies of science education programs in Israel will be reviewed, followed by some description of Israeli projects aimed at instruction in higher order thinking skills. Then, the course *Thinking in Science* will be described. Finally, a qualitative evaluation study of the course will be reported, highlighting learning processes that took place during the course.

CULTURAL CONTEXT AND NATIONAL POLICIES

The changes in policy towards science education in Israel have essentially paralleled those in many other countries: disciplinary reform in the 60s, interdisciplinary reform in the 80s, and socio-technological reform in the 90s.

A few years after the Holocaust, Jews from all over the world immigrated to Israel, which finally became an independent state in 1948. Under those circumstances, love of the Jewish homeland was considered a central educational value. Learning about nature in Israel was seen as an educational means towards achieving the important goal of instilling love of the homeland and strengthening the bond between the people and their land (Dressler & Levinger-Dressler, 1996). During that period, the dominant approach to science education was naturalistic-romantic.

In 1953, the National Education Board was established and a single science curriculum titled "Nature and Agriculture" was written. That curriculum included the following aims:

> Knowing the laws of natural phenomena, scientific observation methods and scientific thought... knowledge of the nature of the homeland... fostering an intimate relationship with the land and its wildlife... fulfilling the dream of agricultural labor and rural life as a valuable lifestyle...fulfilling the goal of pioneering building of the homeland. (Ministry of Education and Culture, 1954, p. 1)

In the political context of that period, agricultural development was thought of as a prominent way for fulfilling the value of loving the land. The most important characteristic of that generation was the emphasis on teaching bodies of information, focusing on facts, and emphasizing their applied and practical aspects.

In the 1960s, following the launching of the first Russian Sputnik into space, echoes of curricular reforms that took place around the world reached Israel. Translated materials of the American BSCS and the English Nuffield programs became prevalent curricula, emphasizing inquiry as a way of teaching and learning. The curricula of that period expressed the desire to produce excellent scientists who would contribute to the advancement and development of Israel. However, it is important to note that some of the goals of those programs were only partially achieved. For example, although the Israeli matriculation exam in biology demands comprehensive scientific inquiry skills (Tamir, 1985), it seems that a large proportion of biology teachers in high school teach scientific research processes technically rather than meaningfully. This is done by focusing on teaching algorithms for succeeding in the exam instead of focusing on thinking processes (Friedler & Tamir, 1984; Mendelowitz, 1996; Zohar, Schwartzer, and Tamir, 1998).

The 1980s brought about a change in the aims of science education: it was no longer seen as the initial training of future scientists but in terms of "science for all." People in Israel, like in many other modem countries, are exposed daily to circumstances that require scientific knowledge and technological-scientific literacy. This new reality, together with students' tendency to avoid studying science, gave rise to the requirement that science teaching be anchored in social contexts, emphasizing the relevance of science to everyday life. The curricula of the 1980s emphasized STS (Science, Technology arid Society). STS programs diminished the role of inquiry learning as the predominant method; inquiry became only one of several suggested instructional methods from which teachers could choose.

At the beginning of the 1990s, a national committee, The High Committee for Science and Technology Education, was formed to examine the state of science education in Israel. The result of the committee's work was the Harary (1992) report, "Tomorrow 98," which has since guided the basic principles of science education in Israel. The essence of its suggestions is that:

> Science and technology education is the core of scientific infrastructure...The government of Israel will announce a national curriculum to strengthen, deepen and improve the learning preparing the next generation of citizens for life in the techno-scientific age. Implementation of this policy includes an interdisciplinary approach to the subject... science and technology in our time are inter-linked and overlap in a variety of surprising ways... the learning of science and technology must be combined. (pp. 3-4)

Computers are seen as "a most important instructional tool for any subject and for all age groups" (pp. 76-77). A fair amount of space in the report is allocated to the issue of developing students' thinking and problem-solving skills:

> In many places in the world today there are programs designed to improve the individual's creative thinking, inventive thinking, logical thinking etc ... This issue is worthy of exploration. The intention is to investigate the feasibility of including such programs in our schools. (p. 47)

Likewise, the report emphasizes the central role of the teacher in science and technology education. "The best curricula and the most equipped laboratories will not bear fruit without good teachers. In the end, education stands and falls according to the quality, skills and dedication of teachers" (p. 10).

The STS approach (which characterized the programs of the 1980s) is validated in the 1990s as one of the recommendations of the Harary report. As a result of the Harary report, new curricula for science education were published. In junior high school, for example, a new curriculum was published in "Science and Technology Studies in Junior High School" (Ministry of Education, Culture and Sport, 1996). Its main aims are to educate the citizens of the next century towards technological-scientific literacy, and to prepare the background for later studies in high school. The main characteristic of this curriculum is its interdisciplinary approach, which integrates various scientific disciplines with technology in social contexts and emphasizes instruction of learning and thinking skills. "Students should be involved in the designing, carrying out, analyzing, drawing conclusions, discussing and assessing findings or solutions.. .in a wide range of topics in science and technology" (p. 15).

THINKING DEVELOPMENT PROJECTS IN ISRAEL

There are currently a number of Israeli educational enterprises in the field of teaching higher order thinlung. We will first review two central activities in the field and then focus on the project which is at the heart of this chapter.

One of the oldest and most wide-reaching projects in Israel is the program "Instrumental Enrichment," whose aim is to improve the learning ability of the individual through developing his thinking skills (Feurstein, 1991; Feurstein et al., 1980). The program has been translated from Hebrew into many other languages and is currently implemented in many countries.

Another major enterprise in this field is the "Branco Weiss Institute for the Development of Thinking," which was established in 1990 with the aim of developing the thinking of children in the Israeli educational system. The Institute develops and produces teaching and learning modules for teachers and students; publishes a quarterly distributed to all schools in the country, as well as to private subscribers; and translates into Hebrew books on critical and creative thinlung, intelligence, and related topics. The Institute also runs education programs and courses for teachers, principals, tutors, supervisors and other educators, as well as thinking clubs for children (Vinner, personal communication, 1997).

This chapter focuses on another Israeli project called "Thinking in Science Classrooms" (TSC) that was established as part of the Harary reform. The TSC project emphasizes the integration of higher order thinlung skills into the science curriculum. The goal of the project is to design learning activities that aim to foster higher order thinlung skills according to the infusion approach to teaching thinking (Ennis, 1989). The contents of the learning activities match topics from the regular science syllabus, so that teachers may incorporate the learning activities in the course of instruction whenever they teach a topic covered by one of these activities. The project's goal is that a set of opportunities calling for "thinking events" take place in multiple science topics. The activities are designed to foster the growth of both scientific concepts and scientific reasoning skills. The emphasis on skills does not mean that skills are taught as context-free entities. Instruction always begins with concrete problems (regarding a specific scientific phenomenon) that students are asked to solve. After students have used the same reasoning skill in various concrete contexts, they are encouraged (usually through class discussion) to engage in metacognitive activities that include generalization, identification of skills, and formulation of rules regarding those skills. In order to avoid fixed patterns of learning activities (which might eventually train students to deal with problems merely in an algorithmic way), varied types of learning activities were designed (Zohar & Weinberger, 1995): a) inquiry and critical thinlung skills learning activities; b) investigation of microworlds; c) learning activities designed to foster argumentation skills about bioethical dilemmas; and, d) open-ended inquiry learning activities.

Within the TSC project, inservice and preservice staff development courses are conducted with the aim of educating teachers to implement the TSC methods and approach in their classrooms. Below we describe and analyze a preservice course, *Thinking in Science,* that is taught to prospective junior high school science teachers in a large college in the center of Israel.

THINKING IN SCIENCE: COURSE DESCRIPTION

Researchers report that educating preservice teachers in critical thinlung and inquiry teaching may result in both improved attitudes and improved thinking skills (Sesow, 1991). It therefore seems worthwhile to introduce issues that involve teaching and learning of higher order thinking skills into preservice science teacher education. Previous research also shows that introducing changes in teacher behavior in general, and changes specifically geared towards using more inquiry-oriented teaching approaches, is definitely more complex than originally thought (Adams & Krockover, 1997; Casey & Howson, 1993). Such desired changes require that teachers not only learn new facts, but also rethink what they already know. In order to change, teachers need to adopt new knowledge and desired practices related to teaching (Adams & Krockover, 1997; Hewson, Kerby, and Cook, 1995). Therefore this complex change process requires well-designed and focused education programs. The design of the *Thinking in Science* course described below was aimed at that goal.

Purpose

The purpose of the course is to address the following issues:

1. To discuss the importance of fostering students' higher order thinking skills in science lessons.
2. To review several projects and/or curricula designed to foster higher order thinking.
3. To improve preservice teachers' higher order thinking skills and their awareness of metacognitive processes.
4. To consolidate preservice teachers' perceptions regarding instruction of higher order thinking in science.
5. To introduce the TSC learning materials.
6. To advise preservice teachers in planning ways of integrating those learning materials into their practical work in science classrooms.

Course Structure

The course consists of three basic components (see Table 1) that are included in each unit:

1. Mini lectures and class discussions. This component of the course includes several general theoretical issues regarding instruction of higher order thinking. The main issues are: a) definition and clarification of concepts regarding instruction of higher order thinking; b) the rationale for integrating instruction of higher order thinking into science lessons;

c) review and analysis of various projects and/or curricula designed to teach higher order thinking; d) cognitive aspects of thinking; e) developmental stages of thinking strategies; and f) assessment of higher order thinking.

2. Active practice. This includes experience with a wide variety of learning materials (taken from the TSC project). Preservice teachers solve problems presented in the learning materials, analyze their logical structures, analyze typical difficulties that children encounter while they interact with those learning materials, and think about appropriate means of instruction.
3. Reflective practice. This component of the course addresses metacognitive processes. Students reflect upon the thinking skills they applied while engaged in solving the TSC problems and upon their own learning processes.

The way in which the three parts of the course are combined is described in Table 1. During the first part of the course (lessons 1 -5), the mini lectures and discussions component are predominant. During the middle part (lessons 6-9), active practice is highlighted, and during the final part (lessons 10-14), the emphasis is upon reflective practice.

Sample Lesson Plan

In order to demonstrate how the three components are combined in a specific topic, we will describe a sample unit that was taught at the middle of the semester (lessons 7 and 8). This unit revolved around one of the TSC learning activities which investigates factors that may influence the rate of seed germination. The learning activity for the students included a computer simulation, a set of worksheets, and a video of a pupil working with the learning activity (Zohar, 1996). The unit included the following stages:

1. Active practice: Students solved the problems presented in the learning activity (in the same way that school pupils usually do).[1] The goal of this stage was to let preservice teachers get acquainted with the learning activity.
2. Reflective practice: Students reflected upon their own thinking processes (that took place during the problem solving stage), focusing on analyzing the thinking skills they had used.
3. Active practice: Students were then prompted to think "as teachers". First, they were asked to predict pupils' difficulties while solving the

[1] In order to avoid confusion between college students and school children, we refer to college students as "students" and to school children as "pupils."

Table 1. Three Basic Components in Thinking in Science Course

Lessons 1 - 5	Lessons 6 - 9	Lessons 10 - 14
Reflective practice unit Reflection on instructional processes that took place during instruction.	Reflective practice unit Writing reflection number 1. Discussing: meaningful learning/teaching.	Reflective practice unit Writing reflection number 2. Assessment of the portfolio. Reflecting on conceptual change. Assessment of the learning and thinking processes.
Active practice unit Analysis of a case "Harry S." "Melinark"activity. "Thiamin in rats" activity.	Active practice unit "The particular structure of the matter" activity. "Microworld"activity. Logical analysis of the microworld. Pupils' confrontation with the microworld. "Water in Living Organisms" activities. Critical reading of articles and commercials.	Active practice unit "There is no hole in Ozone" activity. "Zemmelweiss"activity. Designing HOT learning activities. Reading an article about instruction of HOT.
Mini lectures & discussion unit Educational purposes. Psychological aspects of HOT. Definitions of HOT concepts: "Generative Knowledge" "Knowledge" "Information" Rationale of integrating HOT into instruction.	Mini lectures & discussion unit Various approaches for instruction of HOT. Stages in acquisition of new thinking strategies. Assessment of HOT.	Mini lectures & discussion unit Principles of instruction of HOT.

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problem. Then segments of the video were shown, and students were asked to diagnose the pupils' difficulties and propose how they would continue their lesson if this pupil was in their classroom. Students first thought of those issues independently and later shared their thoughts with the whole class.

4. Mini lectures and class discussion: The instructor led a class discussion about diagnosis and treatment of pupils' thinking difficulties. Then she supplemented the ideas that came up in class with a theoretical mini lecture about the development of thinking strategies (Kuhn, Garcia-Mila, Zohar, and Anderson, 1995; Siegler & Jenkins, 1989). Finally, the instructor presented all the learning materials (including worksheets) that were prepared by the TSC team for that learning activity, and discussed their rationale.

EVALUATION RESEARCH

The course *Thinking in Science* has been accompanied by an evaluation research. The full evaluation study consists of three parts:

1. The first part is a quantitative research addressing preservice teachers' prior knowledge and dispositions towards thinking.
2. The second part documents and analyzes the learning processes that took place throughout the course.
3. The third part examines the degree to which the content of the course is reflected in the practical teaching of four preservice teachers.

Part 2 of the study and some of its findings are described in this chapter.

Participants

Participants were students in a preservice program for junior high school science and technology teachers. The 4-year program includes courses in science, education, and science education, as well as extensive guided field work in schools: a group of two to four students collaborates in teaching one science class (for two consecutive years). The program grants a bachelor's degree in education (B.Ed.). The students who participated in the *Thinking in Science* course were in their second or third year of the program. There were 22 females and two males. Their ages ranged between 22-29 years.

Student Portfolios

Preservice teachers' work during the course was documented in a portfolio that reflected their achievements or progress. The portfolio for the *Thinking in Science* course followed the principles of Arter and Spandel (1992). In order to avoid a random collection of materials, the following specific materials were selected:

1. A collection of documents, sampling students' written work. The collected documents included questionnaires, assignments, and products of creative workshops. Data from assignments in which the same issues were addressed at different times were useful for portraying developmental trends throughout the course.
2. At least one additional document chosen by each student was included, in order to allow individual expression of student development.
3. Individual reflections were written on two different occasions at the middle and at the end of the semester. In these reflections students were asked to:

   Explain in detail your views and opinions about: 1) instruction in higher order thinking; 2) learning higher order thinking; 3) the course Thinking in Science; 4) processes you went through during the course; and 5) anything else you may care to write about.

Management of the portfolio. The portfolio was owned by the student. Therefore he/she was responsible to collect all relevant materials and to turn them into the teacher for assessment. Particular tasks were handed to the teacher throughout the semester. The whole portfolio, including students' self assessment, was turned in at the end of the semester.

Assessment of the portfolio. The portfolio was used as the only means of grading students' work. The quality of students' work was assessed according to the following criteria:

1. Perceptions regarding instruction of higher order thinking.
2. Mastery of higher order thinking, including procedural and metacognitive knowledge.
3. Mastery of instructional means appropriate for teaching higher order thinking.
4. Ability to design new learning materials aimed at instruction of higher order thinking integrated into science content.

The portfolio was jointly assessed by the student and the teacher. First each student assessed her portfolio based on given guidelines (see Table 2). Then the teacher assessed the portfolio using the same criteria. Finally the teacher and the student met to discuss and compare the two assessments as well other topics relevant to the course raised by either student or teacher.

Table 2. Guidelines for Portfolio Assessment

1. Organize the documents in the portfolio in chronological order. The content of the portfolio reflects your progress and achievements during the semester.
2. The "evidence"in the file should allow you to characterize the processes that you have undergone in at least four areas:
    - Perceptions regarding instruction of higher order thinking.
    - Mastery of higher order thinking skills.
    - Mastery of instructional means appropriate for teaching higher order thinking.
    - Designing new learning materials suitable for fostering students' higher order thinking.

    a. Describe and assess your progress in each of the areas listed above as demonstrated by the contents of the portfolio (consider each section separately).

    b. In summary, make a short assessment of your work and achievements in the course as demonstrated by your portfolio.
3. Write a reflection summarizing the topic "Developing Thinking in Science Teaching." Relate to any aspect you consider relevant (do not worry about repeating things you have already mentioned elsewhere).
4. Hand in your assessment together with the portfolio itself by the due date. Within two weeks of handing in your work, the instructor will meet with you to discuss the portfolio and jointly assess it.

Documentation and Analysis of Learning Processes

Evidence of development in students' thinking during the course are based on three sources:

1. **A questionnaire about fostering higher order thinking in science education.** The questionnaire was given in the first session of the course in order to reveal students' ideas and opinions prior to the course. The questionnaire presents briefly two approaches as to the aims of science instruction in schools and asks students to relate to them. The first approach emphasizes the delivery of a wide range of information on science related topics, the second emphasizes the development of scientific thought. Students were asked to indicate arguments for and against each approach and indicate which approach they supported and to justify their choice (to take a stand).
2. **First and final reflection.** The first reflection was written in the sixth lesson of the course, the final at the end of the semester.
3. **Overall portfolio assessment.** At the end of the semester, students and instructor assessed student portfolios.

Characterization of processes that took place during the course was carried out by analyzing the questionnaire, reflections, and other portfolio documents according to the contrast/comparative method (Miles & Huberman, 1994). First, we read the documents found in the portfolios thoroughly, and jotted down ideas about repeating themes. Then, we separated those documents into several different aspects according to the following themes: a) ideas about instruction; b) opinions and attitudes regarding the course; c) experiences in the development of higher order thinking learners; and d) experiences in the development of higher order thinking as teachers.

The unit of analysis was a single statement. First, in each activity, statements were categorized and counted. In the second stage, the number of statements in each category and the categories themselves were compared in different periods during the semester, in chronological order.

When reading the findings below, it is best to bear in mind the plan of the course (depicted in Table 1) so that the content of students' statements at the middle and at the end of the course may be compared to the overall course plan.

FINDINGS: THE DEVELOPMENT OF STUDENTS' ATTITUDES AND KNOWLEDGE REGARDING INSTRUCTION OF HIGHER ORDER THINKING IN SCIENCE EDUCATION

This section describes students' learning processes expressed by their written work[2] at three separate times during the course: at the beginning, the middle and the end (see Table 3). Four different aspects were considered:

1. Ideas about instruction of higher order thinking.
2. Opinions and attitudes regarding the course Thinking in Science.
3. Experiences in developing higher order thinking (as learners).
4. Experiences in developing pupils' higher order thinking (as teachers).

Analysis of students' ideas about instruction of higher order thinking was based on three sources from the portfolios: the questionnaire given at the beginning of the course, reflection number one, and reflection number two. Analysis of students' ideas regarding the other three aspects was based on the two reflections only.

Ideas About Instruction of Higher Order Thinking

<u>At the beginning of the semester,</u> 12 students' references to the issue of higher order thinking instruction were tautological; for example: "It's important to teach science together with development of thinking. because thinking is a very important issue in instruction." Others' ideas about instruction of higher order thinking skills were limited to two topics: a) the importance of developing students' thinking skills: "Developing one's thinking is a tool that will remain with the student forever and will help her to cope with challenges and to acquire knowledge in various fields;" and b) reference to the explosion of information that is typical of today's culture: "Knowledge accumulates very fast so there is no way we can teach it all." It should be noted that all students' arguments at this stage were general theoretical statements about education and not practical ideas that could be used in teaching.

At the beginning of the course, the attitudes of 14 students towards instruction of higher order thinking in the context of science education was found to be positive. However, this finding should be treated with caution because of social desirability. The students had answered this questionnaire in the first lesson of a course entitled *Thinking in Science* and so may have accommodated their responses to please the lecturer.

[2] It should be noted that the data excerpts were translated from Hebrew by the authors.

By the middle of the semester, students' knowledge and ideas were more sophisticated and multi-dimensional in comparison with the beginning of the semester. In addition to the ideas that appeared before, new ideas started to emerge. Some students displayed usage of professional terminology, such as:

1. References to a child-centered educational approach:
   Instruction of higher order thinking is focused on teaching thinking skills. creativity and open mindedness. It encourages acquisition of learning skills such as individual work, group work and team work, i.e., it emphasizes child development in a child-centered approach.
2. References to a constructivist approach:
   Instruction of higher order thinking is based upon active construction of knowledge by the students who think and solve problems.
3. References to the idea of "generative knowledge" (Perkins, 1992):
   Instruction of higher order thinking helps to internalize knowledge, to acquire meaningful knowledge which can then be used in the future, to organize knowledge and to connect it to prior information.

Another new point emerging at this stage of the course was that students started to bring up issues related to instructional aspects of higher order thinking:

Instruction according to the TSC approach is appropriate for the new science curriculum and improves teaching.

In this context, students noted the contribution of the course to the professional development of the prospective teacher and to changes in teachers' conceptions and work habits:

Instruction according to the TSC approach necessitates a change in the ideas and in the thinking methods of the students and require teacher education.

It is especially important to point out that, at this stage of the course, nine students expressed negative attitudes, noting difficulties and drawbacks in teaching higher order thinking. Students thought that teaching thinking is expensive, requires a lot of time, will be at the expense of covering the curriculum, and that instruction of higher order thinking may cause difficulties because it requires radical changes in teachers' thinking and working habits.

At the end of the semester, students' knowledge and ideas about instruction of higher order thinking were more solid and multi-dimensional compared to the middle of the semester. Students' ideas by the end of the course were diverse and included many different aspects:

1. General education rationale:
   It is important to incorporate instruction of higher order thinking to science lessons, because it will prepare pupils for the future and will develop their skills and abilities.

Table 3. Summary of the Results

At the beginning of the semester	At the middle of the semester	At the end of the semester
Ideas about instruction of HOT	Ideas about instruction of HOT	Ideas about instruction of HOT
One reference and only a few aspects. Difficulties in expression and formulation of ideas. Positive attitudes towards instruction of HOT. General theoretical statements. Reference to the learning aspect.	2-3 references to multi-dimensional aspects. Improvement in formulation of ideas with usage of professional terminology. Appealing the positive attitudes toward instruction of HOT. General theoretical statements. Reference to the teaching aspect.	3-4 references to four dimensions. Usage of correct professional terms in correct contexts. Reference to the professional demands required from teachers. Positive attitudes towards HOT instruction. General theoretical and practical statements. Reference to principles of instruction of HOT.
	Opinions and attitudes regarding the course	Opinions & attitudes regarding the course
	Some mentioned contributions of the course and some absence of contribution.	Detailing of the contributions of the course.
	Experiences in developing HOT as learners	Experiences in developing HOT as learners
	Lack of experience with HOT and expression of the need.	Positive experiences in developing HOT.
	Experiences in developing HOT as teachers	Experiences in developing HOT as teachers
	Dilemmas and fears in implementation of the approach. Few implementations of the approach in instruction.	Reports of using the TSC approach in teaching, applying TSC learning materials, changing the way of teaching, tracing pupils' improvement in HOT.
	Awareness to processes	Awareness to processes
	Gaining knowledge in thinking and teaching. Awareness to thinking processes. Awareness to learning processes. Vague concepts of the course.	Growing awareness to processes they underwent during the course: a) understanding the essence of the course; b) awareness of the learning skills; c) changing ideas about teaching science; d) metacognitive processes; and e) empowerment.

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2. Rationale related to instructional methods:
   Using the TSC approach improves learning processes and internalization of information.. . induces active learning.. . increases motivation and challenges pupils.
3. Science education rationale:
   The TSC approach is suitable to the spirit of the new science curriculum ... to teaching scientific thinking skills.. . to teaching procedural aspects of science.
4. Principles of instruction of higher order thinking:
   The TSC approach creates a learning atmosphere that is characterized by openness to different forms of thinking. The TSC learning materials create opportunities to practice thinking skills and engage in metacognitive activities.

This last aspect is a striking addition to the ideas that appeared in the middle of the semester. Specific principles of instruction that are of practical nature bear testimony to an additional level in students' knowledge:

Instruction according to the TSC approach requires perseverance in letting pupils exercise their thinking skills, in order to improve their thinking.

In teaching according to the TSC approach it is important to use metacognitive processes in order to generate pupils awareness of thinking skills on a general level.

In addition, in most of their responses, students had used correctly professional terms that were studied in the course and had applied them in correct contexts:

In teaching according to the TSC approach, the teacher navigates her pupils and leads them by organizing a learning environment that will allow pupils to experiment thinking and to construct knowledge.

At this stage all the negative feelings that were articulated by the middle of the semester expressing concerns regarding the TSC approach had disappeared. Instead, the opposite attitude was stated:

Teaching according to the TSC approach is not necessarily instead of teaching subject matter.

Some students commented on the professional demands required of teachers:

Instruction according to the TSC approach demands from the teacher much thought and investment during lesson preparation and during teaching. In addition she needs to be proficient in the theoretical, instructional and content-knowledge aspects of the subject.

Such statements reflect student knowledge about the professional tools which are needed for effective teaching according to the TSC approach.

These findings clearly demonstrate the development of students' ideas during the course regarding instruction of higher order thinking.

Students' Opinions and Attitudes Regarding the Course Thinking in Science

In the middle of the semester, 14 students wrote that the course had contributed to their own individual general knowledge and/or to their instructional abilities:

The course conceptualized and arranged knowledge that we had before.

Through the course I became familiar with different teaching and learning methods.

The course makes me look at things I learn from a different angle.

I have learned to recognize different ways of thinking.

Through the course I have gained useful tools for developing thinking — both my own thinking and mypupils.

The course has clarified and sorted out things I already knew.

The course is a preparation for practical work: it has given me ideas about how to organize my teaching, it has exposed me to practical ways of using the TSC approach and has pointed out areas to watch for in the course of instruction.

However, six students expressed difficulties and concerns about whether or not there were any meaningful benefits to the course:

I don't know if I gained much from the course.

I don't see much connection between the theoretical side we have learned in the course and field implementation.

Evaluating the course, at the middle of the semester, students emphasized that the course was interesting and important:

The lessons were enjoyable and interesting.

Everyone should take this course.

The reflections written at the end of the course, as well as the portfolio assessment, show that students thought the course contributed to them in:

1. Revealing new ideas:

   The whole issue of developing students' thinking was only revealed to me for the first time in this course. It had opened up for me a whole different way of working with pupils.

   During the course we were exposed to many new ideas and opinions.

2. Raising awareness of their own learning and thinking processes:

   I feel that this [the course] helped to the crystallization of new knowledge within me.

   The course helped me in that it exposed me to the subject and made me more sensitive to it.

During the course, with the help of a variety of activities, some order has been established 'amongst the mess' I had in my mind before and now I am able to distinguish between the different thinking skills.
Now that I look back, I can see that it's not that my own thinking was so deficient, it is just that I was not aware of everything that I am aware of today.
Another difference is that during the course I was exposed to far more opportunities to think.

3. Improving their competence in instructional means for teaching higher order thinking:
I believe that a great advantage of the course is that it made me understand that thinking should not be taken for granted, that you must interfere (with regular teaching) and explain about thinking skills, discuss each specific thinking skill and understand that both adults and children have difficulties applying it.

Some of the references were similar to those from the middle of the semester, although they were somewhat richer or more profound. However, the issue of students' awareness 'of their own learning and thinking processes was added at this stage. In general, the course was described as a process that demanded "thinking and practical ability," gave a lot of practice in thinking, and provided feedback. The students emphasized that the course was important and contributed to their education as teachers. Five students pointed out that the course should have been continued for another semester:
The course was too short. It is a pity that we could no carry on for another semester.

In summary, our findings by the end of the semester indicate that students thought that the course was important for their professional development and that they were aware of some specific aspects of its contribution.

Experiences in Developing Higher Order Thinking (as Learners)

Student reflections <u>in the middle of the course</u> indicated that the classes they had taken in college did not involve higher order thinking:
Developing thinking requires practice and personal experience. In college most classes are taught frontally and developing thinking is not encouraged.

Students were critical towards that situation, expressing the opinion that:
The college needs to emphasize the development of higher order thinking in its science courses as well.

In addition, students wrote that practice would improve their ability to teach according to the method in the future:

Learning [according to the approach of] developing thinking skills will enable us to teach according to that approach in our classrooms.

In the reflections written at the end of the semester as well as in their portfolio assessments, students made fewer references, compared with the middle of the semester, to experiences in developing higher order thinking as learners (9 versus 19 references respectively). In the middle of the semester, students referred mainly to the absence of instruction of higher order thinking in the college and the associated disadvantages. Now, at the end of the semester, students referred mostly to their positive experiences in the TSC course and its contribution to their learning:

Exercising and practicing higher order thinking skills during the course helped me to internalize that approach and to use it in my teaching.

According to the students' reports, the course gave them basic practice and experience that would enable them further development in this area:

I now have a good foundation in thinking development but I still need to learn more and improve my own ability as well as my teaching abilities regarding this method.

Students mentioned that their success resulted from the practical experiences they were engaged in during the course. In summary, our findings by the end of the semester indicate that students experienced a development in their own thinking.

Experiences in Developing Pupils' Higher Order Thinking (as Teachers)

Students' reflections in the middle of the semester indicated that only five students experienced instruction of higher order thinking in their practical fieldwork. Those experiences were described in several different ways:

1. A structured effort to make pupils think:
   During the lesson I make my pupils think in a structured manner, as I learned in the course.
2. A change in teaching methods:
   Teaching according to the TSC approach influences the way I teach (non-frontal).
3. Creating an atmosphere of openness that may foster thinking:
   While teaching according to TSC approach, the atmosphere in the class is different [than in other lessons].
4. Awareness of instructional means for teaching thinking:

When I am preparing my lesson plan, designing teaching materials or observing others teaching or preparing projects, I think of how I can develop pupils' thinking.

In contrast to this positive feedback, however, one third of the students (seven students) expressed dilemmas or concerns regarding instruction of higher order thinlung. One of their dilemmas stemmed from a difficult choice they believed they must make between two central educational values: transmission of knowledge versus fostering higher order thinking:

I have a dilemma with regard to teaching by this method: what is more important, covering the material or developing thinking? It seems to me that we have to combine the two and to adapt them in accordance with the level of the class.

Dilemmas like these did not appear at the beginning of the course, even though the questionnaire "invited" references of this kind. Other concerns raised in the middle of the course revolved around the difficulty of changing pupils' and teachers' existing thinking patterns and the need for support in the application of the theoretical principles which were learned in the course:

I have a dilemma about teaching by this method; I am not yet sure that I will be able to apply what I have learned within the framework of my teaching at school.

At the end of the course, students' reports showed an increase in the number of students who reported using the TSC approach with their pupils compared with the middle of the semester (15 versus 5 students respectively). Some of the instructional means that had been used included an application of the TSC learning materials. However, students also reported that they introduced thinlung to their pupils in non-structured ways by asking higher order thinlung questions when leading whole class discussions and by using unexpected opportunities that occurred during instruction to practice thinking:

During my lessons, I make my pupils think in a structured manner (as I learned in the course). I use suitable learning materials, include aspects of thinking development in whole-class discussions and try to expose pupils as much as possible to thinking processes. I try to let my lessons flow and I improvise in accordance to pupils' ideas and reactions.

This quotation indicates that the open-mindedness and flexibility required of teachers engaged in instruction of higher order thinking, had been transferred from a theoretical to a practical level. Likewise, ten students wrote that the developing thinking method changed the way they taught:

Teaching by the TSC approach has changed the way I teach. I make greater use of worksheets, the pupils are more active and I create an atmosphere conductive to practicing thinking skills.

Students reported, too, that they were aware of the issue of thinking development when they prepared their lessons:

> *When Iprepare my lesson plan, create teaching aids, or when I observe other teachers, I think how I can develop pupils [thinking].*

Students' references at this time began to include unique descriptions of their classrooms as they taught according to this method. For example, some traced their pupils' improvement in thinking ability:

> *During instruction it is interesting to watch the way pupils' thinking develops and improves, to listen to their answers and watch as they succeed to solve problems.*

These data provide evidence that students applied the TSC principles in their practical fieldwork. Again, the concerns and dilemmas that we witnessed at the middle of the semester were no longer found at the end of the course. These findings clearly demonstrate development of students' experiences in higher order thinking as teachers.

CONCLUSIONS

Based on our findings, it is possible to describe students' development during the course. At the beginning of the course, students' attitudes towards instruction of higher order thinking were positive. Their ideas at this stage were based on general knowledge or on social desirability, and not on specific knowledge. Many of them had difficulties expressing their ideas. As the course continued, two developmental trends became apparent.

First, during the course, students gained new knowledge about instruction of higher order thinking. This knowledge was not only theoretical, but also included practical aspects of instruction. With time, students' ideas became more complex and more sophisticated. Students reported an increase in using the TSC method in their practical work with a growing feeling of confidence. Their attitudes both towards the course and towards the TSC approach were increasingly positive.

A second trend that can be observed from our data is that the progress described in the previous section was not always smooth and linear. By the middle of the course the students were equivocal in their opinions on thinking development. Some of the ideas presented in the course did not fit in with their prior knowledge. This caused concern, doubt, and even dilemmas about issues raised in the course. Feelings of bewilderment and even objections were common in the reports. Students were aware of difficulties and pointed out drawbacks and dilemmas associated with the TSC method.

By the end of the course, feelings of concern and bewilderment disappeared from students' reports. It seems that at this stage, they had acquired a new level of knowledge. Each student related to a wide range of aspects and used correct professional terminology. They made strong references to practical aspects of teaching by the TSC method (as opposed to the general theoretical ideas expressed at the beginning of the course). The concerns described at the middle of the semester gave way to optimistic feelings of improved competence and empowerment, expressing the need to continue using the TSC method in the future.

The knowledge acquired by students during the course refers to Shulman's category of pedagogical content knowledge (Shulman, 1986). This category includes knowledge about instruction of specific subjects. The knowledge is influenced by general pedagogical knowledge and by specific matter knowledge. In our case, it refers to procedural and metacognitive knowledge of thinking (Zohar, 1999).

In summary, students' development during the course can be characterized by the following three stages:

1. A stage of cognitive balance at the beginning of the course. At this stage students expressed intuitive ideas that were unambiguous but limited.
2. A stage of cognitive dissonance at the middle of the course. At this stage students may have known more about the issues taught in the course, but they also experienced confusion, lack of confidence, vagueness and mixed attitude towards the course.
3. A stage of restored cognitive balance at the end of the course, this time at a more advanced cognitive level.

The changes occurred in two domains:

1. <u>The cognitive domain</u>. Starting with simple, general ideas, which were then made more complex, accompanied by feelings of concern and bewilderment. Finally more knowledge was assimilated and the cognitive balance restored.
2. <u>The affective domain</u>. Starting with positive attitudes which were later distorted, expressing concerns and difficulties. Finally, positive attitudes were restored again together with a feeling of empowerment and ability to succeed in the challenging new instructional way.

Implications and Limitations

Implementation of higher order thinking in schools is nowadays a major goal for many educators. Finding adequate methods to prepare teachers for the complicated task of teaching higher order thinking is a considerable challenge. The major implications of this chapter are that it is possible to introduce this issue into teacher preparation programs and to evaluate its effect.

Our findings show that the course was effective in inducing changes in students' thinking and practice. However, we think that what we did has two limitations, which are constraints of the educational setting in which we work. We agree with our students' critique that the course was too short, as well as with their comments about the need to integrate higher order thinking into their science courses. We believe that the *Thinking in Science* course should have been longer to allow students to consolidate their new knowledge and ways of practice. Previous research conducted with inservice teachers using the TSC method has shown that continuous support from a university team during implementation of the method was a vital role to its success (Weinberger, 1992; Zohar, no date). We also believe that, according to the infusion approach, instruction of higher order thinking in teachers' colleges should take place in disciplinary science courses, not only in one special pedagogical course. However, these two desires could not have been accomplished in the educational setting where we work. Since similar practical constraints are prevalent in many educational institutions, it is especially important to realize that even a course of one semester may induce some change towards the goal of developing pupils' higher order thinking.

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