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# Case-based Long-term Professional Development of Science Teachers

Yehudit J. Dori[a,b*] and Orit Herscovitz[a]
[a]*Israel Institute of Technology, Israel;* [b]*Massachusetts Institute of Technology, USA*

Reform efforts are often unsuccessful because they failed to understand that teachers play a key role in making educational reforms successful. This paper describes a long-term teacher professional development (PD) program aimed at educating and training teachers to teach interdisciplinary topics using case-based method in science. The research objective was to identify, follow and document the processes that science teachers went through as they assimilated the interdisciplinary, case-based science teaching approach. The research accompanied the PD program throughout its 3-year period. About 50 teachers, who took part in the PD program, were exposed to an interdisciplinary case-based teaching method. The research instruments included teacher portfolios, which contained projects and reflection questionnaires, classroom observations, teacher interviews, and student feedback questionnaires. The portfolios contained the projects that the teachers had carried out during the PD program, which included case studies and accompanying student activities. We found that the teachers gradually moved from exposure to new teaching methods and subject matter, through active learning and preparing case-based team projects, to interdisciplinary, active classroom teaching using the case studies they developed.

## Introduction

A major goal of science education is to develop students' scientific understanding, higher-order thinking and problem-solving abilities. Achieving this goal should account for societal and economical considerations as well as learning scientific facts and processes through dealing with real-world problems (Dori & Herscovitz, 1999; Dori & Tal, 2000). The need for integration among science, technology and society (STS) is at the basis of new curricula in science education both worldwide (Bybee, 1985; Bybee & Ben-Zvi, 1998; Yager & Tamir, 1995) and in Israel (Dori et al., 2003; Zohar & Dori, 2003).

*Corresponding author. Department of Education in Technology and Science, Technion-Israel Institute of Technology, Haifa 32000, Israel. Email: yjdori@tx.technion.ac.il

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A case-based teaching methodology, which incorporates assessment of high-level thinking skills through related activities, is an effective approach to attain these goals (Herreid, 1994a; Tal et al., 2000).

Educators and researchers generally agree that teachers play a key role in making educational reforms successful. The success depends primarily on proper implementation of new curricula in their classes (Tal et al., 2001). A proper, well-planed teacher professional development (PD) program is needed to ensure that innovative curricula be introduced in a sustainable manner (Bell & Gilbert, 1996). This paper describes a teacher PD program aimed at educating and training the participating teachers to teach interdisciplinary topics in science and technology. The research described in this paper accompanied this PD program and was conducted throughout its 3-year period. During the PD program, teachers were exposed to an interdisciplinary STS approach and the case-based teaching method. The purpose of the research was to identify, follow and document the processes that science teachers went through as they assimilated the interdisciplinary, case-based science teaching approach.

During the long-term professional development program we investigated 51 teachers and their learning processes. These processes began with their first exposure to the case-study teaching approach as a method of integrating technological, industrial, environmental, and social aspects into scientific topics. Including case studies in science teaching in heterogeneous classrooms helps develop abilities of learners at all academic levels to integrate and analyze various data sources. This, in turn, fosters independent higher-order thinking and problem-solving skills. The research assumption was that the teachers' exposure to the case study method will improve their professional development. More specifically, teachers' professional growth was expected to improve both during the PD program and later, in the teachers' classrooms, if they experience learning with, developing, and applying case studies.

The research focused on identification, follow-up and documentation of change processes in teachers' professional development throughout the PD program. The research instruments included teacher portfolios (which contained projects and reflection questionnaire), classroom observations, teacher interviews, and student feedback questionnaires. The portfolios contained the projects the teachers had carried out during the PD program, which included case studies and accompanying student activities. We applied content analysis to the teachers' projects and questionnaires. This analysis served as a tool to assess the teachers with regard to the research questions. Selected observations and teacher interviews are also presented in this paper, along with their interpretation.

An approach to increasingly involve the teachers in developing and editing learning materials was formulated during the research. The teachers gradually moved from exposure to new teaching methods and subject matter, through active learning and preparing case-based team projects, and finally to interdisciplinary, active classroom teaching using case studies.

The introduction of a new STS curriculum in Israel made it necessary to conduct long-term teachers' PD programs aimed at educating and training middle schools teachers to teach science in an interdisciplinary fashion. At the Technion, this PD program revolved around the case-based method that builds upon the social constructivist theory. Hence, in what follows, we elaborate on these three related topics; namely, teachers' professional development, the social constructivist theory, and the case-based method.

## Theoretical Background

Bell (1998) suggested that a science teacher's development has three constituents: professional development that includes content and pedagogical content growth; social development that involves the negotiation and reconstruction of what it means to be a teacher of science; and personal development, which involves each teacher constructing, evaluating and accepting or rejecting the new socially constructed knowledge about the meaning of being a science teacher, and reflecting about one's own beliefs. Indeed, the theoretical underpinnings of our research are rooted in studies on three major issues that directly impact education in general, and science education in particular: (1) teachers' professional development and career path, (2) social constructivism, and (3) the case study teaching approach. Laying out the theoretical background accordingly, we next discuss each of these subjects separately and show how they mesh with each other to form an adequate framework for our case-based teaching approach in a PD program and in-class implementation.

### *Teachers' Professional Development and Career Path*

Teachers often face various obstacles that are interrelated with their life cycle or career path (Fessler, 1985; Fuller, 1969; Huberman, 1993, 1995; Sherry et al., 2000). A teacher's career path starts when the teacher struggles to survive consistent daily routines of teaching. It continues in stages of relative stability, when the teacher is ready to introduce innovations and changes in his/her traditional teaching, and goes on to the last stages of the career that might lead the teacher either to adopt a stable, continuous innovative approach or go into an indifferent attitude towards teaching.

Various models for teachers' PD programs have been suggested worldwide. Different programs emphasize content knowledge, pedagogical content knowledge, building communities of practitioners, and building on teachers' beliefs (Bell & Gilbert, 1996; Guskey, 1986; Marx et al., 1998; NRC, 1996; Supovitz & Turner, 2000). In the Collaborate–Enact–Reflect–Adapt model, suggested by Krajcik et al. (1994), teachers collaborate in order to construct meaning, enact new practices in the classroom, reflect on their practice and, eventually, adapt materials and practices. Using this framework allows researchers to address the expected role of the science teacher as a facilitator, who encourages the student's curiosity (Salomon, 1998). In the PD model of Bell and Gilbert (1996), New Zealand teachers of science learned new teaching activities based on a constructivist view of learning that enabled them to take into account students' thinking. Teachers shared their own experiences while implementing the new teaching activities in their classrooms.

Teachers' roles included teacher as learner and researcher, and teaching as reflecting and supporting.

The increasing emphasis on science as a whole, rather than its compartmentalization into the various disciplines (physics, chemistry, biology), has underscored the weaknesses in pre-service and in-service teacher PD programs (Bell & Gilbert, 1996). For example, Krugger et al. (1990) found that primary teachers' comprehension of key science concepts is often inadequate. Such findings underline the need for ongoing long-term teacher PD programs, in which such teachers' view of science in a holistic approach would be fostered.

Individual differences among teachers with regards to subject matter knowledge (Cocharan & Jones, 1998; Tobin et al., 1994) and using innovative teaching approaches in class naturally exist. Various researchers aimed to identify characteristics of such innovating teachers (Harris & Grandgenett, 1999; Sherry et al., 2000; van Braak, 2001). These teachers initiate and try new ideas, design new curricula (Parke & Coble, 1997), hold a practical approach to teaching, and are aware of the advantages of the new technologies (Dori et al., 2003; van Braak, 2001). Relating to schools that create a positive atmosphere towards introducing information technology, Hodas (1993) argued that such schools end up elevating their teachers' contribution to good science education by encouraging them to have new experiences and get involved in change processes.

Supovitz and Turner (2000), who studied the effects of PD on science teaching practices and classroom culture, claimed that teachers who felt supported by their principal reported significantly greater use of reform approaches than did teachers who did not feel encouraged. Professional development as a part of teacher development involves not only the use of different teaching activities, but also the development of beliefs and concepts underlying these activities. A teacher's social development involves the renegotiation and reconstruction of what it means to be a teacher through interaction with peers in her/his environment (Bell & Gilbert, 1996). This is a major point of contact with social constructivism.

### *The Social Constructivist Theory*

The outcome of instruction through simplistic straightforward transmission models of teaching is often rote learning, leading to inert knowledge (Bruer, 1993; Perkins, 1992). The constructivist theory puts the construction of knowledge in one's mind as the centerpiece of the educational effort. A basic assumption of teaching according to the constructivist learning approach is that knowledge cannot simply be transmitted from teachers to learners, so learners must be engaged in constructing their own knowledge (von Glaserfeld, 1991). The constructivist approach fosters meaningful learning and deep understanding of the physical phenomena, and the learner needs to be able to create the knowledge in his/her mind (Osborne & Wittrock, 1985). In so doing, the learner becomes the 'owner' of the knowledge. Such ownership enables the learner to understand the knowledge such that conceptual change takes place within a person's mind. Conceptual change can also be viewed as a consequence of casting meaningful learner relationships with the world in particular contexts (Duit & Treagust, 1998). Social constructivist ideas enable one to investigate and support the notion that knowledge becomes obvious as being distributed and shared rather than being the property of individuals. Social constructivism acknowledges the socio-cultural aspects of learning. Carefully constructed learning environments can facilitate students' understanding of concepts in science.

A recent research focus has been the social circumstances of cognitive activities in communities of scientists, practitioners, and learners (Duschl & Hamilton, 1998). The shift from a focus on individuals to a focus on members of the community has implications on science teaching in general, and on conceptual change in particular. Shifting from knowing and reasoning of individual scientists or learners to communities of scientists or groups of students requires a fundamental change in the science learning environment. It also calls for a change in what we ask our students, as well as teachers in student situations (such as during a PD program) to do in those environments.

From a constructivist perspective, science teachers' conceptions of science and the way they teach it is a result of the way they were taught in their schools (Hewson & Hewson, 1988). The methods by which science instructors were taught are often inconsistent with contemporary educational approaches and therefore a conceptual change is required. Such a change on the part of science teachers requires the development and implementation of new curricula and the adaptation of new teaching and assessment methods that foster conceptual understanding (Dori, 2003; Tal et al., 2001).

Bell and Gilbert (1996) claimed that there is an intimate relationship between personal and social constructivism; the personal construction of knowledge is mediated by the social construction of knowledge, and vice versa. The role of the teacher in a constructivist setting is not to always stand back (as the inquiry approach might be criticized). At the teacher's discretion, he/she may either tell the science up-front or guide the students' though processes to facilitate getting to the science on their own (Bell & Gilbert, 1996).

As Bybee and Ben-Zvi (1998) indicated, in the past science educators focused primarily on content and secondarily on instruction, leaving implementation to others or completely ignoring them. They acknowledged that this places additional burden on the curriculum developers, but claimed that the challenge is worth the effort, as the resulting program is complete, coherent, and consistent. This was indeed the outcome of the long-term PD program that served as the basis of this research.

The research presented in this paper builds on principles of social constructivism, as it fosters teachers' teamwork in developing innovative case-based learning materials and integrating new ways of student activities that significantly depart form the traditional teaching modes. The PD program that served us as the research environment was designed to create supporting conditions for teachers' conceptual change through group interaction in teams of increasing size following social constructivist principles.

### *The Case Study Teaching Approach*

Case studies, also known as case narratives, are 'stories with a message' or 'stories to educate' (Herried, 1997). Originating from business and medical schools, the case study method provides a context for exploring particular principles or problems (Sykes & Bird, 1992). It becomes a means for effective learning that draws the attention of the student audience by portraying real-life scenarios. Case studies are usually real stories, examples for us to study and appreciate, if not emulate. They can be close-ended or open-ended, they can require a single correct answer or various resolutions of a dilemma. Since, open-ended cases contain scientific aspects that involve emotions, ethics or politics, they can present unresolved dilemmas or yield multiple solutions.

Tobin et al. (1990) viewed cases as 'windows into science classrooms' and discussed the use of their contribution to professional development and teacher preparation. According to Kobballa and Tippins (2000), the use of cases has only recently been studied and there are several common themes that serve as foci of the research agenda. These themes include cases as a tool for professional preparation and development, cases as a discipline-based teaching method, cases for facilitating critical thinking and exploring dilemmas, and cases as an assessment tool. Dori (2003) and Dori and Herscovitz (1999) emphasized the use of case studies as science-based teaching and assessment tools, and argued that the case-based method develops students' higher-order thinking skills. Case studies that are based on contemporary science problems that students encounter in the news make science more relevant to the students' daily lives (Herreid, 1994b, 1997).

Comparing four problem-based teaching methods, Lohman (2002) and Mayer (2002) identified the underlying features of the case study approach to professional development. They have characterized the case study as a well-structured, expert-oriented, non-routine problem, which requires the reader to list and evaluate possible causes and solutions. Developing a case study is a time-consuming endeavor, while much less time is required for its implementation. The method is appropriate for application in large groups and its outcomes are near transfer of content knowledge and skills, and the ability to solve authentic problems.

Cases are chosen because they serve to illustrate general principles and good practices. Wheatley (1986) argued that case studies provide a mechanism for allowing students to practice decision-making or to study the consequences of the intersection of STS. Good discussions that follow the presentation of a case study are invaluable in providing feedback to the teacher on the status of the student comprehension, and are particularly valuable in early exposure of misconceptions (Challen & Brazdil, 1996). Studies related to teaching students at various ages using case studies (Dori & Herscovitz, 1999; Dori & Tal, 2000; Hofstein et al., 1999) have indicated that the case study method is effective for raising students' conceptual understanding, question posing and critical thinking abilities. The case study method fosters a constructivist learning environment and provides for evaluating students' thinking skills (Dori, 2003; Wassermann, 1994) as well as teachers' pedagogical content knowledge (Peterson & Treagust, 1998). Accounting for these traits of case studies, it should come as no surprise that we have elected to base our long-term teacher PD program to a large extent on the case-based method, as we describe in detail in the sequel.

## The Research

Due to changes in science and technology curricula (Harari, 1994), the Israeli Ministry of Education decided to provide teachers with a series of on-going science teacher PD program of one day per week for a period of three academic years. The goal of the research was to study the case-based approach in the context of teachers' professional development and growth. This encompassed how teachers developed learning materials that incorporate the case-based approach and elements of alternative assessment, how they viewed the implementation of case studies in their classrooms, and how the teachers' deliverables were evaluated. The research focused on identification, follow-up and documentation of change processes in teachers' professional development and growth throughout the program.

The research questions were:

1. How did the teachers' ability to modify and develop various learning activities using the case study approach change as a result of the PD program?
2. What were the teachers' reflections regarding the role of the STS teacher, the implementation of the case-based approach and learning materials in their teaching, and the impact of the PD program on their professional growth?

### *Research Population*

This research followed two groups of science teachers who participated in a 3-year PD program at the Department of Education in Technology and Science at the Technion. The teachers, who came as teams from middle schools in the northern part of Israel, were released from teaching duties to participate in the PD program one day per week during the 3-year period.

The research population included 51 teachers, who were divided into two groups that started the PD program in consecutive years. Sixty percent of the teachers came from the Jewish sector and 40% from the Arab sector. About 80% of the teachers were women, 65% were biology teachers, and the rest were chemistry, physics or technology teachers. About two-thirds of the science teachers had over 10 years teaching experience and were in the relative stability or experimentation stages in the career cycle (Huberman, 1995). Therefore, most of the teachers were ready to introduce innovations and changes in their traditional teaching.

### *Research Setting*

The case-based long-term PD program included three types of enrichment: theoretical, content knowledge, and pedagogical content knowledge (Shulman 1986), as described in Figure 1.

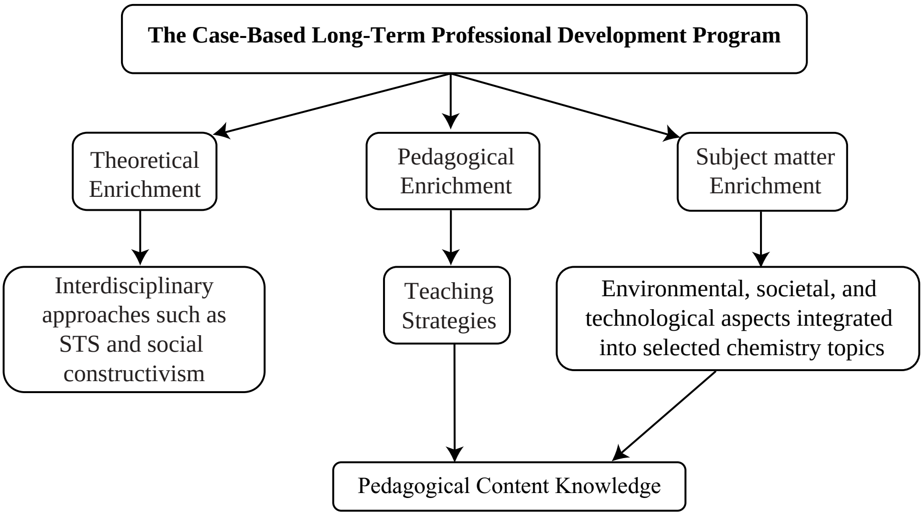


Figure 1. The PD enrichment plan

Environmental, societal and technological aspects of several science topics were presented through laboratory experiments, case studies and cooperative learning. Since the subject matter expertise of most of the teachers was biology, the PD program emphasized topics in chemistry and physics, as well as technology. In this paper we focus on the chemistry topics. Relating these topics to biology enabled the biology teachers to broaden their interdisciplinary knowledge and see the links between seemingly disparate science areas.

Table 1 presents the main chemistry topics in the PD program to which teachers were exposed as part of the content knowledge enrichment. The teachers received similar types of content knowledge enrichment in physics and technology. Since most of the teachers were biology teachers less time was devoted to biology content knowledge.

Following the STS approach (Bybee, 1987), each topic presented in Table 1 included chemical aspects that were integrated with technological, industrial, environmental and social aspects. This kind of integration was an important element in the PD program as it underscores the idea that science is interdisciplinary in its nature and touches upon multiple daily life issues. Table 2 elaborates on the *Elements and the Periodic Table* topics from Table 1, as an example of enrichment in content knowledge intertwined with enrichment in pedagogical content knowledge.

For example, the teachers studied about the elements through a Web-based periodic table; were exposed to various molecules, bonds, and geometric structures via computerized molecular modeling; and discussed ethical, health, and scientific dilemmas through role-playing and case studies.

The PD program multi-dimensional learning environment was designed to allow the teacher to evolve, first of all, as a student. The teachers were exposed to the

Table 1. Main case studies and experiments integrated in the PD program

| Topic | Main case study | Experiments/Web activities |
|---|---|---|
| Introduction — the chemistry language: element symbols, formulas and equations | | |
| Chemical mixture separation | 'Nesher' — a cement plant and the air pollution problem | Various methods for separating chemical mixtures |
| The atom structure and nuclear energy | The Chernobyl radiation disaster[a] | Assembling and operating an electrochemical watch |
| The elements and the periodic table | • The radon gas problem<br>• Silicon implants problem[a] | Various Web activities with the periodic table |
| Chemical structure, bonding and substance properties | The solubility phenomenon and the oil spill problem[a] | • Examining solubility properties in water of various substances<br>• Identifying the substance's bonding type by solubility and conductivity properties in water |
| Oxides, acids, bases and salts | $SO_x$ oxides and air pollution: the 'Historic London episode' | Examining acids and bases properties[a] |

[a] Marked activities were taught using the Jigsaw method (see more details about the Jigsaw method in Lazarowitz & Hertz-Lazarowitz, 1998).

case-based teaching approach. They were engaged in planning activities, adapting a case study to an appropriate activity, developing a subject matter that involves case studies, and applying it in class. The teachers' horizons and professional competence were expanded through creative and applied learning in the classroom, allowing the teachers to go through a change process, and carrying out the reform in their classrooms.

The teachers got increasingly involved in planning their teaching and developing new, inter-disciplinary learning materials. The second year concluded with the integration of inter-disciplinary teaching in classrooms. The learning environment was built on five central educational elements we call pillars, described in Figure 2, which were taken into account throughout the professional development. These pillars involved the teachers as both students and learning material developers.

The five pillars of the learning environment were:

I. *Case studies and their integration into the existing learning materials*. As learners, the teachers gained experience throughout the PD program in case study analysis. This included critical reading of the case study and posing question at various thinking levels. As teachers, they gained experience in exploring finding, editing existing case studies or developing new ones, and adapting them to students at different academic levels. These assignments were given in steps that involve increasing difficulty level, beginning with planning an activity for a given case, and concluding with developing a topic for teaching that combines case studies,

Table 2. STS rational of the Elements and Periodic Table topic

| | Chemical aspect | Technological aspect | Environmental–social aspect |
|---|---|---|---|
| Goals | Understanding the relations between atom structure and the periodic table | Industrial usage of silicon | Environmental and health impact of radon and asbestos |
| | Studying the properties of several elements | | The impact of interaction between science and society on ethics aspects |
| Content | Periodic properties of elements: metals, atomic radius, ionization energy, melting and boiling points | The use and characteristics of transistors, silicon chips and semi-conductors | The radon hazard |
| | The geometric structure of silicon and silicates | | The public hearing in court concerning the silicon implants |
| | Radioactive properties of radon gas | | The use of every-day products containing silicon |
| Activity | Working sheets contains open and close questions | Group discussion | Group discussion on ethical and moral aspects raised in several case studies |
| | Studying Web-based periodic tables | Concept maps | Role playing |
| | Molecular modeling | | Expressing arguments and opinions and making decisions |

and applying it in a classroom. The research described in this work focused on this pillar, namely case studies.

II. *Diverse information sources*. To advance the teachers ability to find out and develop new case studies they had to search for articles in popular science journals, daily newspapers and websites, sorting them into different subject matter topics and adapting them for use by students at different academic levels.

III. *Teaching strategies*. Through their projects, the teachers used various considerations in choosing and adapting different teaching strategies to different topics, in order for them to be able to expose their students to a wide range of activities, including laboratory experiments, physical and computerized models, educational software, concept maps, and field trips.

IV. *Team work*. As learners, the teachers experienced cooperative learning in small groups, with focus placed on the jigsaw method, group discussion, and brainstorming (Lazarowitz & Hertz-Lazarowitz, 1998). As teachers developing a learning environment for their students, they prepared projects that required coordinating and sharing of the workload. This holds true for both creating original learning materials, and applying them in the classrooms.

V. *Alternative assessment methods*. Following each project the teachers were introduced to and experienced peer assessment, self-assessment of their own projects, and student evaluation (during the third project) in their classes.

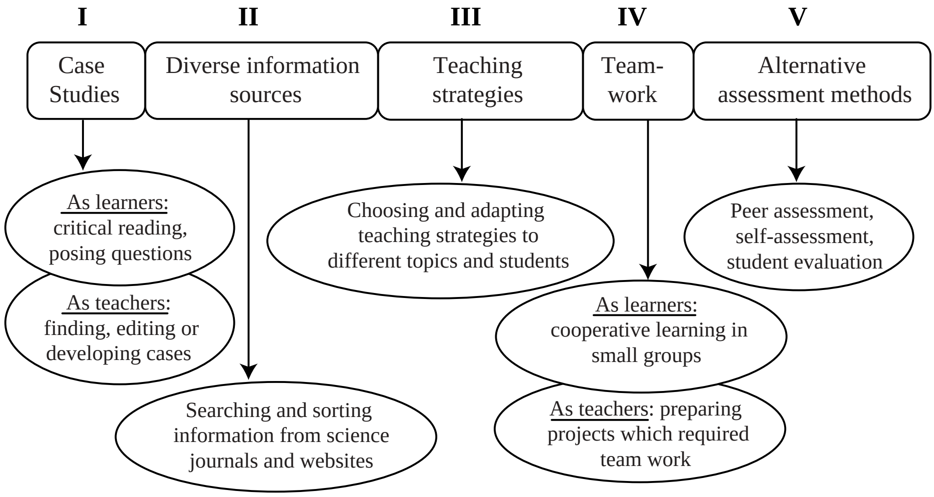


Figure 2. The five pillars learning environment

These experiences demanded them to be open to criticism and be ready to accept and offer assistance to each other.

*Teachers' Professional Development and Growth*

The schematic graph in figure 3 depicts the professional growth of the teachers who implement case-based teaching in the PD program.

The vertical line shows teachers moving from the use of ready-made case studies to implementing their own self-made case studies. They do so through five phases along the horizontal time line. In phase I — exposure — the teachers were exposed to the case-based approach in teaching, experienced it as students, and studied various STS-related topics using these case studies. From phase II onward, the initiative and responsibility for planning the teaching was transferred from the science education researchers to the teachers. In phase II — planning — the teachers planned a student activity that was based on a given case study. In this phase, the teachers were handed two different half-page cases: one of a cement factory near a big city, and one of finding radon gas in schools and residential area. The teachers read the two cases and were asked to write a few questions about each case and plan a student activity that would follow reading the case study by their students.

In phase III — designing and developing — the teachers received diverse sources and references, such as popular journal articles, books, and websites dealing with a certain subject matter. They had to choose a case study for their students and plan a matching activity.

In phase IV — gathering, developing, and assessing — the teachers were entirely responsible for initiating, planning, and development of an STS-related topic for

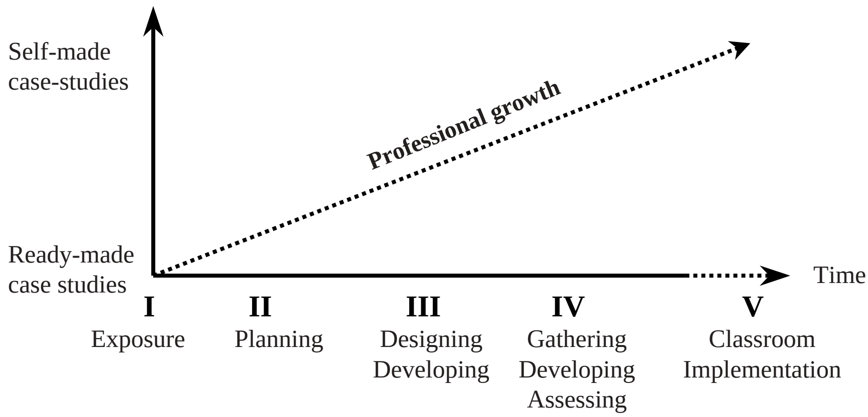


Figure 3. Teachers' professional growth through the implementation of case-based teaching — a change process

classroom teaching that involved case studies of their choice. While preparing the air and water pollutants project, the teachers worked in pairs. They collected assorted data, edited at least one appropriate case study, and planned student activities to complement these case studies. In the final phase V — classroom implementation — the teachers worked in teams of three or four to develop a case-based approach to a topic of their choice, and to apply it in their classrooms, while their peers and the science educators observed and assessed the class implementations.

From phase III onward, the teachers implemented peer assessment and reflective thinking on their involvement and perceptions regarding professional growth processes they were undergoing. As part of this process they also suggested possible improvements for the future. The diagonal line in Figure 3 describes schematically the trend of transferring the responsibility of choosing the case study topic and authoring the case study and its related activities from the science education researchers to the teacher population. Although straight, the graph does not necessarily describe a linear progressive relationship, since the rate of professional growth in the different phases is not constant. Moving along the time line, autonomy in developing student-centered, case study-based learning materials is increasing.

The five phases teachers went through during their professional development process show the teachers' gradual professional growth, starting with their experience as learners using ready-made case studies and ending with development of self-made learning materials, their application and their assessment. This significant progression was achieved by decreasing the academic support and increasing teachers' academic independence and pedagogical initiative, while endowing the teachers the appropriate capabilities, as presented in Table 3. Such profound change can only be achieved through a long-term program that takes a couple of years to complete.

Table 3. Gradual expansion of teaching strategies as a way for teachers' professional growth through case-based learning and teaching

| Stage | I, Exposure | II, Planning | III, Designing and developing | IV, Gathering, developing and assessing | V, Classroom implementation |
|---|---|---|---|---|---|
| Teacher's activity and experience | As learner | As teacher | As developer | As developer | As implementer |
| Active learning in small groups | ✓ | ✓ | ✓ | ✓ | |
| Developing learning activities for students | | ✓ | ✓ | ✓ | ✓ |
| Developing cases and adapting them for students | | | ✓ | ✓ | ✓ |
| Peer assessment and self-assessment | | | ✓ | ✓ | ✓ |
| Gathering information from diverse sources | | | | ✓ | ✓ |
| Team work | | | | ✓ | ✓ |
| Developing a case-based project | | | | | ✓ |
| Class implementation of the case-based project | | | | | ✓ |
| Evaluating students' reflection | | | | | ✓ |

### *The Case Study Rationale*

Following suggestions and findings of several researchers (Herried, 1994a, 1994b, 1997; Kobballa & Tippins, 2000; Lohman, 2002; Mayer, 2002; Wheatley, 1986) we developed a case-based teaching and learning environment suitable for science and technology interdisciplinary courses in middle schools. The environment includes three components: the case study, student activities, and classroom implementation. These components and their characteristics are described in Table 4.

Keeping in mind the three case-based environment components and their characteristics presented in Table 4, we developed a set of categories while analyzing the teachers' projects described in Tables 5 and 6.

An example of a case study entitled 'Oil spills in the sea: an unavoidable pollution?', which we developed for the PD program as part of the 'Chemical structure, bonding and substance properties' topic, is described in appendix 1.

## Research Instruments

The research instruments included assessment of the teachers' projects, a reflection questionnaire, classroom observations, teachers' interviews, and students' feedback.

Table 4. The three components of the case-based environment exemplified

| Component | Characteristics |
|---|---|
| The case study | Written as a narrative in a clear and concise way (about 250 words)<br>Concerns real, everyday issues relevant to the student's world<br>Focused on a clearly defined phenomenon, problem, or dilemma emphasizing scientific aspects<br>Presented in a way that encourages the student to pose questions, further investigate it, and present optional solutions to the problem<br>Promotes an interdisciplinary approach by including technological, environmental or societal aspects in addition to the scientific aspect |
| Student activities | Questions requiring various thinking skills:<br>● understanding the subject matter<br>● implementation of previous knowledge<br>● analysis of information and data up to higher-order thinking skills, e.g. critical thinking<br>● expressing a well-argued opinion<br>● posing questions or raising creative solutions to a problem taking in mind the advantages and disadvantages of each proposed solution<br>Complementing activities such as experiments, movies, concept map drawing, class discussions, field trips, and debates<br>Integration of science aspects with environmental and/or social aspects |
| Classroom implementation | Encouraging the students to be autonomous learners following to the constructivist approach<br>Learning cooperatively in small groups<br>Involving the student in his/her assessment |

Classroom observations, the interviews, and students' feedback questionnaire were carried out while the teachers implemented the third project in their classrooms. The first two research instruments were designed specifically to address the two research questions, respectively.

### *Teachers' Projects*

The data collected from teachers' projects served to address the first research question — 'How did the teachers' ability to modify and develop various learning activities using the case study approach change as a result of the PD program?'

As part of the 3-year course, the teacher participants experienced carrying out three projects related to developing learning materials for students using an interdisciplinary approach combined with case studies. These projects, which were carried out through the first 2 years of the PD program, served both as a means to further the teachers' professional growth and as a research instrument.

The first project was given to the teachers towards the end of the first year, when the teachers were asked to prepare an individual project. This project, called

Table 5. Categories for case study analysis and their scores

| Category | Scoring scheme |
|---|---|
| Inter-disciplinary nature (In) | 1, One domain (scientific, societal, etc.) only is involved<br>2, Two domains are involved, but poorly integrated<br>3, Two or three domains are involved, highly integrated |
| Suitability to student (Sb) | 1, Low — the case study is unclear/disorganized/ unfocused/too long<br>2, Intermediate — the case study is clear, but has no main issue/dilemma/has a main dilemma but is too long and contains too much irrelevant details or too short and doesn't have enough details<br>3, High — the case study is interesting, well written, presents a clear dilemma, which encourage the student to further broaden and investigate the issue |

*Elements*, concerned a case study on a chemical element taken from a popular science journal. They then designed student activities based on the case study they had developed.

In the middle of the second year, the teachers prepared the second project in pairs. They chose between air or water pollutants as an example of general scientific/technological topics. The assignment included modifying a case study for this topic and preparing student activities that related to this case study.

For the third project, which started toward the end of the second year, teams of three or four teachers chose a subject to their liking. The teams prepared a comprehensive, interdisciplinary study plan, which included a case study and student assignment. The teachers taught this project in their own classrooms, and it was accompanied by peer assessment and students' feedback. During the third year of the PD program, the teachers were engaged in developing web-based learning materials, which are described in detail in Dori et al. (2002).

### *Reflection Questionnaire*

The data collected from teachers' reflections served to address the second research question — 'What were the teachers' reflections regarding the role of the STS teacher, the implementation of the case-based approach and learning materials in their teaching and the impact of the PD program on their professional growth?'

The elements that characterize teaching processes are usually identical, but different teachers understand and interpret these processes differently. By thinking about their views and perceptions, the teachers ask themselves questions regarding their profession; questions that most teachers, especially veterans, do not give much thought to during their career. Our reflection research tool was a questionnaire, in which the teachers were asked to rethink their teaching methods. The questionnaire was handed out to the teachers at the beginning of the PD program and towards the end of its second year. The questionnaire included several open-ended questions,

Table 6. Categories and scores for assessing case study student activities

| Category | Scoring scheme |
|---|---|
| Inter-disciplinary nature (In) | 1, One domain only (scientific, societal, etc.) is involved<br>2, Two domains are involved<br>3, Three domains are involved |
| Variety (Va) | 1, All activities are of the same type: teacher questions to the student<br>+1, An extra point is given for each additional activity (e.g., experiment, movie, concept map, class discussion, field trip, debate, etc.) |
| Relation to the case study (Re) | 1, Low — superficial treatment, which does not touch the essence of the problem; activity has little to do with the case study<br>2, Intermediate — reasonable treatment and relation to the case study; no deep treatment of the problem raised in the case study<br>3, High — deep, serious treatment of the case study; gradual, logical construction that leads to profound student understanding |
| Complexity (Co) | 1, Low-order cognitive skill: the answer is contained in the case study. It requires knowledge and understanding<br>2, High-order cognitive skill: the answer is at most partially contained in the case study. It requires analysis and synthesis<br>3, Very high-order cognitive skill: the answer is not contained in the case study. It requires value judgment, system thinking, assessment, or opinion |

which dealt with the role of an STS teacher, the development of STS learning materials, advantages and difficulties of implementing the case-based method, and the extent of professional change that teachers thought they underwent as a result of the PD program.

## Data Analysis

In order to enable the teacher in the PD program experience the use of various means of assessment methods, each group assessed each project, as did the PD program lecturer, who was one of the researchers. After reading their peers' project portfolios, groups of three to four science teachers suggested criteria for assessing the projects. Six criteria were finally selected in a plenary session. Some of these criteria, such as design/aesthetics, and originality/creativity, were concerned with project assessment in general, and were therefore also applicable to student projects. Other, more specific criteria, related to the assessment of the teacher portfolios, and included the level of interdisciplinary nature of the project, suitability for the students, and variability of the accompanying activities.

To gain further insight into the projects that teachers developed in the PD program and to assess them thoroughly, we carried out content analysis of all the projects. Using some of the criteria proposed by the teachers during the peer assessment processes described earlier, and adding new ones, we developed two sets of criteria: one for the case studies and the other for the accompanying activities. Two science education experts (in addition to the two researchers) validated these two sets of criteria. Later, these experts also validated the assessment of a sample of the projects, which was based on theses two sets of criteria.

### *Case Study Analysis Scheme*

The analysis of the case study was based on: (1) its level of interdisciplinary nature (In), and (2) the suitability to student thinking skills (Sb). These categories are described in table 5 along with their scoring scheme.

### *Case Study Activities Analysis Scheme*

We analyzed the accompanying activities at two levels: the activity content and the activity assessment. The activity content analysis was based on three categories: (1) relevance of the activities to the topic or problem presented in the case study; (2) the presentation of and discussion about possible solutions to the problem the case study presents; and (3) references to aspects or areas that are related to the topic or problem at hand but are not directly presented in the case study.

For the activity's assessment we used four categories: (1) the activity's level of interdisciplinary nature (In), (2) the variety of the set of activities (Va), (3) relation of the activity to the case study (Re), and (4) the activity's complexity (Co). These categories along with their corresponding scoring schemes are described in table 6.

## **Findings**

Since case studies were the focus of the research, we analyzed the main characteristics of case studies and accompanying activities that the teachers authored or adapted during the PD program. Along the 3 years of the program, each teacher participated in designing three projects: an individual project, a project in pairs, and a project in teams of three to four teachers.

### *Project Descriptions and Comparisons*

The following are the three project statements and their applications. The first is an individual project, while the third in the series of teacher projects is a team work. The same teacher who carried out the application of the first project was also part of the three teacher team who carried out the application of the third project.

*Project I (individual): teaching the* Elements *topic using the case-based method*. Project statement:

> Below is a list of articles from various sources about different chemical elements. Your assignment is to individually choose one article, edit it into a short case study, and create a student activity relating to the case study.
>
> It is important to note the source of the article you used. If you choose to use additional materials, please indicate their source as well and append them to your project.
>
> The case studies and activities you hand in will be distributed among your peers. Please hand in a clear, aesthetic printed version of your work!

The project statement included also a list of elements that included chlorine, calcium, magnesium, lead, nitrogen, arsenic and others. Each element had related references, such as the one for iron [Zilber-Rosenberg, Ilana (1996). Food and Nutrition in health and sickness: food for thought (Israel: Open University Press) (in Hebrew)].

Based on this project definition, one of the teachers designed a case study entitled 'Iron and the human body'. Table 7 describes briefly the case and its accompanying activities, along with its analysis and interpretation.

*Project II (pairs): modifying a case study*. In Project II, teachers were required to modify a case study that concerns air or water pollutants and their effect on humans and the environment. Each pair of teachers was asked to provide the following:

1. A short explanation about the nature of the activities, classroom time, and special teaching aids.
2. Sources upon which the case study was based.
3. Documentation of the teamwork process: choosing the topic, dividing the workload, deliberations, and meetings.

*Project III (team of three teachers): planning, implementing and assessing an interdisciplinary topic using the case-based approach.* The project consists of three phases. Project statement:

> Phase 1: Prepare a short learning unit that includes several different aspects of a subject matter of your choice. The unit must include a case study and related activities. The handed-in paper should include a project rationale and explanations/guidelines for a novice teacher who would implement this learning material. Make sure to include sources for the case study and documentation of your teamwork.
>
> Phase 2: One or more of your team members will teach the subject matter according to your plan, while another team member will document the teaching process. The team members will then meet to summarize their reflections, and improve their project accordingly.
>
> Phase 3: Present your project to peers in the PD program. Prepare a poster or a computer-based presentation summarizing your teaching plan, learning materials, and the documentation of the classroom implementation. Peers from another team will assess your project.

Table 7. The case study 'Iron and the human body' and its analysis — project I

| Case synopsis | Analysis |
|---|---|
| Iron exists in the human body's blood. Its main function is to carry oxygen from the lungs to the cells through the hemoglobin mechanism. Low levels of iron cause anemia — a feeling of weakness and exhaustion — as well as digestive problems and loss of appetite. High levels of iron cause metabolism problems. It is very important to periodically check iron levels in order to prevent metabolism dysfunction | This is an inadequate, poorly written case study. The informative style describes the impact of iron on the human body and has only one scientific aspect.<br><br>The total case study score, 3, is the sum of its interdisciplinary nature score (In), which was 1 (biological aspect only), and student adequacy score (Sb), which was 2 (medium level) |
| *Questions*<br>1. What is the main function of the iron in the human body?<br>2. Name at least two problems caused by lack of iron in the body.<br>3. What causes high level of iron and what are its effects on the human body?<br>4. What kinds of food contain iron? | The accompanying activity of the case study consisted of only four questions. Content analysis of these questions revealed that all four questions were directly related to the topic introduced in the case study and required the same thinking skill. We assigned them the following scores:<br>Variety (Va) = 1. All questions are of the same 'teacher asks student' type<br>Relation between the case study and the activity (Re) = 2. The activity is related to the topic presented in the case study but there is no deep treatment of the problem raised in the case study<br>Complexity (Co) = $4 \times 1 = 4$. All four questions were knowledge and understanding low-level questions; the answer to which is found in the case study<br>The total score of the activities was 7 |

This project was carried out in teams of three or four teachers from the same school but from different disciplines (biology, chemistry or physics). Table 8 describes briefly one implementation of project III, the case and its accompanying activities, along with its analysis and interpretation.

As noted, the teacher who developed the individual case study entitled 'Iron and the human body' in the first year of the PD program was also one of the three members in the team who developed the case study 'Chlorine – the "green" death' during the third year of the PD program. This teacher indicated that she had undergone a significant professional growth process during the 3 years of the PD program. This major change is evident when one compares the structure and respective scores of these two projects.

These two project examples are typical of the change that teachers went through during the long-term PD. Quantitative analysis of the entire set of projects using the

Table 8. Case study 2: 'Chlorine — the "green" death' and its analysis — project III

| Case synopsis | Analysis |
|---|---|
| Chlorine and its products are considered 'wonder substances' because of their properties and applications in industry and household. It turns out that these valuable properties are a 'two edged sword' and chlorine products consists deadly risk. The element chlorine exists in nature only in compounds like the common salt sodium chloride (NaCl) …<br><br>*Exemplary questions*<br>● Mark the main concepts in the case and build a concept map for 10 of them<br>● What is the difference between the element chlorine and the chlorine ion?<br>● Find the chlorine element in the Periodic Table. What can be learned about its properties from its position in the table? | This is a well-written case study, which scored 6, while its accompanying activities scored 35. The case study is written in a narrative, clear and interesting style, though it is quite long. The case study is divided into two parts, which makes its reading easier for the students. The first part of the case study focuses on the scientific aspect of the topic, while the second part presents the environmental and social aspects of manufacturing and using chlorine-containing materials. Finally, the case study presents social dilemma of the awareness and desire to avoid manufacturing and using these materials on one hand and the economical aspects of doing so on the other<br><br>The accompanying activity of the case study consisted of 16 questions, seven of which were given at the end of the first part and the rest at the end of the entire case study |
| In a research conducted in Israel, high levels of organo-chloric compounds were discovered in humans, including dioxin, a highly toxic compound that causes liver, kidney, nerve and fertility problems<br>The Mediterranean Sea is highly polluted with chlorine compounds which caused the death of many dolphins in recent years<br>The American Environmental Protection Agency published strong recommendations forbidding the pouring of chlorine and its products into the open sea<br><br>*Exemplary questions*<br>● What are organo-chloric compounds and how do you think they enter the human body?<br>● Compose two questions that cannot be answered by reading the case study. Try to answer them. If you were not able to do so, what experts do you think should be consulted?<br>● Propose ways to alleviate the environmental problem presented and write down the pros and cons of each suggestion | |

same scoring scheme is described in the following. Analyzing the level of the interdisciplinarity in the first project we found that one-half of the case studies (20 out of 40) that the teachers modified were concerned with only one discipline, and only 8% of the case studies demonstrated a well-integrated interdisciplinary approach that involved at least two disciplines or knowledge domains. In the second project, which the teachers carried out in pairs, all the projects exhibited an interdisciplinary approach, with one-half of them (eight out of 16) discussing two disciplines and the rest involving three disciplines or more. In the final project, 80% of the case studies that the teachers designed encompassed three disciplines or more and were well integrated.

Turning to the criterion of suitability to students, we found a clear progression throughout the DP program in the teachers' ability to develop a case study in ways that make it increasingly suitable for the target audience, namely the students. Such suitability can be manifested by the narrative flow of the case study in a story-like manner, and by the case study's ability to raise interest by presenting a central problem or dilemma. This dilemma should excite the student and encourage him/her to deepen the knowledge upon which the case study is based. Such knowledge building is solid, as it is acquired in a constructivist manner, both individually and socially. Using the knowledge gained in the process, the student can engage in analyzing the case study.

In the first project, over 40% of the case studies teachers modified featured low suitability to the student, and only one-quarter were highly suitable. In the second project, only one-fifth of the case studies exhibited low suitability while nearly one-half were highly suitable. In the final project, 60% of the case studies were highly suitable for the students, and none of them exhibited low suitability.

To obtain a more comprehensive view of the progression teachers made in their ability to design high-quality case studies, we combined the two criteria, interdisciplinarity and suitability for students. Each criterion could score between 1 and 3 points, so the composite score, which was the sum of the two scores, could range between 2 and 6.

The total scores in the three projects, presented in Figure 4, show that both criteria come into play in a coordinated manner. The graph shows a clear shift toward the higher scores along time. In the first project, most of the scores were 3 or 4, and only one case study scored 6. In the second project, one-half of the case studies received the higher scores of 5 and 6. No case study scored 2, and only one scored 3. In the third and final project, the vast majority (90%) scored 5 or 6. Only one case study received a score of 4, and none scored below 4. As noted, we also analyzed the accompanying activities; the results of the activity analysis are presented in Figure 5.

Figure 5 shows a trend of improvement of the total score of case study activities in each one of the three projects. The mode of the score in project I was 6–to 15 (with a frequency of 80%), in project II was 16–25 (50%), and in project III was 26–35 (70%). In project III, 20% of the activities were ranked in the range of 52–85. No activity in project I or project II was ranked in this range.

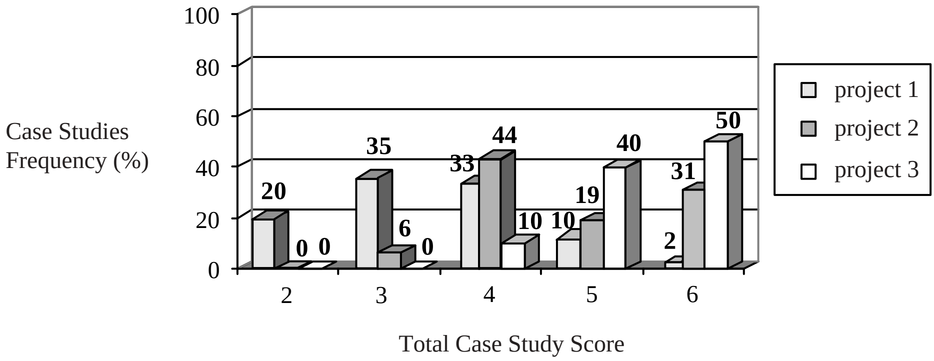


Figure 4. Total case study scores

*Teachers' Reflection*

In the beginning and towards the end of the second year of the PD program, the teachers were asked about their teaching and educational beliefs in open-ended reflection questionnaires. Table 9 describes two questions from these reflection questionnaires, our interpretation remarks and teachers' examples.

Teachers were also asked to indicate advantages and difficulties in implementing the case study approach and the likelihood of implementing the case-based method in their teaching as a result of the PD program. Teachers' responses towards the implementation of case studies in their teaching are presented in Table 10.

Initially, teachers were not familiar with the case-based method and were excited about the possibilities it opens. They considered the integration of case studies based on press or popular science articles to be a good method that should be embraced. At the beginning, their lack of experience prevented them form anticipating problems,

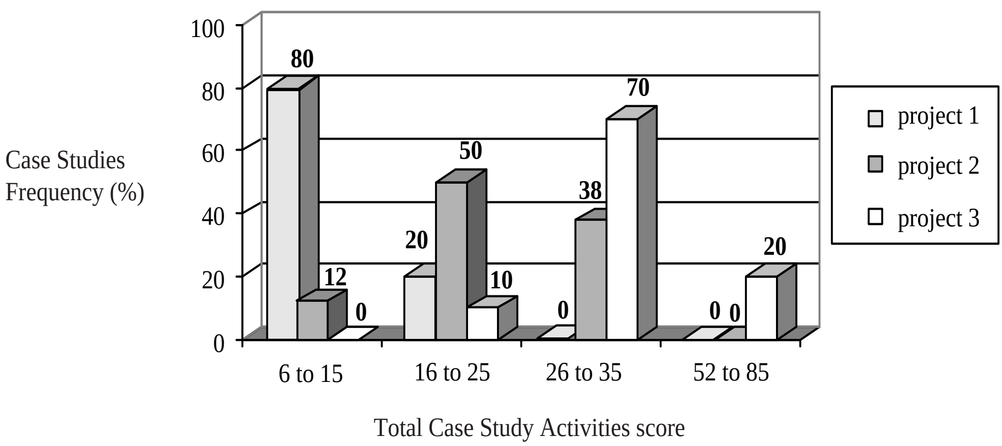


Figure 5. Total score of the case study activities

Table 9. Analysis of two questions from the reflection questionnaires.

| Findings and interpretation | Teachers' response examples |
|---|---|
| *Question 1*: 'What do you believe is the main task of an STS teacher?' In the pre-PD questionnaire, this question was a source of great confusion among the teachers. They had heard some ideas of the new role of teachers in other PD programs, but most of them were no more than shallow slogans In the post-PD questionnaire, the teachers emphasized the complexity of the teacher's role and put the students' needs at the focal point of their teaching responsibility | 'I know that an STS teacher has to go through a fundamental change which I am willing to undergo, but frankly I don't know what this change should be and how to do it'<br><br>'My role is to guide our students to learn in small cooperative groups; to prepare the student to be an autonomous learner; to foster inter- and multidisciplinary thinking among our students and to be able to deal with new and unfamiliar science learning materials and issues' |
| *Question 2*: 'Who do you believe has to develop STS learning materials for junior high students — teachers or experts from universities and the Ministry of Education?' In the pre-PD questionnaire, about two thirds (63%) of the teachers suggested that this should be done by a combination of experts and teachers while 30% chose the experts | 'We [the teachers] have to concentrate on teaching learning materials developed by experts since they have the expertise, the time and the knowledge how to develop, to implement and to evaluate learning materials' |
| Only 7% of the teachers chose the teacher option, and even here, analyzing their explanations revealed that what they meant was adapting learning materials rather than developing new ones | 'The teacher has to organize the learning materials to fit his/her class since only he/she knows the students and their needs' |
| In the post-PD questionnaire 100% of the teachers voted for a combination of teachers and university experts to develop learning materials. Their explanations show more willingness to be involved in developing learning materials and a sense of criticality. Great emphasis was placed on the teachers' responsibility and initiation in developing learning materials and creating school teams in order to develop unique learning materials. | 'University experts will bring new ideas and involve teachers in the learning material development process. On one hand, the expert is not familiar with everyday school problems. On the other hand, the teacher lacks the professionalism to develop learning materials. Experts and teachers working together are the sensible and most appropriate combination'<br><br>'It is very important that we get suggestions from expertise but their ideas need not always be taken as the ultimate authority. Leading teams in schools have to develop unique curricula based on a variety of learning materials taking into account school and student characteristics' |

Table 10: Advantages and difficulties in implementing case-based teaching — teachers' reflection

| | Category | Characteristics | Examples |
|---|---|---|---|
| Advantages | Effect on students' cognitive level | Improvement in students' thinking skills | 'Student can link theory with reality… it broadens students' thinking skills …' |
| | Effect on students' affective level | Connecting learning with reality | '… Encouraging student to read about science beyond science textbooks so they acquire new knowledge concerning learning materials/subject matter' |
| | | Interest, curiosity, motivation | 'Case-based teaching makes learning relevant, as it deals with real-life issues …' |
| | | | 'The case study method stimulates students' learning and curiosity' |
| Difficulties | Lack of time | Implementation | 'Teaching with case-studies takes a lot of time so we can't teach all the required subject matter …' |
| | Content knowledge and pedagogical content knowledge | Teacher's aspect | 'It is difficult to find appropriate articles and to adapt them for students at various academic levels …' |
| | Content knowledge, reading, and comprehension | Student's aspect | 'Teachers must have extensive knowledge and be well-versed in many subjects in order to cope with case-based teaching' |
| | | | 'Cases from scientific articles are often difficult for students to understand, as they contain concepts or context with which they are not familiar' |
| | | | 'Students with reading difficulties, minorities or immigrants find it hard to cope with scientific case-studies' |

with the exception of 'lack of time'. Having participated in the PD program, the teachers underwent a conceptual change, and realized that developing higher-order thinking and learning skills through the use of case studies in class is more important than covering more ground. Teachers' awareness of the difficulties involved in the implementation of the case based method is a testimony to their serious, realistic attitude towards this method.

In the last question of the post-PD program reflection questionnaire, teachers were asked: 'Considering the activities and portfolio you have been developing in the

PD program during the last two years, do you see any professional change in yourself as a teacher? Please explain'.

Analyzing the teachers' responses, we found three main professional change categories: cognition, pedagogy, and educational views and beliefs. Table 11 presents teacher quotes for the various attributes in each category.

The distribution of teacher responses by categories was such that 90% of the teachers used two (47%) or three (43%) of the three professional change categories,

Table 11. Teaches' reflections on their professional change

| Category | Attributes | Teachers' quotes |
|---|---|---|
| Cognition | STS interdisciplinary approach | 'Now I can integrate several aspects in any science topic in order to induce my students or collogues to think in a meaningful way' |
| | Knowledge enrichment | 'The various activities which I experienced during the last two years have expanded my science knowledge' |
| Pedagogy | Teaching strategies | 'During the last two years I have come to know various teaching strategies, most of which were new to me' |
| | Teaching with case studies | 'Before the PD program, I had sometimes used newspaper articles in class, but not successfully. Now I learned to prepare a case study form these articles accompanied by questions at different cognitive skill levels' |
| | Cooperative learning | 'I realized that cooperative learning in small groups makes students think for themselves and helps create more meaningful understanding' |
| | Class implementation | 'The PD program made a significant change in my teaching. Now I am using articles, case-studies, Web-based activities and group discussion in my class for almost any topic I teach' |
| Educational views and beliefs | Team work | 'Personally, the main professional change I went through was the understanding of the importance of team work with collogues. My successful and pleasant experience in team work throughout the PD program made me believe that this is the perfect way to be a better teacher' |
| | Teacher–student interaction | 'I can see a change in the way I interact with my students and the way I stimulate them to get to higher order thinking' |
| | Teacher–mentor interaction | 'Your [the mentor's] approach, attitude and direct relation with us enabled me to undergo a professional change' |
| | Teacher–school system interaction | 'I am sure I went through a major professional change, but if the school system won't let me change my teaching strategies in class I won't be able to continue my professional growth' |
| | Affective aspect | 'Now I feel more confidence in my ability to implement case studies in my class and deal with various aspects of science topics' |

indicating the high level of depth most teachers attributed to the extent of the PD change they had gone through.

### *Class Observations and Interviews*

In the final project, the teachers implemented the learning unit they had developed in at least one class of one of the teachers in the team. In one-half of the groups, two teachers implemented the learning unit in their classes; and in one of the groups, all the teachers chose to implement the learning unit.

One of the researchers (who was the lecturer in the PD program) was an observer in these classrooms and then interviewed the teachers. The following is an example of such observation and interview.

*The case of Soher.* Soher, female, 9 years of teaching experience in the Arab sector, has a B.Sc. degree in Chemical Engineering and a teaching diploma in chemistry.

The class — eighth grade, 19 students (10 boys and nine girls).

Description — the 90-minute lesson started with a short movie describing the drowning of the Titanic ship. In order to understand some of the scientific background for the drowning of the ship, the students were given a short case study based on the Titanic drowning and were divided into groups. Each group worked on a different aspect of density and conducted experiments. Each group had to present its aspect and the experiment results in front of the class.

Observations — the lesson was well prepared and organized. There were no discipline problems and Soher answered every question raised by the students in a short and informative way. The students worked in a very organized way in their groups. During the lesson, Soher decided to make some changes. She explained later that when she saw that the groups' work was progressing faster than what she had planned she decided to allow more time for the student presentations. Toward the end of these presentations, which went quite well, Soher felt relieved, started smiling, and provided her students with ample positive feedback.

Interview summary — Soher was pleased with the lesson and her students' participation. In her words: '… it is one of my best classes in school but I manage very well with all my other classes … the learning materials which I developed with my team are suitable for $8^{th}$ grade students and I am sure I will use them again next year'.

Soher emphasized that her participation in the PD program was 'an important part of my professional life. The PD program enables me to implement immediately new ideas after making some modifications'.

Soher was very optimistic and had a lot of esteem from the school principal. She even invited the school photographer to film the lesson so her teacher colleagues and school administrators could view it. Concerning her professional life she noted: '… I feel I have to continuously improve for my students and I am indeed improving all the time … I want to be promoted and have more roles in my school and also to be a district moderator so I can advise other teachers in the Arab sector how to be more professional teachers as I feel after I will finish the PD program … I want to share my knowledge with colleges'. Soher is dedicated to her teaching work and see her future career in teaching. She is moving into the impact stage in her professional career. This is the third stage, in which the teacher is interested in their students' thoughts, ideas and feelings, and tries to adapt various instructional modes to her students' needs (Fuller, 1969). She is full of enthusiasm and is heading to harmonic path in her career (Huberman, 1993), in which the PD program played a major role.

*The case of Orly.* During the PD program, the teacher experienced three types of peer assessments, each of which took place during a presentation of one of the three projects. Several teachers tried to implement peer teaching in their classes. One of them, Orly, a biology teacher and a science coordinator in a middle school, invited one of the researchers to observe the process in her class and was then interviewed.

The lesson — the final stage of a 5-week project related to the digestion system. During the 90-minute lesson, seven groups had about 10 minutes each to cooperatively present their work. Every student of the class got a list of criteria to assess the projects. These criteria had been built by the students together with their teacher 5 weeks earlier.

Observation — the lesson was well organized; each group knew when its turn to present the project was. Orly asked the students for some clarifications and gave each group a positive feedback.

Interview summary — Orly demonstrates professional and personal confidence and is willing to try new teaching approaches and ideas. She specified that: 'I know and use a variety of teaching strategies but the turning point in the PD program for me was the self and peer assessment … I knew I had to try them in my class and now I am sure this is the right way to involve the students and to make them take responsibility for their learning and achievements … I feel I improved myself and there is no way I am going to turn back to old teaching ways'. Orly described how she integrated peer assessment and self-assessment several times during the year with her students, who developed their understanding, and their willingness to cooperate in teams increased over time. This approach was so successful that in the last project the peer assessment and self-assessment accounted for 70% of the project grade. Clearly, Orly involves her students in a graduate process that is becoming a new way of teaching. Her participation in the PD program has certainly broadened and expanded her teaching professional knowledge and encouraged her to try out new ideas.

*Senior teachers.* Almost one-fifth of the teachers in the PD program were senior teachers with over 25 years of teaching experience. Unlike most of the teachers, some of these senior teachers were not in favor of the new teaching methods. Most of them were not active in their team groups. A few teachers expressed exhaustion, bitterness and were very skeptical about introducing new ideas to their teaching. As an example, one of these senior teachers noted: 'developing case-studies and preparing them for students require too much work … I have no support from the management and the students are too rude … the huge efforts needed to introduce new teaching strategies are not worthwhile'. Two of these senior teachers retired at the end of the second year of the PD program.

### *Students' feedback*

In the final project, the teachers were asked to prepare a feedback questionnaire for their students. They administered this questionnaire to the students after having implemented in their classrooms the case-based learning unit they had developed as a project.

About 40% of the teachers prepared an open-ended questionnaire, while the others preferred a closed structure questionnaire. Analyzing 35 questionnaires from one class, we classified the questions into three categories: interest and enjoyment, learning materials, and learning organization. Since the learning unit involved a variety of well-planned learning activates, it came as no surprise that the teachers focused on these categories. The following question and answer excerpts from the questionnaires represent some of the students' responses in the three question categories.

#### *Interest and enjoyment category*

Question: Did you enjoy learning with your group?
Student C: It was fun learning with friends; everyone gave ideas and had the opportunity to express his opinion.
Student T: … I wish we could have this kind of activity again, with the same friends.

#### *Learning materials category*

Question: Did you experience difficulties understanding the topic?
Student B: I didn't have any difficulties because the learning was not a routine task. I was stimulated by the class discussions concerning the case-study, which improved my understanding of the subject matter.

#### *Learning organization category*

Question: Did your group act cooperatively? Did you experience difficulties learning together?
Student G: … part of the time there were arguments between the members of the group but at the end we were able to answer all the questions in the case-study. I think the assignment of students for groups needs some improvement.

This multidimensional assessment of the learning unit, achieved by the variety of question types in the students' feedback questionnaires, reflected the various levels of teaching/learning process that took part in the classroom. One of the teachers noted: 'We had a desire to compare our perceptions and feelings towards the new material we developed during the PD program to the classroom reality as viewed by our students'. All the teachers indicated that they had never administered feedback questionnaires to their students before, and reading their students' responses was a very interesting and enlightening experience.

## Discussion, Limitations and Implications

Teachers in new, creative educational system environments are faced with a set of requirements that is fundamentally different from traditional teaching (Bybee, 1987; Yager & Tamir, 1995). Van Driel et al. (2001) have argued that reform efforts in the past had often been unsuccessful because they failed to take teachers' prior knowledge and attitudes into account.

This research has presented a comprehensive framework for long-tem teacher professional development that focuses on case-based teaching and takes into account teachers' prior knowledge. Building on principles of social constructivism, teachers' life cycle, and active learning through engaging in preparing case studies, our PD program induced a significant change in a group of over 50 science teachers. Along the PD program, the participating teachers went through a major change in their abilities to design high-quality case studies and related activities.

This study partially overlaps the model of Bell and Gilbert. On one hand, we have augmented this model in two modes: we applied case studies and STS-related activities as teaching activities. Later on during the PD program, we had teachers develop their own learning materials. On the other hand, our PD program emphasized mainly teachers' role as learners and less as researchers. Regarding the three aspects of the PD model of Bell and Gilbert (1996) — social, professional and personal development — our model is very similar in initiating collaborative ways of working among the science teachers, initiating development of new ideas and classroom practices, and empowering the teachers.

Our findings are in accord with those of Supovitz and Turner (2000) and of Loucks-Horsley and Matsumoto (1999), who found that teachers' content preparation and involvement in implementing novel learning materials have a powerful influence on teaching practice and classroom culture. Our teachers managed to advance from editing case studies and activities individually in the first project to selecting their own topic and designing complete case studies from scratch, including a set of related activities in teams of three or four. In the final project, teachers developed case studies that were highly suitable to their students. The number of involved disciplines and their level of integration increased as well. The accompanied activities improved, from the first project to the third one, in all four categories: interdisciplinary nature, variety, relation to the case study, and complexity.

Overall, our findings support the claim that teachers underwent professional growth through developing and implementing case-based teaching applying a student-centered approach to learning.

This study has a number of limitations. One is the fact that teacher interviews and classroom observations were carried out only while the teachers implemented the third project and not throughout the whole process. The other limitation is the need to follow-up these teachers not only during the PD program but also after the academic support had stopped. Such long-term study requires commitment over time and funding on a larger scale. There is also lack of evidence that the teachers' professional growth had an impact on students' cognitive learning outcomes. However, as Loucks-Horsley and Matsumoto (1999) noted, research on teachers does not necessarily have to be accompanied by assessment of the performance of the students of these teachers. They argued that 'fixating' on student learning ignores other critical outcomes.

Elliott (1999) emphasized that there is a need to develop a global perspective on teachers' professional development, team teaching, reflection, and peer assessment through analysis and aggregation of the results of national and regional investigations.

The experience teachers gained in our regional PD program can be classified into two broad aspects:

- Learning — active studying of general science and chemistry topics from several different aspects, with a focus placed on reading, discussing and analyzing case studies. The topics were developed and edited specifically for the PD program.
- Teaching — planning, modifying, developing and applying learning materials that included topics from the junior high school science curriculum. The case study approach was successfully integrated into the classroom setting.

Our PD program for practicing teachers followed the recommendation of Hewson et al. (1999) for closer cooperation between schools and universities. The science teachers in our PD program prepared the final (third) project in teams that consisted of teachers who belonged to the same school. This cohesive team structure contributed to strengthening the professional links among science teacher teams, who are expected to collaborate in their schools throughout their career. The approach that advocates that learning to teach should be a long-term experience was a central theme in the PD program. This attitude contributed towards more significant progression in the science teachers' professional growth, as the long duration of the PD program enabled us to gradually decrease the academic support teachers received and increase their academic independence and pedagogical initiative.

The use of case studies has only recently been studied, and several themes that serve as a foci of the research agenda (Kobballa & Tippins, 2000). The most studied one among these themes is the case study as a tool for professional preparation and development. In science education, investigating the impact of case studies as a discipline-based teaching and assessment method is less documented. Lohman (2002) and Mayer (2002) indicate the need for a corpus of well-designed research on the cognitive consequences of problem-based methods in PD programs. Our study contributes toward this goal as it combines the social constructivist theory with empirical evidence proving that the case study approach as a discipline-based teaching and assessment method can be successfully implemented in science teachers' long-term professional development.

The research results have implications on the professional growth potential of science teachers to become the reform agents and catalysts of profound educational change in their schools. To increase the teachers' motivation and involvement in the introduction of the desired educational change, it is recommended that teachers be partners not only in the implementation of new curricula, but will also act as designers, developers, and assessors of case-based learning materials.

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## Appendix 1: The case study 'Oil spills in the sea: an unavoidable pollution?'

Based on *Environmental Issues, Edison-Wesley Publishing Company, USA, 1995*

The dying and expected death of cormorants during the Gulf war in 1991 touched many people around the world who watched anxiously their attempts to survive in a huge oil spill in the Persian Gulf. Pictures of the dying cormorants turned to a symbol of that war, in which Iraq used oil as an ecological weapon. The Iraqi government ordered to spill millions of tons of crude oil into the sea, which covered wide areas in the Persian Gulf and caused damage to the marine ecological system for many years to come. Giant oil spills are created occasionally by oil tankers as a result of accidents in the sea, or from washing the tanks in sea water and flushing them back to sea.

### Student Activity

1. Given that crude oil floats on water,
   a. Explain this phenomenon at the microscopic level.
   b. When crude oil floats on water it prevents oxygen from dissolving in water and blocks sunlight. What are the consequences of these phenomena?
2. The Gulf war is called "the first ecological war". Why is this name justified? Explain.
3. Sea oil spills feature two opposite aspects:
   - Water pollutions caused by tanker accidents, such as the Exxon Valdez in 1990, harm the marine organisms
   - People need affordable oil for energy supply. Strong regulations imposed on oil tankers in order to prevent spills will increase prices of gasoline, home heating oil and other petroleum products.

   b. Explain in detail the influence of an oil spill on the marine ecological system.
   c. Are the strong regulations enforced on oil tankers companies by the USA government justified?
   d. Suggest a long term solution for the oil spills in the sea.
4. The following activity is a model for cleaning up an oil spill in the sea.
   - Fill three fourths of a pan with water.
   - Pour a spoonful of oil into the water in the pan.
   - Try to clean up the oil by the methods in the following table and fill in the blanks.

| The cleaning method | Observations and conclusions |
|---|---|
| Scoop up the oil with a spoon | |
| Remove the oil using paper strips | |
| Remove the oil using sawdust | |

Explain why it is so hard to clean up an oil spill from water and more difficult to clean oil spill in the sea?