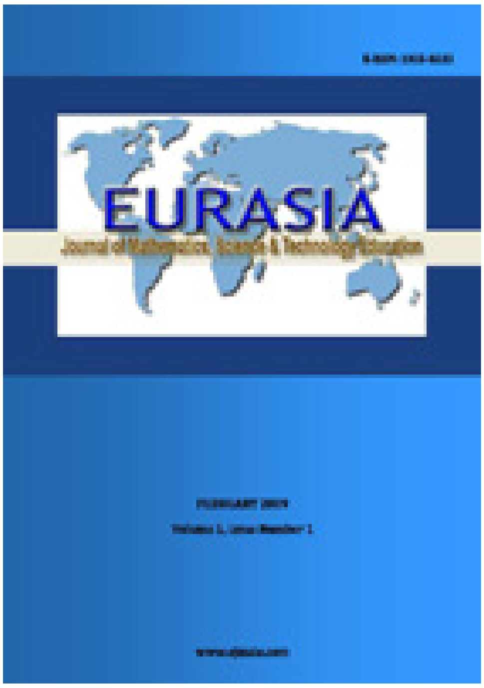
Eurasia Journal of Mathematics, Science & Technology Education
www.ejmste.com



Laboratory Activities in Israel

Rachel Mamlok-Naaman
Weizmann Institute of Science, ISRAEL

Nitza Barnea
Ministry of Education, ISRAEL

Received 13 March 2011; accepted 29 November 2011
Published on 27 February 2012

APA style referencing for this article: Mamlok-Naaman, R. & Barnea, N. (2012). Laboratory Activities in Israel. *Eurasia Journal of Mathematics, Science & Technology Education*, 8 (1), 49-57.

Linking to this article: DOI: 10.12973/eurasia.2012.816a

URL: http://dx.doi.org/10.12973/eurasia.2012.816a

ISSN: 1305-8223 (electronic) 1305-8215 (paper)

The article starts with the next page.

Eurasia Journal of Mathematics, Science & Technology Education, 2012, **8**(1), 49-57

Laboratory Activities in Israel

Rachel Mamlok-Naaman
Weizmann Institute of Science, ISRAEL

Nitza Barnea
Ministry of Education, ISRAEL

Received 13 March 2011; accepted 29 November 2011

Laboratory activities have long had a distinctive and central role in the science curriculum, and science educators have suggested that many benefits accrue from engaging students in science laboratory activities. Many research studies have been conducted to investigate the educational effectiveness of laboratory work in science education in facilitating the attainment of the cognitive, affective, and practical goals. In Israel, on 2000, the chemical education committee, based on a needs assessment survey, recommended that the new syllabus include a whole unit of inquiry-based laboratory as part of the learning sequence. The reform highlighted the laboratory unit as the central component in the new curriculum. In this paper we will describe the chemistry laboratory curriculum in Israel, its development, implementation and assessment strategies.

Keywords: chemical education, secondary school, curriculum, practical work, science

INTRODUCTION

Laboratory activities have long had a distinctive and central role in the science curriculum, and science educators have suggested that many benefits accrue from engaging students in science laboratory activities (Hofstein & Lunetta, 1982, 2004; Lunetta, 1998; Tobin, 1990; Dori, Sasson, Kaberman & Herscovitz, 2004).

Many research studies have been conducted to investigate the educational effectiveness of laboratory work in science education in facilitating the attainment of cognitive, affective, and practical goals. These studies have been critically and extensively reviewed in the literature (Blosser, 1983; Bryce & Robertson, 1985; Hodson, 1990; Hofstein & Lunetta, 1982, 2004; Lazarowitz & Tamir, 1994). Although the science laboratory has been given a distinctive role in science education, from these reviews it is clear that, in general, research has failed to show simplistic relationships between experiences in the laboratory and student learning. Hodson (1990) criticized laboratory work and claimed that it is unproductive and confusing since it is very often used unthinkingly without any clearly thought-out purpose. He therefore suggested that more attention be paid to what students are actually doing in the laboratory. Similarly, Tobin (1990) wrote that "Laboratory activities appeal as a way to learn with understanding and, at the same time, engage in a process of constructing knowledge by doing science" (p. 405). He also suggested that meaningful learning is possible in the laboratory if students are given opportunities to manipulate equipment and materials to be able to construct their knowledge of phenomena and related scientific concepts.

Gunstone (1991) suggested that using the laboratory to have students construct and restructure their knowledge is straightforward; however, he also claimed that this view is naıve. This is true since the picture regarding practical work, as derived from constructivism, is more complicated. In addition, Gunstone and Champagne (1990) claimed that learning in the laboratory will occur if students are given ample time and the opportunities for interaction and reflection to initiate discussion. According to Gunstone (1991), this approach was underused since students in the science laboratory are usually involved primarily in technical activities, with few opportunities for metacognitive activities. Baird (1990) referred to these metacognitive skills as "Learning outcomes associated with certain actions taken consciously by the learner

Correspondence to: Rachel Mamlok-Naaman, Professor of Science Education, Weizmann Institute of Science, P.O. Box 26, Rehovot 76100, ISRAEL
E-mail: *Rachel.mamlok@weizmann.ac.il*

ISSN: 1305-8223

State of the literature

- Laboratory activities have long had a distinctive and central role in the science curriculum, and science educators have suggested that many benefits accrue from engaging students in science laboratory activities.
- Inquiry-centered laboratories have the potential to enhance students' meaningful learning, conceptual understanding, and their understanding of the nature of science.
- Teaching by using the inquiry approach is much more complex and different from traditional classroom teaching. It requires from the teacher different kinds of skills and a high level of expertise.
- Supporting teachers has potential in enhancing teachers' professional practice in our attempt to attain new, higher pedagogical standards.

Contribution of this paper to the literature

- Inquiry-type experiences in the science laboratory should be conducted in the context of, and integrated with, the concept being taught.
- Alternative assessment methods, e.g., potfolio, should be used in an inquiry-type laboratory program.
- Teachers who teach chemistry according to the inquiry approach should develop a novel approach regarding their content knowledge and pedagogical knowledge.

during a specific learning episode" (p. 184). Metacognition involves elaboration and application of one's learning, which can result in enhanced understanding. According to Gunstone (1991), the challenge is to help learners take control of their own learning in their search for understanding. In addition, students should be provided with frequent opportunities for feedback, reflection, and modification of their ideas (Barron et al., 1998); however, as Tobin (1990) and Roth (1994) noted, in general and thus far, research has not provided clear evidence that such opportunities exist in most schools in the United States or in other countries.

The curricular modifications in Israel – a historical view

Until the early 1980's, the laboratory unit in the traditional approach included close-ended, hands-on laboratory activities, where the students carried out pre-defined experiments and were examined on qualitative analytical chemistry. As a result of changes in the syllabus, the laboratory unit was replaced at the early 1990s' by a theoretical topic related to the chemical industry (Hofstein and Kesner, 2006). Between the 90s and the beginning of the 21st century, all the parts of the matriculation examination (final examination set centrally by the Ministry of Education) were given as paper and pencil test with no laboratory component.

As a result of this change, since assessing students' achievement in the laboratory was not included in the final examinations, the laboratory lost its centrality in the chemical education program. What actually happened was that fewer hours were devoted to hands-on laboratory experiences, thus, affecting students' motivation and enjoyment of Chemistry. This may be one of the reasons for the drastic drop in the number of chemistry students during those years. Throughout the years 1995-2001 (the year in which the inquiry-based laboratories were introduced) the number of students that enrolled in the more advanced chemistry programs decreased significantly (from about 8500 students to about 6600). In most schools the laboratories were neglected, and principals did not provide financial resources for laboratory development and maintenance. Other factors that have reduced the use of laboratories in chemistry were the safety regulations for toxic and dangerous reagents, the long time consuming needed for experiments and the high cost of chemicals.

The curricular modifications – the new approach

The chemical education committee, based on a needs assessment survey, recommended that the new syllabus include a whole unit of inquiry-based laboratory as part of the learning sequence. The reform highlighted the laboratory unit as the central component in the new curriculum.

The laboratory unit consists of 90 lessons of 45 minutes each and is taught in 11th and 12th grades, mainly as a whole unit. However, since the change is gradual, and requires investment in equipment for schools, as well as professional development programs for teachers (Dori, Barak, Herscovitz & Carmi, 2005) an option of half a laboratory unit (45 lessons) exists as well. The recommended laboratory activities include both guided and open-ended experiments. The skills required for the guided experiments are as follows: following instructions, using instruments, collecting and analyzing data, comparing graphs, and writing scientific reports with conclusions. The open-ended experiments require posing questions, raising scientific hypotheses, planning the work, examining the assumptions, searching for scientific background references, and drawing conclusions. The embedded assessment of the laboratory is continuous throughout the whole period of study (the 11th and 12th grades of high school). A student is assessed on his/her portfolio of laboratory reports by his/her teacher and by either an external reviewer or a special case-based assignment in the national matriculation examination. The score of this oral or written examination contributes only 25 % of the students' final grade while the other 75% is based on the information (i.e. reports, reflections, teacher-based assessment) collected continuously in a personal portfolio.

Parallel to the discussions at the program committee level, three academic institutions developed unique approaches for the laboratory. These innovations were developed and implemented in pilot classes during the years 2000-2008 by these institutions: an inquiry-based laboratory by the Weizmann Institute of Science in Rehovot , a case-based and computerized-based inquiry laboratory by the Technion in Haifa (Barnea, Dori, & Hofstein, 2010) and a micro scale laboratory developed by the Chemistry group in Bar Ilan University. The principles of each approach are outlined below.

Study 1. *The development and implementation of the inquiry-based experiments: Characteristics and components (The Weizmann institute)*

About 100 inquiry-based experiments were developed and implemented in 11th and 12th grade chemistry classes in Israel (Hofstein, Shore & Kipnis, 2004). Most of the experiments were integrated into the framework of the key concepts taught in high-school chemistry, namely: acids-bases, stoichiometry, oxidation-reduction, bonding, energy, chemical-equilibrium and the rate of reactions.

Typically in the chemistry laboratory the students perform the experiments in small groups (3-4) by following the instructions in the laboratory manual. In the first phase (the pre-inquiry phase), the students are asked to conduct the experiment based on specific instructions. Thus, this phase provides the students with very limited inquiry-based experiences. The 'inquiry phase' (the second phase) is where the students are involved in more 'open-ended-type' activities such as asking relevant questions, hypothesizing, choosing a question for further investigation, planning an experiment, conducting the experiment (including observations) and finally analyzing the findings and arriving at conclusions. It is thought that this phase allows the students to learn and experience science with greater understanding and to practice their metacognitive abilities.

Study 2. *The development and implementation of the inquiry-based experiments: Characteristics and components (Technion Institute)*

The case-based computerized laboratory (CCL) chemistry study unit was developed at the Technion. It was designed for 11th or 12th honors chemistry students with embedded assessment in mind (Dori, 2003). The CCL curriculum, developed within the framework of reforming the Israeli honors chemistry curriculum, integrates computerized desktop experiments with emphasis on scientific inquiry and case studies (Dori et al., 2004). Case-based computerized experiments expose students to advanced laboratory methods and a variety of data representations. The students were required to read authentic problems, carry out inquiry-based laboratory experiments, process data collected by sensors, and then interpret the resulting graphs that appeared on their desktop computer screens.

One central component in the CCL environment was case studies, followed by a question posing task. Each of the five laboratory sessions (e.g., energy, acid-base) began with a case study introducing chemical phenomena from daily life related to the inquiry laboratory that the students were about to experience. The laboratory activities included data collection using temperature, pH, and conductivity sensors, graphs construction in real time, and interpretation of the results. The last part of each session included another case study which dealt with a different aspect of the subject under study.

The organic chemistry part of the unit was taught in a computerized molecular modeling (CMM) environment, where students could investigate daily-life organic molecules using two CMM software packages downloaded from the Internet. Students were able to construct the molecules by determining the kinds of atoms and their numbers, as well as the covalent bonds between them (single, double or triple). The molecule is built according to the bonding rules. At the end of the construction process, the students get a two-dimensional structure of the molecule and they can view the molecule while constructing it in various 3D representation modes. The software enables the transfer of the 3D drawing between three molecular representation modes: line, ball-and-stick, and space-filling (Kaberman & Dori, 2009). An important goal underlying the CCL environment was developing higher order thinking skills, such as, posing questions, inquiry, graphing, and molecular modeling.

Study 3. *The development and implementation of the micro scale experiments: Characteristics and components (Bar Ilan University)*

The use of multigram quantities for the chemistry laboratory is sometimes very expensive and dangerous. Since the 80's of the 20 century the idea of small scale was introduced as an innovation in the Universities, where the amounts are reduced by 100-1000, in comparison to the classic lab. In order to perform experiments in the small scale equipment and techniques were developed worldwide. The Bar Ilan group developed 50 small scale experiments, with the coordinating equipment. (Livneh et al, 2002). Some of the benefits of micro-scale chemistry and small-scale science include:

- ✓ *Reduced chemical and equipment costs*
- ✓ *Improved air quality and pleasant working atmosphere*
- ✓ *Reduced exposure to toxic materials and increased safety*
- ✓ *Reduced waste generation*
- ✓ *Enabled use of a wider variety of chemicals*
- ✓ *Shortened experiment times*
- ✓ *Limited chances of fire or explosion*
- ✓ *Saves time for preparation and clear away*
- ✓ *Smaller storage area*
- ✓ *Reduced reliance on intensive ventilation systems*
- ✓ *More time for evaluation and communication*

In these experiments students learn to use the new technique and learn about green Chemistry by saving both the quantities of materials and waste.

Assessment Tools for Open-ended Inquiry-based Experiments

In order to assess students' achievement and progress during the performance of the experiments, two assessment tools were developed (Levy Nahum 2000; Hofstein, Shore, & Kipnis, 2004). These tools are used continuously by the chemistry teachers in their classroom laboratories. The assessment tools combine the teams' assessment tool - a "*hot report*" and the teacher's observations of the individuals in each group. The '*hot report'* is the group's product and is prepared in the laboratory during or immediately after the laboratory exercise. The development of this assessment tool is included in the identification of assessment criteria and the weight assigned to each criterion. This procedure was conducted by the first experimental chemistry teachers who participated in the intensive professional development workshop. The workshop was aimed at preparing them for the implementation of the inquiry experiments in their schools.

During the two year period, the students who opted to specialize in high school chemistry in grades 11 and 12 (in schools in which the inquiry-based laboratory was implemented) conducted about 20 inquiry-based experiments. In this way, they were involved in the following components of the inquiry method: identifying problems, formulating hypotheses, designing an experiment, gathering and analyzing data and drawing conclusions about scientific problems or science phenomena. The laboratory manual that was developed provided the necessary control regarding what students were required to do during the laboratory sessions. Each group of students produced a *'hot-report'*. These reports were analyzed regarding the questions that the students asked, the question that was selected for further investigation and the experiment that was suggested to investigate the selected question. Altogether 25 '*hot reports'* were analyzed (obtained from 25 small groups of students). Analysis of the group reports revealed that through conducting inquiry-based experiments, students have opportunities to develop understanding of the process of scientific protocols (scientific thinking) namely asking relevant questions, hypothesizing, formulating researchable questions and finally designing an experiment in an effort to obtain an answer to the question.

Assessment tools in the CCL environment

New modes of assessment were applied in the CCL unit. These included students' laboratory portfolios and pre- and posttest questionnaires, targeted at assessing the students' thinking skills rather than testing for knowledge alone. We used pre- and posttest questionnaires to assess students' higher order thinking skills. The questionnaires included a case study related to a chemical story and a variety of assignments for investigating various thinking skills, notably question posing, inquiry, and modeling skills. Throughout the course, the students compiled portfolios that were continuously assessed. Upon completing the unit, groups of 2-3 students carried out an independent (PBS type) inquiry project, in which they raised an inquiry question in chemistry, formulated a hypothesis, designed and conducted a computerized, sensor-based experiment, analyzed its results, and drew conclusions that were related to their hypothesis. At the end of the course, the students also took the national case-based test, which included posing their own questions about the case study they read as well as modeling questions.

Disseminating the changes and innovations in the curriculum, is not simple, it takes a few years for these changes to be implemented in all the classes and schools. The reform in Israel has reached almost 90% of the students in the laboratory.

In order to motivate both teachers and students to disseminate use of the inquiry lab and the use of scientific texts, we updated the assessment methods, so that they will fit the teaching and learning methods. The assessment of students' progress in the lab is done by Continuous evaluation of lab work, Portfolios of mini-projects, theoretical works, and industrial inquiries as well as Assessment of reading and understanding scientific papers in a written exam.

The three pillars of dissemination can be seen in fig. 1. One component consists of the curriculum, the standards, and the learning materials; the second important component focuses on the professional development of teachers and the educational staff via pre and in-service training, and the third component is the adaptation of the assessment so that it will be integrated into internal and external exams.

In order to enhance the process and help teachers cope with the change, after the new curriculum and the learning materials have been developed and publicized, we in Israel work with the Fan Method, which is presented in Figure 2.

DISSEMINATION

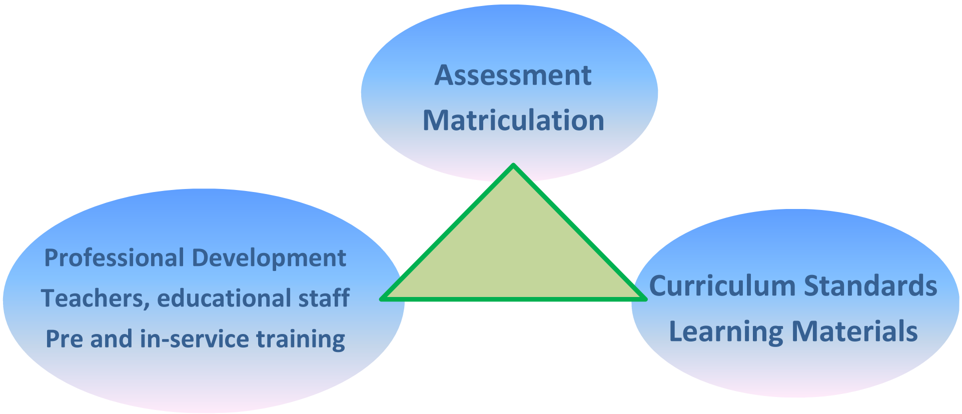


Figure 1. The three pillars of dissemination

DISSEMINATION

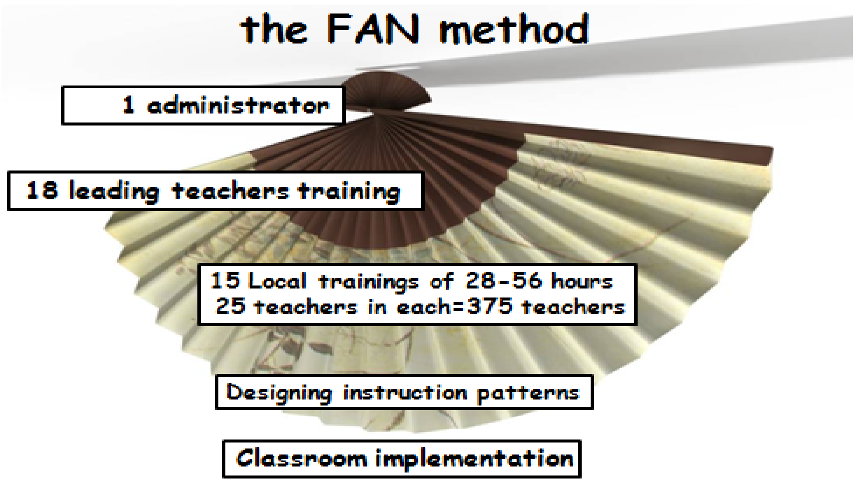


Figure 2. The fan model for dissemination

The idea underlying the Fan Method is to spread the innovations in a descending and widening way, beginning with the supervisor and the committee that decided on the change. A group of 15-20 leading teachers, together with the supervisor, work as a team and a study group. This group, which is composed of highly motivated exemplary teachers, creates the first cohort of learners and teachers who can explain and disseminate the new agenda. In addition to their school chores, these teachers work 1 or 2 days a week as teachers' guides. This group meets regularly every month for 8 hours of group learning and discussions, in a workshop for preparing training materials for the teachers.

Each teacher from the group is responsible for a district of the country: the north, the center, Tel-Aviv, Jerusalem, the south, etc. All around the country, these teachers organize 15 training sessions of 28-56 hours each. A training session unites 25 teachers from the region who meet to study together, and develop teaching sequences and learning aids for implementation in the classroom. In addition to face-to-face meetings, there is an accompanying closed forum for the training where participants:

- ✓ *Receive support from the guide and from other participants.*
- ✓ *Exchange learning materials, give and get critiques on the materials they provide.*

Each in-service training session consists of 2 virtual meetings and each participant has to write or respond a minimal number of times. The products consist of a wide range of learning materials, presentations, exercises, and exam questions. These materials are arranged by categories in a central open site, with practical advice, for the benefit of all teachers. In this way, we can keep in close contact with about 375 teachers every calendar year. Summer training sessions involve about 100 more teachers. Usually teachers need more than one training session to get enough confidence to implement new ideas. Support from the leading teachers in private, or in small group meetings, or by telephone or e-mail is also necessary.

The change seems to help in maintaining the number of students who study Chemistry in Israel in the last 8 years, as can be seen in Table 1.

The number of students who took the national matriculation examinations has increased since 2001 in both the 3-unit track and the track having 2 additional units. There were internal distribution changes as well. Fewer students were examined by the theoretical questionnaire only, whereas the number of students who chose the full 1-laboratory unit greatly increased. This trend is continuing, and we estimate that in the coming years the vast majority of chemistry students will elect studying the laboratory unit.

Teachers' practice in the inquiry chemistry laboratory

Practice in science teaching can be defined in terms of the knowledge that teachers need in their teaching (Magnusson, Krajcik, & Borko, 1999; Shulman, 1987). According to Hofstein, Shore and Kipnis (2004), accomplished teachers who are involved in this programme should have the following skills and abilities:

(1) To encourage students to interact professionally, including sharing knowledge with their peers, community members, or experts.

(2) To help students: solve problems, ask high-level questions, and hypothesize regarding certain unsolved experimental problems.

(3) To assess students continuously using a variety of alternative assessment methods.

(4) To customize the new activities according to their needs, and make decisions regarding the level of inquiry suitable for their students.

(5) To align the experiment with the concept taught or discussed in the chemistry classroom.

In order to implement the inquiry approach, teachers need to undergo an intensive and comprehensive process of professional development so that they will experience the same skills, knowledge, and thinking habits as their own students (Windschitl, 2003). Moreover, they should also undergo the entire inquiry process, so that they will be able to instruct their students better (Krajcik, Mamlok & Hug, 2001). In order to strengthen theses skills a long-term professional development should take place. Teachers need to receive guidance and support throughout the entire phase of the initial implementation phase (Loucks-Horsley & Matsumoto, 1999). An important aspect of teachers' professional development is the ability to reflect on their own work, collect artifacts from their classroom-laboratory, and construct evidence-based portfolios. These actions, instructed by the professional development facilitators, can lead teachers to focus on student learning through using student data to get information regarding their teaching practices. Using student learning data is a key component of effective professional development design (Loucks-Horsley, Love, Stiles, Mundry & Hewson, 2003). The student data over a relatively long period of time can be used for the construction of a portfolio. Portfolios have been defined in different ways, depending on their purpose, which could include certification and selection, appraisal and promotion, or the CPD of teachers. The portfolio used for CPD

Table 1. The number of students who took the chemistry national matriculation examinations by study units between 2001 and 2010.

No. of Units / Year	3 units* basic course Total	Additional 2 units track – honors students			
		No Laboratory	1/2 Laboratory Unit	1 Laboratory Unit	Additional 2 units* **Total**
2001	6616	3806	1653		5459
2003	7480	3032	1694	1073	5818
2005	8104	2637	2340	1784	6757
2007	9154	1763	2467	2798	7023
2008	10008	953	1808	4001	6762
2010	8798	631	1698	4251	6580

purposes can include materials and samples of work that provide evidence for critical examination of teaching and learning practices (Klenowski, 2002). A critical aspect of portfolio development, initially recognized by Shulman (1992), is the importance of discussing teaching and learning with colleagues. Since then, other authors have noted the importance of sustained discussion and the use of teams to support the portfolio development processes (Davis & Honan, 1998). Grant and Huebner (1998) suggest that the portfolio include a reflective commentary, the result of deliberation and conversations with colleagues, which allows others to examine the pedagogical decisions? underlying the documented teaching. Moreover, constructing a portfolio encourages reflection, which is an essential tool regarding teachers' professional development (Green & Smyser, 1996).

A continuous development program (CPD) for teachers, was initiated as part of a more comprehensive project conducted in the Chemistry Teachers' National Center located in the Department of Science Teaching at the Weizmann Institute of Science, and may serve as an example (Taitelbaum, Mamlok-Naaman, Carmeli & Hofstein, 2008). A CPD model that is evidence-based was developed in the chemistry group, in the Department of Science Teaching at the Weizmann Institute, Israel, as part of a more comprehensive and collaborative CPD project that was conducted between Kings' College, London and the Weizmann Institute of Science (Hofstein & Mamlok-Naaman, 2004; Hofstein, 2005). The key objective of the CPD model was to develop teachers' knowledge and pedagogy, so that they will be able to scaffold their students in acquiring the inquiry skills. This CPD model, which was tried out using a research design approach (Fortus, Dershimer, Krajcik, Marx, & Mamlok-Naaman, 2004), was designed and implemented throughout the period of three years. The first year focused mainly on developing a teacher's guide and planning a summer induction course. In the second and third years the CPD model was implemented. The CPD model was modified between the second and the third year. Seven high-school chemistry teachers participated in this programme each year. They were novices in teaching the inquiry approach in the chemistry laboratory, but most of them had several years of experience in teaching chemistry.

Based on our findings and observations we suggest that teachers who teach chemistry according to the inquiry approach should develop a novel approach regarding their content knowledge and pedagogical knowledge. In order to provide students with guidance and support, the teachers themselves need to develop the various above mentioned inquiry skills. The model developed and implemented in this study was time consuming and very intensive. However, reflecting upon the preparations and the enactment of the inquiry activity helped them in understanding their professional improvement and progress.

The results also indicate that a change in the content knowledge such as phrasing inquiry questions is not immediate, and participating in a summer induction course is not enough for this change to happen. It is suggested that involving teachers in a reflective-type process accompanied with a continuous support and scaffolding can promote the necessary professional development to include both content knowledge and pedagogical knowledge. In addition, once the teachers have acquired this knowledge, they could use it explicitly while they guide and provide support for their students, and thus make their guidance effective and meaningful. It is suggested that during the CPD initiative the teachers had gained more self-confidence to criticize their own work and to understand their teaching strategies in leading and tutoring students who work in small collaborative groups, or to develop the investigative skills of students, such as discussing the types of questions posed, the nature of the hypotheses raised, the questions selected for further investigation, and the process of planning more experiments (Davis & Honan, 1998).

Teaching by using the inquiry approach is much more complex and different from traditional classroom teaching. It requires from the teacher different kinds of skills and a high level of expertise (Crawford, 2000). This is why teaching the inquiry approach puts a lot of stress on the teachers, and it takes time for the teachers to become familiar and comfortable in teaching it. Supporting teachers continuously (as in this study, or by teacher-leaders) has potential in enhancing teachers' professional practice in our attempt to attain new, higher pedagogical standards.

SUMMARY

In the last 15 years, chemistry teachers in Israel have been involved in a reform regarding the way chemistry is taught, and has begun to integrate inquiry-type experiments into their chemistry classroom-laboratory. It is suggested that inquiry-centered laboratories have the potential to enhance students' meaningful learning, conceptual understanding, and their understanding of the nature of science. The *National Science Education Standards* (National Research Council [NRC], 1996) reaffirm the conviction that inquiry is central to the achievement of scientific literacy. However, inquiry-type experiences in the science laboratory should be conducted in the context of, and integrated with, the concept being taught.

Teaching science using the inquiry approach presents challenges both for the teachers and for students (Clough, 2002; Hofstein & Lunetta, 2004; Krajcik, Mamlok, & Hug, 2001; Lunetta, Hofstein, & Clough, 2007). Teaching students by this approach necessitates the involvement of the students in the following activities:

1. *conducting experiments according to the teacher's instructions;*
2. *making observations;*
3. *raising as many questions as possible;*
4. *choosing one question to be analyzed;*
5. *constructing a hypothesis for the research question, based on scientific principles;*
6. *designing an inquiry experiment to resolve the research question;*
7. *making and organizing observations once again;*
8. *analyzing and summarizing the inquiry experiment;*
9. *presenting the results to the whole class; and*
10. *raising more questions (Hofstein, Navon, Kipnis, & Mamlok-Naaman, 2005; Hofstein, Shore, & Kipnis, 2004).*

Teaching by using the inquiry approach is much more complex and different from traditional classroom teaching. It requires from the teacher different kinds of skills and a high level of expertise (Crawford, 2000). This is why teaching the inquiry approach puts a lot of stress on the teachers, and it takes time for the teachers to become familiar and comfortable in teaching it. Supporting teachers continuously (as in this study, or by teacher-leaders) has potential in enhancing teachers' professional practice in our attempt to attain new, higher pedagogical standards.

REFERENCES

Baird, J.R. (1990). Metacognition, purposeful inquiry and conceptual change. In E. Hegarty-Hazel (Ed.), *The student laboratory and the science curriculum* (pp. 183–200). London: Rutledge.

Barnea, N., Dori, Y.J., & Hofstein, A. (2010). Development and implementation of inquiry-based and computerized-based laboratories: reforming high school chemistry in Israel. *Chemistry Education Research and Practice,* 11(4), 218-228.

Barron, B.J.S., Schvartz, D.L., Vye, N.J., Moore, A., Petrosino, A., Zech, L., & Bransford, D.J. (1998). Doing with understanding: Lessons from research on problem and project-based learning. *Journal of the Learning Sciences*, 7(3/4), 271–311.

Blosser, B.F. (1983). The role of the laboratory in science teaching. *School Science and Mathematics*, 83, 165–169.

Bryce, T.G.K.,& Robertson, I.J. (1985). What can they do? A review of practical assessment in science. *Studies in Science Education*, 12(1), 1–24.

Clough, M. P. (2002). Using the laboratory to enhance student learning. In R. W. Bybee (Ed.), *Learning science and the science of learning* (pp. 85–94). Arlington, VA: National Science Teachers Association Press.

Crawford, B. A. (2000). Embracing the essence of inquiry: New roles for science teachers. *Journal of Research in Science Teaching, 37*(9), 916–937.

Crawford, B.A. (2007). Learning to teach science as inquiry in rough and tumble of practice. *Journal of Research in Science Teaching, 44*(4), 613-642.

Davis, C. L., & Honan, E. (1998). Reflections on the use of teams to support the portfolio process. In N. Lyons (Ed.), *With portfolio in hand: Validating the new professionalism* (pp. 90–102). New York: Teachers College Press.

Dori Y. J. (2003). From nationwide standardized testing to school-based alternative embedded assessment in Israel: students' performance in the "Matriculation 2000" project. *Journal of Research in Science Teaching, 40*(1), 34-52.

Dori Y. J., Sasson I., Kaberman Z. and Herscovitz O., (2004), Integrating case-based computerized laboratories into high school chemistry. *The Chemical Educ*ator, 9(1), 4-8.

Dori Y. J., Barak. M., Herscovitz O. and Carmi M., (2005), Preparing pre- and in-service teachers to teach high school science with technology. C. Vrasidas and G. V. Glass. (Eds). *Preparing teachers to teach with technology*, 2nd Volume of the book series: Current Perspectives on Applied Information Technologies. Information Age Publishing.

Fortus, D., Dershimer, R. C., Krajcik, J., Marx, R. W., & Mamlok-Naaman, R. (2004). Design-based science (DBS) and student learning. *Journal of Research in Science Teaching, 41*(10), 1081–1110.

Grant, G. E., & Huebner, T. A. (1998). The portfolio question: The power of self-directed inquiry, In N. Lyons (Ed.), *With portfolio in hand: Validating the new professionalism* (pp. 156–171). New York: Teachers College Press.

Green, J. E., & Smyser, S. O. (1996). *The teacher portfolio: A strategy for professional development and evaluation.* Lancaster, PA: Technomic.

Gunstone, R.F. (1991). Reconstructing theory from practical work. In B.E.Woolnough (Ed.), Practical science. Milton Keynes, England: The Open University.

Gunstone, R.F. & Champagne, A.B. (1990). Promoting conceptual change in the laboratory.In E. Hegarty-Hazel (Ed.), The student laboratory and the science curriculum (pp. 159–182). London: Routledge.

Hofstein, A. (2005, April). *Evidence-based continuous professional development (CPD) programmes in six science domains.* Paper presented at the meeting of the National Association for Research in Science Teaching, San Francisco, CA, USA.

Hofstein, A., & Lunetta, V. N. (1982). The role of the laboratory in science teaching: Neglected aspects of research. *Review of Educational Research, 52*(2), 201–217.

Hofstein, A., & Kesner, M. (2006). Industrial chemistry and school chemistry: Making chemistry studies more relevant. *International Journal of Science Education. 28* (9), 1017-1039.

Hofstein, A., & Lunetta, V. N. (2004). The laboratory in science education: Foundation for the 21st century. *Science Education, 88*(1), 28–54.

Hofstein, A., & Mamlok-Naaman, R. (2004). *Chemistry inquiry lessons.* Paper presented at the meeting of the American Educational Research Association, San Diego, CA, USA, April.

Hofstein, A., Shore, R., & Kipnis, M. (2004). Providing high school chemistry students with opportunities to develop learning skills in an inquiry-type laboratory: A case study. *International Journal of Science Education, 26*(1)*,* 47–62.

Hofstein, A., Navon, O., Kipnis, M., & Mamlok-Naaman, R. (2005). Developing students' ability to ask more and better questions resulting from inquiry-type chemistry laboratories. *Journal of Research in Science Teaching, 42*(10)*,* 791–806.

Hodson, D. (1990). A critical look at practical working school science. *School Science Review*, *71*(1), 33–40.

Johnson, D. W., & Johnson, R. T. (1999). *Learning together and alone: Cooperative, competitive, and individualistic learning.* Boston, MA: Allyn and Bacon.

Kaberman, Z., & Dori, Y. J. (2009). Question posing, inquiry, and modeling skills of chemistry students in the case-based computerized laboratory environment. *International Journal of Science and Mathematics Education, 7*(3), 597-625.

Klenowski, V. (2002). *Developing portfolios for learning and assessment.* London: Routledge Falmer.

Krajcik, J., Mamlok, R., & Hug, B. (2001). Modern content and the enterprise of science: Science education in the twentieth century. In L. Corno (Ed.), *Education across a century: The centennial volume* (pp. 205–238). Chicago, IL: National Society for the Study of Education.

Loucks-Horsley, S., Love, N., Stiles, K. E., Mundry S., & Hewson, P. W. (2003). *Designing professional development for teachers of science and mathematics* (2nd ed.). Thousand Oaks, CA: Corwin Press.

Loucks-Horsley, S., & Matsumoto, C. (1999). Research on professional development for teacher of mathematics and science: The state of the scene. *School Science and Mathematics, 99*(5)*,* 258–271.

Lunetta, V. N. (1998). The school science laboratory: Historical perspectives and contexts for contemporary teaching. In J. B. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 249–262). Dordrecht, The Netherlands: Kluwer.

Lunetta, V. N., Hofstein, A., & Clough, M. P., (2007). Learning and teaching in school science laboratory: An analysis of research, theory and practice. In S. A. Abell & N. G. Lederman (Eds). *Handbook of research in science education* (pp. 393–442). Mahwah, NJ: Lawrence Erlbaun Associates Publishers.

Magnusson, S., Krajcik, J., & Borko, H. (1999). Nature, sources, and development of pedagogical content knowledge for science teaching. In J. Gess-Newsome & N. G. Lederman (Eds.), *Pedagogical content knowledge and science education* (pp. 95–132). Dordrecht, The Netherlands: Kluwer Academic Publishers.

Marx, R. W., Freeman, J. G., Krajcik, J. S., & Blumenfeld, P. C. (1998). Professional development of science teachers. In B. J. Fraser & K. G. Tobin (Eds.), *International handbook of science education* (pp. 680–776). Dordrecht, The Netherlands: Kluwer.

National Research Council. (1996). *National science education standards.* Washington, DC: National Academy Press.

Putnam, R. T., & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning? *Educational Researcher, 29*(1), 4–15.

Roth, W.M. (1994). Experimenting in constructivist high school physics laboratory. *Journal of Research in Science Teaching*, *31*(2), 197–223.

Sharan, Y., & Sharan, S. (1992). *Expanding cooperative learning through group investigation.* New York: Teacher College Press.

Shachar, H., & Sharan, S. (1994). Talking, relating and achieving: Effects of cooperative learning and whole-class instruction. *Cognition and Instruction, 12*(4)*,* 313–353.

Slavin, R. (1990). *Cooperative learning: Theory, research and practice.* Englewood Cliffs, NJ: Prentice Hall.

Shulman, L. S. (1987). Knowledge and teaching: Foundations of the new reform. *Harvard Educational Review, 57*(1)*,* 1–22.

Shulman, L. (1992, April). *Portfolios in teacher education: A component of reflective teacher education.* Paper presented at the annual meeting of the American Educational Research Association, San Francisco, CA, USA.

Taitelbaum, D., Mamlok-Naaman, R., Carmeli, M., & Hofstein, A. (2008). Evidence-based Continuous Professional Development (CPD) in the Inquiry Chemistry Laboratory (ICL). *International Journal of Science Education*, *30*(5), 593-617.

Tobin, K. (1990). Research on science laboratory activities: In pursuit of better questions and answers to improve learning. *School Science and Mathematics, 90*(5)*,* 403–418.

Windschitl, M. (2003). Inquiry project in science teacher education: What can investigative experiences reveal about teacher thinking and eventual classroom practice? *Science Education, 87*(1)*,* 112–143.

Yamagata-Lynch, L. (2001, November). *Community of Practice: What is it, and how can we use this metaphor for teacher professional development?* Paper presented at the National Convention of the Association for Educational Communications and Technology, Atlanta, GA, US.

◈◇◈