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Characteristics and Difficulties of Teachers Who Mentor Environmental Inquiry Projects

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Abstract

The paper describes characteristics and analyses difficulties of environmental sciences teachers in mentoring their students in an extended inquiry project, which is a mandatory requirement of the environmental sciences matriculation in Israel. The teachers participated in a professional development program that provided both content knowledge and support for conducting inquiry, and enabled the teachers to guide the students in the inquiry project. Teachers who had experience in inquiry identified more skills required for mentoring students' inquiry, and provided a non-directive guidance pattern, whereas inexperienced teachers acknowledged less skills, and tended to present a directive-authoritative approach. Insufficient content and pedagogical content knowledge affected the teachers who closely controlled their students' work.

Key Words: environmental sciences, inquiry projects, mentoring style, teachers knowledge

This study describes and analyses mentoring styles and the difficulties of Environmental Sciences teachers who are required to mentor their students in an extended field-based investigation at the end of the high school.

In Israeli high schools, students elect their major topics either at the end of Grade 9 or at the end of Grade 10. Most high schools employ a nationwide, standard, traditional battery of tests known as the matriculation examinations. These examinations have been the dominant summative assessment tool of high school graduates over the past half-century. The grades of the matriculation examinations, along with a psychometric test (analogous to SAT in the United States), are a critical factor in college and university admission requirements (Dori, 2003). If a student chooses to major in science, he/she usually elects at least one of the following: physics, chemistry, biology, computer sciences or environmental sciences (ES).

Students who major in ES are required to be engaged in an elaborated investigation of a local environmental problem. This inquiry project, "Ecotop," is part of the matriculation requisites. Extended inquiry projects have a long tradition in biology teaching in Israel. The biology matriculation examination at the end of Grade 12 includes both a laboratory-based inquiry, and an extended field ecology investigation named "Biotope" (Tamir, 1998). However, ES is rather a new discipline and most of the teachers received their academic degree in biology or chemistry. Although most of these teachers have little or no experience in mentoring interdisciplinary-environmental inquiry projects, the Ministry of Education expects them to be involved in mentoring the students throughout the process and to advise the students by preparing them to conduct their inquiry projects.

Despite these goals, the current situation in many schools is that the students get external professional guidance by various informal institutions, and the students are required to pay for these services. Thus, the teachers who are not compensated for the extra mentoring hours and do not feel capable enough to lead the extended inquiry projects encourage their students to get costly external mentoring.

In order to change this situation, and help the teachers, we conducted an intensive professional development (PD) course, which aimed to support environmental science teachers in mentoring their students' inquiry projects. During that period, we observed the participating teachers in the PD meetings, as well as in their classes and in the field activities, and documented their discussions, statements and mentoring patterns.

Our goal was to understand the difficulties the teachers face, while mentoring extended inquiry projects and to support the participating teachers throughout the mentoring they provide in class. Since this group represents a much larger cohort of ES teachers, we hope that this study would make some contribution to their future training.

In the study, we adopted a grounded theory approach, which means that we did not have a clear theoretical framework prior to entering the field (Glaser, 1978; Glaser & Strauss, 1967; Taber, 2000). Inquiry-based learning was the only theoretical anchor at the initial phase, which led our first stage of data collection. In the more advanced stages of data analysis, two other fields of knowledge emerged from the data: teachers' knowledge (Putnam & Borko, 1997; Shulman, 1986, 1987; Turner-Bisset, 1999) and teachers' professional life cycle (Fuller, 1969; Huberman, 1989, 1995). The interviews, at the second stage of the data collection allowed us to focus on these theoretical ideas in order to further analyse and interpret our data (Kvale, 1996).

Theoretical Background

As mentoring students' environmental inquiry projects was at the centre of this study, a clarification of the term is required. The term "inquiry" has had many definitions in the last forty years. In this study we adopted a general view that perceives the student as an active learner who, with more or less guidance, attempts to solve problems (Tamir, 1998). In more detail, we mean that students are engaged in a learning process that involves defining a problem, making hypotheses, formulating research questions and conducting investigations. The learners are supposed to use various methods for data collection, to define research variables, analyse the data, and present findings using tables, figures and graphs, and finally, discuss the findings and draw conclusions (Schwab, 1962; Shulman & Tamir, 1973; Tamir & Lunetta, 1978).

Science curricula that focus on extended inquiry projects are often called project-based science (PBS). The design principles of PBS suggest a context that engages students in extended authentic investigations through the use of a driving question, collaborative work that allows students to communicate their ideas, using cognitive tools to help find and communicate solutions and creating artifacts that demonstrate student understanding and serve as the basis for discussion, feedback and revision (Krajcik, Czerniak, & Berger, 2002; Krajcik, Blumenfeld, Marx, & Soloway, 2000; Marx, Blumenfeld, Krajcik, & Soloway, 1997; Singer, Marx, Krajcik, & Clay Chambers, 2000). The inquiry projects discussed in this study intended to be somewhere on the range between guided inquiry, in which the teacher defines the problem, and the students choose the method and instruments for their study, and open inquiry, in which the students come up with the problem and continue by suggesting methodology for their investigation. Unfortunately, any type of extended inquiry is not common in science classes. Inquiry-oriented teaching places high demands upon teachers' content knowledge (CK), which must be deeper and broader than in the traditional "knowledge transmitting method" (Fishman, Marx, Best, & Tal, 2003; Shulman, 1987). Crawford (1999) lists several roles of the science teacher who successfully conducts an inquiry in the classroom. Among these roles are: the teacher as a motivator, diagnostician, guide, innovator, experimenter, researcher, mentor and so forth. Her research emphasises that the new roles of the science teacher are more demanding than the traditional ones.

Teachers' lack of experience in inquiry is rooted in their own pre-service studies (Tamir, 1983; Windschitl, 2000). It is also strongly connected to issues of content versus pedagogical content knowledge (PCK): the connection between cognitive understanding of the subject matter content and the appropriate teaching methods (Shulman, 1986). Ball (2000) suggested that pedagogical considerations are often important for acquiring content knowledge. She challenged the perception that someone who understands the content is necessarily able to use this knowledge for teaching. Furthermore, she even suggested ways for bridging the gap between the different types of knowledge. In the last decade, PCK has often been described as an integrated component of: knowledge of pedagogy, knowledge of content, knowledge of learning and knowledge of students (Cochran, DeRuiter, & King, 1993; Cochran & Jones, 1998). In the context of this work, mentoring students in extended environmental investigations is dependent on the teachers' subject matter knowledge, their knowledge of scientific methods, and their previous experiences in inquiry-based learning. Turner-Bisset (1999), who presented the knowledge bases of the expert teacher, listed about ten types of teachers' knowledge. She claimed that beginning teachers do not hold all these types; rather, they develop them during their teaching. A teacher's career path starts when the teacher struggles to survive every day's work in class. 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 (Fuller, 1969; Huberman, 1989, 1995). Bell (1998) and Bell and Gilbert (1994) 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 ones own beliefs.

In order to introduce inquiry-based learning and field-based investigations with our teachers we considered the teachers' professional development history, their knowledge, beliefs and previous experiences (Dori, Tal, & Peled, 2003; Guskey, 1986; Marx, Freeman, Krajcik, & Blumenfeld, 1998; Supovitz & Turner, 2000; Tal, 2001, 2004).

Purpose

The general purpose of this study was to investigate teachers' perceptions of mentoring inquiry projects, and to understand their specific difficulties in conducting inquiry in ES, which are unique for their interdisciplinary nature. More specifically, our goal was to answer the following questions:

1. How do experienced and inexperienced teachers perceive the skills needed for mentoring inquiry projects?
2. What are the main stages of the projects that require more teacher's mentoring, and how the teachers define their mentoring style in these stages?
3. How do experienced and inexperienced teachers perceive their difficulties in mentoring inquiry projects?

Method

The "Ecotop" Inquiry Project

Students who major in ES are required to conduct an independent inquiry project at the Grade 12, as part of their matriculation requisites in ES. The project begins at the middle of Grade 11 and ends towards the first third of Grade 12. The students, who usually work in pairs, are required to define a problem in their local surroundings, formulate research questions, design their study, collect and analyse data, and make conclusions and recommendations. Finally, they submit a written report and face an oral exam by an external expert. Most of the students' work is done independently, during after school hours. Their teacher is expected to regularly meet with them to discuss their work, to direct them, suggest ideas, ask questions and provide constant feedback. If the students are doing experiments or collect data in the field, the teacher is expected to help them with setting up the experiments and with the field work. Some examples for students' investigations in one class, that emphasise the interdisciplinary nature and the wide scope of topics, are:

1. What are the seasonal changes in the distribution and concentrations of air pollutants in my neighbourhood?
2. What are the problems of asbestos waste in Naharia,[1] and is the current situation safe?
3. Could we maintain public gardening that is based on “water-saving” plants?
4. What is the water quality in seasonal-natural ponds in an agricultural area?

Settings

In 1998, the national supervisor of Environmental Sciences in the Ministry of Education, together with the National Education Coordinator at the Ministry of the Environment funded an extended PD program that aimed to provide teachers with knowledge and skills that would allow them to mentor their students in conducting environmental field-investigations, the “Ecotop.” The course, which took place at the Technion, Israel Institute of Technology, encompassed 112 hours and addressed the following aspects: (a) improving the teachers’ content knowledge of the relevant topics; (b) getting experience in doing inquiry by participating in short-term inquiry projects that allow the teachers to raise questions, design experiments and collect data and analyse and present their findings.

Fifteen ES teachers participated in the PD course, at the Department of Education in Technology and Science in the Technion. The PD framework was based on the “knowing in action” approach (Schon, 1983), which involved the participant teachers in practical work. The program was based on a cycle of classroom-based learning, practical “field work,” support given at school and reflection meetings (Loucks-Horsley, Hewson, Love, & Stiles, 1998). During the first year of the program, the teachers met every other week at the university, and in the second year they were supported in their classrooms and met once a month for group discussions.

The content knowledge aspect was addressed by professionals, who presented both basic conceptual knowledge, and the recent environmental problems of the country. The teachers discussed these issues and how they related to the high school curriculum in environmental sciences (ES). The pedagogical content knowledge was addressed in several ways. A specially designed website was developed for the group and the teachers were guided to use the web in order to communicate, search for information, share data and present their ideas. Other activities included, for example, guided critical reading of scientific articles; getting to know and use laboratory instruments and methods such as probes for measuring various environmental variables; and water and soil testing processes. Field trips to various sites that allow students’ investigations and environmental education centres that provide guidance, were another segment of the PD that focused on both CK and PCK aspects. Towards the end of the first year, the teachers were requested to start their own research project. In the second year, we supported the teachers in their schools, while they guided their students in their “Ecotop” inquiry projects.

Participants

Some of the 15 teachers did not have any experience with field-based inquiry, while others, who had their masters degree or taught biology, had some experience with inquiry projects. They represented a heterogeneous group with regards to their (a) experience in mentoring inquiry projects; (b) proficiency in the scientific disciplines; and (c) academic degree and teaching experience. Because the overall experience in mentoring environmental-interdisciplinary inquiry projects was low, we divided the teachers into two groups according to their previous experience in mentoring an ecology inquiry project in biology (i.e., "Biotop"). The teachers who had mentored projects in biology and ES for at least five years are referred to as "experienced" and the teachers who had less than five years experience in mentoring inquiry projects are referred to as "inexperienced." Table 1 presents the characteristics of the participating teachers.

Instruments

Borrowing from the qualitative tradition in science education (Gallagher, 1991), and from studies that documented teachers in their everyday teaching and while participating in PD programs (Dori et al., 2003; Kamen, 1996; Treagust, Jacobowitz, Gallagher, & Parker, 2001), the teachers were observed in their natural fields of participation: during the PD meetings, and while teaching their students in class and in the outdoors. The meetings with the teachers were documented during and after each meeting in a researcher's diary. We used an interpretive research methodology (Erickson, 1986; Gallagher, 1991) that involved a minimal intervention in the process, and spent a long time with the teachers in the "fields of their actions." The first author coordinated the PD program and participated as a facilitator in most of the meetings. The co-author participated in all the PD meetings, and followed up the teachers in their schools, while they were mentoring their students. In the first phase of the study we observed and documented every activity and discussion in a journal. In the second phase, after we defined our interest foci, we developed an interview protocol and open ended questionnaires that added the teachers' views to our data source.

Observations

Following previous studies of teachers (Kamen, 1996; Treagust et al., 2001) we used two types of observations:

(a) Participant observation: the co-author took an active part in the meetings and the discussions. Her records were written during, and shortly after each event. The records included questions and answers of the facilitators and the participants and comments that the participants made during class and in recess. In these

Table 1
The Participating Teachers' Characteristics.

	Teacher	Proficiency	Degree	Teaching	"Biotop" mentoring	"Ecotop" mentoring
				Years of experience		
Experienced	1	Biology	M.Sc.	20	15	10
	2			20	15	0
	3			20	7	2
	4			15	10	0
	5			11	10	0
	6			7	7	1
	7		B.Sc.	15	6	6
Inexperienced	8	Biology	M.Sc.	14	4	0
	9			7	0	1
	10		B.Sc.	11	1	0
	11			4	0	1
	12	Chemistry	M.Sc.	17	0	0
	13			13	0	1
	14		B.Sc.	2	0	1
	15	Electrical engineering	Senior teacher*	17	0	0

* Has a teachers' college certificate.

observations, we intended to identify difficulties the teachers expressed about their mentoring processes.

(b) External observations: we observed the teachers in their classes and in small team meetings with the students while the students were working on their projects. In these observations we documented actual difficulties the teachers were facing.

Most of these observations were audio recorded and transcribed.

Interviews

We used constructed open-response interviews (Kvale, 1996), which aimed to provide us with data about the teachers' perception of mentoring skills and about the mentoring styles the teachers demonstrated. In addition, the interviews enabled us to validate the types of difficulties the teachers reported in the questionnaires.

Questionnaires

The two questionnaires which were administered toward the end of the PD, were constructed based on our initial phase of observing the teachers during their mentoring process and included open-ended questions. *The Process and Skills Questionnaire* focused on the stages of the mentoring process and the purpose and the type of the teachers' involvement. A few examples of questions are:

1. Please describe the stages of the Ecotop project in your class. What do you do in each stage? What do the students do in each stage?
2. Who initiates the meetings of the project teams? You? Your students? What are your considerations regarding this pattern?
3. What are the skills required in order to advise your students in their project? Explain.
4. Please describe the atmosphere of your meetings with the project teams in your class. Please express your opinion about it.

The reflection questionnaire included samples of students' work, which the teachers were requested to assess such as students' research questions, the methodology the students suggested and so forth. This questionnaire, which was part of the PD tasks, allowed us to identify actual difficulties the teachers had with inquiry-based learning.

Data Analysis

The data analysis was inductive, and validity was obtained by data, investigator and methodological triangulation (backing up each assertion by data originated from different sources, by different data collectors and using various methods). Triangulation strategy contributes to convergence of claims generated through use of multiple data sources, and decreased inconsistency and contradiction that might emerge while collecting such data (Janesick, 2000; Mathison, 1988). In order to apply member checks, the assertions were presented to the teachers in various stages, for their comments and critique (Janesick, 2000). We analysed the data in three stages:

First stage

We collected all the relevant responses and views, which were obtained by the various instruments. Due to the fact that we did not find contradictions between the views that were collected by the different instruments, we compiled all the statements in one data base. The statements were arranged in two groups according to the teachers' level of experience in mentoring inquiry projects, in view of the fact that even at the beginning of the PD, we noticed that these two sub-groups acted differently regarding their involvement with inquiry projects.

Second stage

Following Patton (1990), we inductively defined the categories after spending a long period of time in the field and according to the understanding we, as researchers, derived from being with the teachers. We searched for repeated elements and patterns in defining the categories. To increase credibility (Janesick, 2000; Patton, 1990), two experts in the field critiqued the content analysis. In cases of disagreement, we re-discussed our classification until an agreement was achieved for the categorisation of every item.

Third stage

We coded and quantified the teachers' mentoring processes. Every action the teacher performed with regards to his/her students' projects was coded. We identified two dimensions in the mentoring process: its *occurrence* (whether the teacher was involved or not in a certain stage) and its *orientation*. The two types of orientation were: *student-oriented* mentoring – when the teacher suggested several ideas or solutions for the student to choose from or to further develop; and *teacher-oriented* mentoring – when the teacher defined the method or the solution for the student to do.

Each mentoring intervention performed by a teacher was coded for: (a) occurrence (0 – none; 1 – occurred); (b) orientation (0 – student; 1 – teacher). Weighted codes (WC) were calculated for the whole group of teachers, and were presented in percentages. Each dimension (i.e., occurrence and orientation) expressed 50% of the group WC. Therefore, the highest code was given for higher occurrence of mentoring interventions when the teacher orientation pattern was used. Figure 1 presents the mentoring dimensions and their codes. An example for the coding process for the whole group is presented in Table 2. The weighted code was calculated for "setting the students' teams" intervention. For that intervention, the experienced teachers'

Dimensions

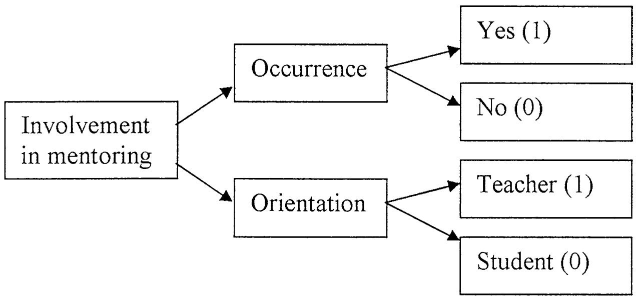


Figure 1: Mentoring dimensions and their codes.

WC were 17% and the inexperienced teachers' WC were 69%. This means that the inexperienced teachers were much more involved in this stage and presented more teacher-oriented involvement.

Findings

In this section we analyse the mentoring processes of the interdisciplinary inquiry projects by experienced and inexperienced teachers through:

(a) describing the skills required in order to mentor an inquiry project as perceived by the teachers;
(b) identifying the stages of teachers' involvement;
(c) characterising the mentoring style the teachers reported; and
(d) identifying difficulties the teachers faced in mentoring inquiry projects when the subject matter was unfamiliar.

Mentoring Skills

We found that the mentoring skills addressed by the teachers represent two categories, which we named: *Researchers' Skills* and *Advisors' Skills.* The Researchers' Skills category included teachers' statements about content knowledge, experience in doing scientific research in general, and mastering research and analyses methods in particular. We did not name these skills "inquiry skills" because the teachers did not particularly name specific inquiry skills. They tended to use more general descriptions such as "research experience" or "knowing methods and equipment." The Advisors' Skills category consisted of statements about social and pedagogical skills such as relationships with students, understanding students' difficulties, patience, providing supportive environments and encouraging students to reach high standards.

Table 3 presents the various skills as were suggested by the teachers and their relative frequencies. It is clear that all the teachers appreciated research skills more

Table 2
Coding the Teachers' Involvement – An Example.

		Experienced teachers ($n = 7$)		Inexperienced teachers ($n = 8$)	
		Occurrence	Orientation	Occurrence	Orientation
1.	Values for: setting the teams stage	1 – one teacher was involved	1 – teacher-oriented	7 – seven teachers were involved	4 – four teacher-oriented; 3 – three student-oriented
2	Value/# of teachers ratio	$1/6 = 0.17$	$1/6 = 0.17$	$7/8 = 0.87$	$4/8 = 0.5$
3.	Percentages	$0.17 \times 50\% = 8.5\%$	$0.17 \times 50\% = 8.5\%$	$0.87 \times 50\% = 44\%$	$0.5 \times 50\% = 25\%$
4.	Weighted code	17%		69%	

Table 3
Mentoring Skills and Their Frequencies in Statements of Experienced ($n = 7$) and Inexperienced Teachers ($n = 8$).

Researchers' skills			Advisors' skills		
Skill	Experienced teachers	Inexperienced teachers	Skill	Experienced teachers	Inexperienced teachers
Knowing the content	5	4	Supporting and encouraging	3	
Knowing data bases	4	2	Increasing students' interest	3	
Having access to experts	2	2	Maintaining good communication	2	2
Having research experience	6	4	Having patience	2	3
Knowing data processing	1	2	Understanding students' characteristics and needs	3	
Knowing methods and equipment	4	1			
Having computer literacy	1	1			
Organising ability	1				
Being courageous	1	1			
Being curious		1			
Total	25	19	Total	13	5

than social and pedagogical skills. Overall, the experienced teachers identified more mentoring skills, and addressed more pedagogical and social skills. The inexperienced teachers were more concerned about research skills; 76% of the inexperienced teachers' compared with 66% of the experienced teachers' statements were classified into the researchers' category.

Teachers' Mentoring Pattern

The teachers' responses to the questionnaires and interviews allowed us to: (a) code the mentoring involvement; and (b) use the interview data in order to describe mentoring styles.

In the questionnaires, the teachers indicated eight major stages of the students' work. As was described earlier, we identified two types of mentoring orientation: *student oriented* mentoring – when the teacher suggests ideas or solutions for the student to choose; and *teacher oriented* mentoring – when the teacher defines the method or the solution and the students do what the teacher tells them to do. Table 4 presents the eight stages and typical teachers' responses that indicate their type of involvement.

We checked these orientation types against our class and outdoors observation data, and found a high accordance between the teachers' statements in the interviews and the questionnaires and their actual performance. Teachers who stated that they actually do certain parts with or for their students were observed while doing things for the students and telling the students what they ought to do in later stages. Table 5 presents various narratives, which were collected while observing a teacher with four years of teaching experience (Teacher 11), who was mentoring an inquiry project for the first time. We observed the class just before they went to a nearby research farm where the students conducted their own experiments. It is apparent that this teacher set up the whole project for her students. She created the teams, suggested and assigned topics and prepared the experiments. In a follow up interview, she expressed her fears from unsuccessful experiments. Furthermore, she stated that she felt that the whole process was still vague for her:

> I feel that everything is very unclear. I am not sure yet, what we expect to get or measure. I hope that things would clear up in the near future. (Interview, Teacher 11)

It appears that Teacher 11, who was inexperienced in mentoring inquiry projects, was uncertain about the sequence of her actions and about her and her students' ability to conduct an open inquiry project. Therefore, she preferred to control the whole process. This was expressed by her intensive involvement in every stage and action that her students made.

As explained earlier in this paper, we measured the involvement of the teachers by coding the two dimensions of the mentoring as presented in Figure 1 and Table 2. The average codes for inexperienced and experienced teachers mentoring involvement in

Table 4
Inquiry Stages and Examples for Teachers' Involvement Statements.

Inquiry stages	Student oriented involvement		Teacher oriented involvement	
	Experienced teachers	Inexperienced teachers	Experienced teachers	Inexperienced teachers
1. Setting the working teams	I am not involved in the students' grouping unless there is a problem and they ask for my help	The students organise the pairs. I suggest to consult with me	I try to set teams according to the students' academic level	I am involved with creating the teams in order to avoid overruling of one student
2. Choosing the topic/problem to study for the whole class or for specific teams	I chose the general topic and each pair of students focuses on what they want	I allow the student to choose from a list I prepare	I am very involved in choosing the topic, so its difficulty level fits the students	I give them the topics according to their abilities
3. Searching for sources of information	I introduce them to a list of journals, books and search engines	I give them a long list of literature to choose from	I search the articles together with my students	The students would not succeed without my help

Table 4
Continued.

Inquiry stages	Student oriented involvement		Teacher oriented involvement	
	Experienced teachers	Inexperienced teachers	Experienced teachers	Inexperienced teachers
4. Summarising the theoretical background	I'd ask only the students' with special difficulties to use my help	I list the topics they have to cover	I teach the relevant theory background in class because my students need constant help	I help in teaching the relevant background in small groups
5. Organising the written report	I try not to be involved in this stage	I ask the students to organise their work according to the exercises we do in class	I help them organise the material because they do not know how to write a paper	Without my help they get lost. They do not know how to write a paper
6. Designing and carrying out the experiments	The students plan their experiments and let me check the plan	They plan the experiments alone. I only suggest relevant experiments	Only the teacher initiates the experiments	The students' independence is limited. I am very involved in

Table 4
Continued.

Inquiry stages	Student oriented involvement		Teacher oriented involvement	
	Experienced teachers	Inexperienced teachers	Experienced teachers	Inexperienced teachers
				planning the experiments
7. Analysing the data	After we practice data analysis in class, the students are able to do their own data analysis		I help them intensively because they cannot analyse their data	I am very involved in the data analysis because it's difficult for my students
8. Writing the report	I help only if they ask. This is a matter of personal style	They only submit intermediate reports for my comments	I actually help them with writing	Their expression skills are limited, so I sit with every team and help them with editing

Table 5
An Inexperience Teacher-Oriented Mentoring in the Inquiry Project.

Excerpts from Toby's introduction in class	Referring to stage	Interpretation
. . . OK, let's see who does what. Ronit and Gali, Sima and Ora, you will work on compostation. Ruth and Rachel will work on water, Adi and Liat, I want you two to work on noise. . . I chose topics that are relevant to you and that you know the background. . . *Students ask*: what about organic agriculture and pesticides? The *teacher replies*: we do not consider these any more.	1. Setting the working teams 2. Choosing the topic/problem	The teacher does not allow the students to come up with their own ideas or problems. She had a list of prepared topics and she assigned teams of students to each topic
Write down please. . . the influence of different substrates of compost from different origins. . .	2. Choosing the topic/problem to study for the whole class or for specific teams	The teacher defines the problem
. . . you know most of the background, because we studied it last year. The only topic we did not cover is noise, which we still have to study.	4. Summarising the theoretical background	The teacher assigned inquiry topics according to the class' curriculum

Table 5
Continued.

Excerpts from Toby's introduction in class	Referring to stage	Interpretation
. . . if we need, we all go to the university library, stay there for the whole day and photocopy whatever you need for your projects. Do not worry, we will find articles for each team.	3. Searching for sources of information 4. Summarising the theoretical background	The teacher perceived her duty to find information sources for her students
What do we measure in this experiment? The humidity in the different stages of the compost, and the temperature. . . we will take one pile from the composter and one untreated pile of organic waste and compare all the data. . .	6. Designing and carrying out the experiments	The teacher suggests the experiments

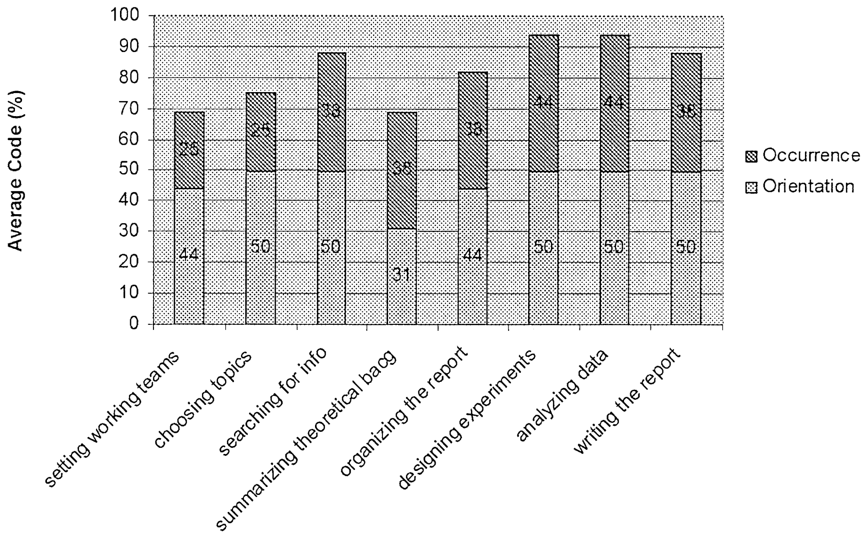


Figure 2: Involvement codes for the mentoring of inexperienced teachers.

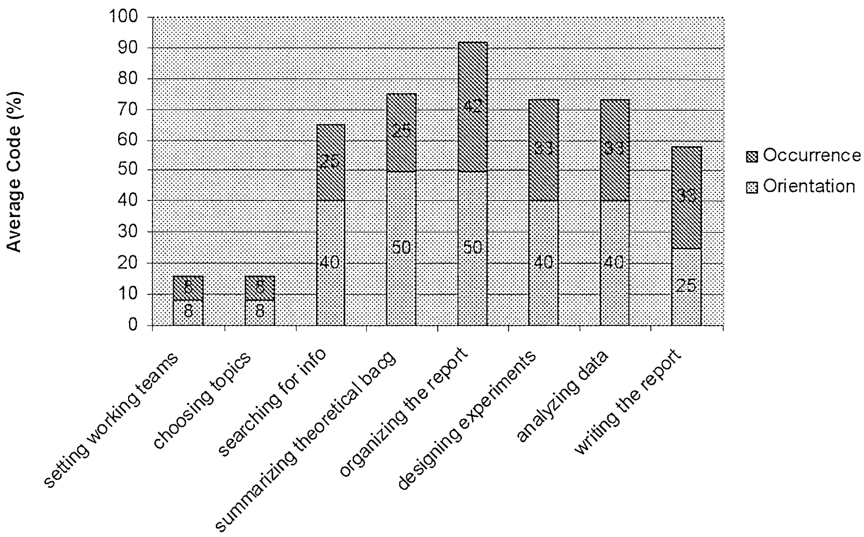


Figure 3: Involvement codes for the mentoring of experienced teachers.

the various stages of the inquiry projects are presented in Figures 2 and 3. The bottom part of each bar represents the occurrence dimension and the upper part represents the orientation dimension of the mentoring.

It seems that the inexperienced teachers were highly involved in most of the project stages. The experienced teachers were intensively involved in summarising the theoretical background and in organising the written report. Unlike the inexperienced teachers they were rarely involved in teaming the students and in choosing their research topics. The upper parts of the bars show higher codes for the inexperienced teachers, which indicate that they used mainly teacher-oriented mentoring. The experienced teachers used a teacher-oriented strategy in "organising the projects," which means that they structured the stages of the students' work and edited the reports. Their involvement in choosing and guiding the experiments, analysing the data and writing the report was lower. The experienced teachers' overall codes for mentoring orientation were lower than that of the inexperienced teachers, nevertheless, it was not low enough to indicate that they used mainly a student-oriented strategy.

An interview with an inexperienced teacher (Teacher 14) supports the findings that show high involvement in a teacher-oriented manner. This teacher used an external agency that helped with mentoring the projects. The italicised sentences indicate our interpretation for the type of mentoring involvement this teacher demonstrated.

Q: Please describe your considerations with regards to your mentoring strategy.

A: Since I do not have prior experience, I prefer that the environmental agency will advise the students. It will help me with some of the experiments. *I already organised the small working groups*, and *assigned research topics* according to the students' academic level, but the experiments make me anxious.

Q: In this case (of the external mentoring), who advises about the literature review?

A: I do, of course. We already divided the theoretical background to chapters, and *I will find all the required articles*. They (the students) do only the experiments over there (with the environmental advisors)... *I think that I go out with them* so I learn how to proceed. We might have to do things again after we analyse the data...

This excerpt allowed us to identify five of eight involvement stages of this teacher: (1) grouping the students; (2) choosing the topics; (3) summarising the theoretical background; (4) experimentation; and (5) data analysis. The italicised phrases emphasise the assignment the teacher executed. As stated earlier, the experienced teachers tended to use a student-oriented approach. Nevertheless, it is clear that they used a teacher-oriented approach with regards to arranging the project.

A different approach is expressed by an experienced teacher (Teacher 2):

I chose the class' general topic, but while we are in the first field trip, I allow the students to choose their own mastering field. They choose their team members as well.

...I intend to practice search methods with them, and challenge scientific articles in class. However, in their own projects, they will do the job alone.

...The approach will be just like having portfolios, it would be their responsibility to submit drafts for my assessment and feedback.

When this teacher was asked about covering the content that is related to the students' specific topic she referred to the ambiguity she uses on purpose:

In my mentoring I allow much disorientation in the process of searching for sources of information. They make mistakes quite often, but they learn a lot from these mistakes.

Mentoring Styles

Based on Fuchs (1995) and Glickman, Gordon, and Ross-Gordon (1998) who addressed supervision approaches and supervisor-teacher relationships, the two mentoring styles we identified were "directive" and "non-directive." Non-directive approaches encourage the student to be in control of his/her work. The teacher's role is to listen, reflect, present ideas and probe for the student to make his/her decisions. Directive approaches occur when the teacher is the major source of information, providing the student with restricted choices.

In the directive mentoring category, teachers' statements described themselves as more experienced and literate than their students, and therefore, they used their knowledge and experience as a guiding principle in the mentoring process. In the non-directive category teachers' statements described how they raised issues regarding the projects with their students, suggested alternatives and allowed them to discuss and choose the most suitable one. One experienced teacher and six inexperienced teachers were identified as directive mentors and five experienced teachers and two inexperienced teachers were identified as non-directive mentors.

The analysis of the data of teacher's mentoring style shows inconsistency. In the interviews, most of the Experienced Teachers (ETs) reported about non-directive style; however, the questionnaire data, which is presented in Figure 3 indicates that the ET were heavily involved in many of their students' working stages. There is a better consistency with the Inexperienced Teachers (ITs) who indicated that they used authoritative mentoring style and their statements are supported by the data we obtained about their involvement orientation and occurrence.

Mentoring Difficulties

The teachers were requested to address their needs and difficulties both in the questionnaires and in the interviews. We classified the statements according to their origin: teachers' or students' needs and difficulties. Altogether, we collected 97 statements that addressed mentoring difficulties. We identified cognitive difficulties emotional difficulties and expressions regarding resource deficiency. Examples for each type are presented in Table 6 according to their origins. The types of the difficulties and their frequencies in percentages are presented in Figures 4a and 4b.

The experienced teachers expressed many more students' difficulties as a reason for mentoring difficulties, while the inexperienced teachers were more aware of their own difficulties. The experienced teachers explained the mentoring difficulties mainly as students' cognitive difficulties, while the inexperienced teachers acknowledged their own cognitive difficulties. We found a difference with regards to the type of students' cognitive difficulties the teachers addressed. The teachers reported either general, unspecified students' difficulties or students' specific cognitive difficulties. Examples for unspecified difficulties were: "the students do not have the necessary skills for this task" or "my students would not succeed without my help." Examples

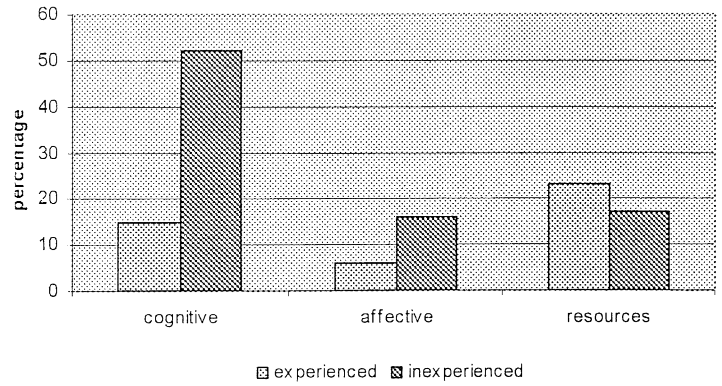
Table 6
Origin and Types of Mentoring Difficulties.

	Student originated difficulties	Teacher originated difficulties
Cognitive	"They cannot transfer knowledge and skills" (Teacher 5, questionnaire) "The students do not know how to write a research report" (Teacher 12, interview)	"I do not know statistics, which I need for data analysis" (Teacher 1, int) "There are topics that they choose, which I know nothing about" (Teacher 3, int)
Emotional	"The 12th graders are under a great pressure" (Teacher 6, interview) "One obstacle is their cynicism" (Teacher 12, questionnaire)	"I feel like I am responsible for their projects" (Teacher 14, questionnaire) "I am afraid that I won't understand that my mentoring direction is wrong" (Teacher 11, int)
Resource shortage	"My students do not have computers at home..." (Teacher 11, questionnaire) "They find it hard to get enough written materials" (Teacher 3, int)	"I mainly don't have enough time for this" (Teacher 10, int) "My mentoring hours are not routinely fixed" (Teacher 5, questionnaire)

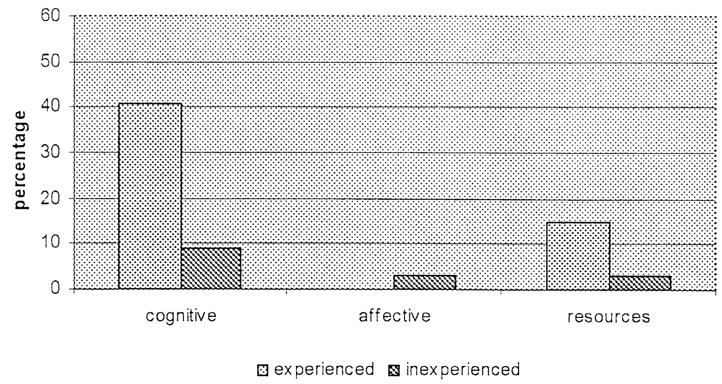
for specified difficulties were: "the students are struggling with data analysis" or "they have never prepared a scientific presentation before." Figure 5 presents the distribution of the teachers' arguments for their involvement in the inquiry projects according to general and specified students' difficulties.

The majority of the experienced teachers expressed specific difficulties of their students, while most of the inexperienced teachers provided vague-general explanations. It might be that the experienced teachers were aware of various difficulties at each stage of the project, while the inexperienced teachers tended to generalise and found it hard to identify specific obstacles.

The experienced teachers rarely addressed their own emotional difficulties and did not address students' emotional difficulties at all. It is possible that because they were more confident and they reported about the good communication they had with their students, they rarely experienced emotional difficulties relating to the inquiry



(a)



(b)

Figure 4: (a) Distribution of teachers' statements about teacher-originated mentoring difficulties, (b) Distribution of teachers' statements about student-originated mentoring difficulties.

projects. All the teachers were aware of the problems associated with their own resources, mainly time management. However, the experienced teachers emphasised the issue of insufficient resources for the students as well, emphasising reading materials in Hebrew; they also indicated competing tasks and lack of time. To summarise, experienced teachers perceived the mentoring difficulties mainly as a consequence of the students' cognitive difficulties, and this perception is in accord with the way these teachers explained their involvement in their students' projects: involvement that addresses the relative absence of scientific skills. Additionally, these teachers were aware of the "resource problem" of both the students and themselves. The inexperienced teachers perceived the mentoring difficulties as a consequence of their own cognitive difficulties – their own vague ideas about conducting an inquiry and their inadequate content knowledge. They acknowledged their own resource prob-

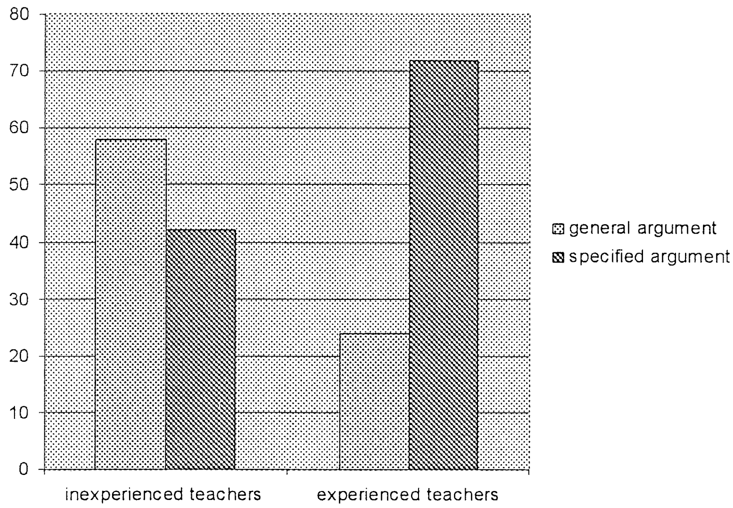


Figure 5: Distribution of teachers' arguments for their students' difficulties.

lem: allocating time, and arrangement of the school time table, however, they were less aware of their students' inadequate cognitive capabilities, as well as resources.

Discussion

The teachers who participated in the PD and support program were diverse with regards to their content knowledge background and their experience in mentoring students' inquiry projects. Nevertheless, even the experienced teachers did not have previous experience in environmental investigations, and most of them did not have a sound background in ES. Although this has study focused on a small group of teachers, which does not allow drawing general conclusions, it highlights unique issues of teachers' function in inquiry-based classes and supports previous works that emphasised CK and PCK as major variables that affect such teaching.

We found that the majority of the required mentoring skills suggested by the teachers represented Researchers' Skills, and that the ET mentioned more skills in general, and more Advisors' Skills in particular. This finding is strongly related to the types of knowledge of these teachers. The ETs' PCK is stronger than their counterparts, and according to Turner-Bisset (1999), it means that they know more about the learners, and about learning processes. The ITs, who just began teaching ES, or had very little experience in inquiry, faced many more challenges in learning the content and acquiring the necessary skills for conducting inquiry projects in their classrooms. This is supported as well by Windschitl (2002) who advocated experiencing inquiry in preservice teaching programs and by Crawford (1999) who described the characteristics of a successful teacher in conducting inquiry as flexible, collaborative, and embraces inquiry both from a content and pedagogical perspective. Zohar, Weinberger, and Tamir (1994) who described a successful biology critical thinking project in Israel highlighted the differences between biology teachers, who had practiced inquiry-based learning, and teachers in other scientific subject matter who did not have such experiences. In our study, the ETs were all biology teachers, while most of the ITs came from other disciplines, a difference that might contribute to an explanation of the differences. The ETs noted more pedagogical skills compared with the ITs, and the overall number of skills they suggested was higher. This is in accord with Ritchie and Rigano (1996) who claimed that an effective mentor has to participate and communicate within the scientific discourse community, but at the same time this person has to maintain supportive learning environment, encourage students, give them challenging tasks and communicate with them in a way that enables them to "bridge the scientific discourse community with their own" (p. 800).

Crawford (1999) described an expert teacher who conducted successful inquiry-based learning in his class and claimed that inquiry-based learning requires more involvement of the teacher than traditional teaching. All the teachers in this study were very much involved in their students' work. However, we identified two types of mentoring involvement, and found that the IT expressed more of the teacher-oriented type of mentoring, whereas the ETs' statements indicated more student-oriented mentoring. We assume that Crawford (1999), who addressed the changing role of the teacher and the students, the collaboration between them, and the discussions they have, advocated the student-oriented type of mentoring involvement. Student-centred teaching is advocated also by Zohar and colleagues (Zohar et al., 1994) as a means for developing critical thinking. Drawing upon Dewey's view of active learning (Dewey, 1938) a real world context, and the modern constructivist theory of learning (Driver et al., 1994; Osborne, 1996; Rogoff, 1990; Tobin & Tippins, 1993), it is clear that student-oriented mentoring means that the students come up with the problem to investigate, suggest means for their investigation, predict the results, collect and interpret data and make conclusions and recommendations. This approach is based on the centrality of students' previous experiences in the learning process, and their ability to revise their work, discuss the work with their teacher and class mates and present it to the public. ITs who set up the whole procedure for their students, did not allow them to challenge their own thinking and mistakes. These teachers did not have adequate PCK (Putnam & Borko, 1997; Crawford, 1999, 2000; Tamir, 1998; Turner-Bisset, 1999). Most of the participating teachers acknowledged the insufficient subject matter knowledge they had in ES. Mentoring the students in an interdisciplinary project requires the teachers to express thorough knowledge in many fields. Inadequate CK caused these teachers to be constantly involved, even in less important stages of the work such as teaming the students, or preparing the literature review with them. In a study of teachers who incorporated Web-based teaching in their science classes Dori and colleagues (Dori, Tal, & Peled, 2003) highlighted similar issues. The teachers, who started teaching with the web for the first time, supervised their students' work very closely and were very central in the learning process.

The reasons the teachers gave for their involvement varied as well, according to their experience in inquiry. The ITs provided more generic ill-defined explanations for the students' difficulties, whereas the ETs listed well-defined difficulties the students had. This finding is in accordance with the literature that discusses teachers' abilities in evaluating difficulties in learning (Kagan, 1992; Loucks-Horsley & Matsumoto, 1999), and that shows that identifying difficulties is necessary in adapting suitable teaching methods for the students' characteristics. ITs do not have sufficient pedagogical knowledge to address knowledge about learners and about the appropriate and relevant teaching methods (Grossman, 1990). The teachers' explanations for their intensive involvement were mainly because the students were facing various difficulties. However, the reason for conducting the inquiry-PD program was the teachers' difficulties and avoidance of taking responsibility in mentoring the students. Our findings indicate that overall, inexperienced teachers reported more difficulties than the experienced teachers. They related the difficulties mainly to their own cognitive difficulties (i.e., CK and PCK). The ET, on the other hand, related their mentoring difficulties, mainly to the students' cognitive difficulties. Only the IT addressed emotional difficulties, and most of them addressed only their own difficulties. The ET identified more difficulties that result from inadequate resources available both for the students and for the teachers.

These patterns reinforce our claim that mentoring students in open inquiry projects requires many skills that inexperienced teachers do not necessarily have. Although we divided the teachers' groups according to their experience in mentoring inquiry projects, we underscore Fuller's (1969) and Huberman's (1989) descriptions of ETs who face a reform or a shift in teaching that causes them to behave as inexperienced ones. Beginning teachers are described as focusing upon their own needs, and are aware of their insufficient knowledge, while teachers who have some years of experience in classroom teaching are more concerned about the tasks and the students. However, when experiencing an innovation, or a need to apply new methods or go through a major reform, they often exhibit behaviours of beginning teachers. It was evident that the ET in this study, whom had better CK and PCK were aware of the individual cognitive styles and the particular needs of their students, and were able to identify more well-defined difficulties. This issue is highly related to the teachers' mentoring style. The ITs reported a more directive mentoring style. Their tendency to make the decisions for the students is in accord with their lack of professional self confidence. They believe that their knowledge is better than the students' knowledge and therefore, they should direct the students' actions. The ETs, who are more confident about their abilities, give their students more freedom to make decisions and mistakes and act as non-directive or informative mentors. This finding is supported by Windschitl (2000) who found that beginning teachers, who enacted open and guided inquiry in their classes, were individuals who acquired research experiences in their undergraduate studies. It is also in accord with Rithchie and Rigano (1996) who were doubtful about the ability of teachers with limited disciplinary background to provide effective mentorship. Their concern was that inexperienced teachers might depend heavily on the warrant of authority for knowledge claims and therefore search for expected results rather that challenge actual results. Tillema and Kremer-Hayon (2002) who studied mentor-student-teacher relationships reported that in order to develop the self regulated learner, teacher educators have to change their roles. Similarly, teachers who wish to develop students, who are self regulated learners have to adopt a collaborative, non-directive mentoring approach.

Although the ET reported a non-directive approach, their involvement pattern presented a somewhat different picture. They were very much involved in arranging their students' projects, allocating relevant literature and in collecting and interpreting the data. This might indicate that the ETs expressed their expectations rather than their actual behaviour. This assertion is supported by the mentoring difficulties they reported, which were mainly students' cognitive difficulties. The ETs, who knew that they were expected to provide informative-non-directive guidance but presented a different pattern of intensive-teacher oriented instruction might suit the "stabilisation stage of the teacher's life cycle" (Huberman, 1995). In this stage the teachers tend to follow expected rules and regulations, and to apply low-risk strategies. Using Huberman's model, Dori and colleagues (Dori et al., 2003) identified these stages within a community of science teachers who participated in a long PD program that aimed to introduce Web-based teaching. Last but not least is the issue of mentor-student relationships. Although most of the literature deals with student-teachers and their in-service mentors, this body of literature often deals with the type of mentor-protégé relationships, which is relevant to this study as well. Awaya and colleagues (Awaya, McEwan, Heyler, Linsky, Lum, & Wakukawa, 2003) describe these relationships as a journey, in which every student has different needs and learning styles and seeks to pair with a mentor who can work without a how-to manual and evaluation checklist. The mentor should provide mainly moral support and a space for the student to show what he or she could do alone.

The inquiry-based PD program and our study support the call to provide substantial inquiry experiences to pre-service teachers. This might encourage the young teachers to experience more open ended inquiry in their classes and reduce their level of anxiety. Actual experience of the teachers in various stages of the process of inquiry and facing challenges such as "unexpected results" or multiple answers might contribute a lot to inquiry-based science teaching.

Limitations and Summary

As Roth (1994, 1995) described and claimed, teachers who mentor their students in independent research projects ought to have thorough content knowledge, so they would be able to direct their students to achieve specified goals. They should understand their students' needs and their intellectual, emotional and social difficulties. All these are required in order to allow the students to experience active, open-ended and independent learning (Berger, 1992; Cohen, 1995).

"Ecotop" inquiry projects are rather new within environmental sciences at Israeli high schools. Even the teachers, who had some experience in inquiry, had not mentored students in interdisciplinary environmental investigations prior to the study. We assumed that having such teachers as part of the group we studied, might contribute to our understanding of the mentoring process and the difficulties the teachers face.

A longitudinal follow-up could provide us with more information about these teachers after having some years of mentoring experience. Further support could enhance a community of practice focused on inquiry-based learning (Palincsar, Magnusson, Marano, Ford, & Brown, 1998). However, the support we provided ended after two years, and some teachers did not continue teaching ES after the program ended.

Our findings point to the differences in mentoring patterns among teachers in different stages of their career. Open and guided inquiry projects require that the mentoring teachers exhibit a unique combination of teacher's knowledge. As indicated earlier in this paper, environmental sciences in Israeli high schools is rather a new field, and currant teachers have various levels of content and pedagogical content knowledge in this area. This diversity causes many inconsistencies in the way the teachers describe their actions, especially with regards to inquiry projects. Although we found a few inexperienced teachers who encouraged their students and used student-oriented guidance that allowed much freedom, most of the teachers in this group acknowledged their insufficient knowledge, and provided very structured, teacher-oriented guidance that resulted in doing much of the work for their students. These teachers need continuous support with the challenges of teaching a dynamic subject matter, and with the complex task of applying inquiry-based learning.

Note

1. Naharia – a city that once had a large asbestos factory.

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