

An interview with Avi Hofstein, Department of Science Teaching at the Weizmann Institute of Science in Israel

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Received 18 April 2008; accepted 22 April 2008

The conversation between Professor Avi Hofstein and me took place in Rehovot, Israel (at the Weizmann Institute of Science) on March 5th, 2008. The purpose of the conversation was to elaborate on the past, present, and future of science education research as well as to provide insights for beginning researchers.

Keywords: Inquiry-type experiments, science for all, scientific literacy, context-based teaching, chemistry learning.

INTRODUCTION

Professor Avi Hofstein, who is currently the head of the Department of Science Teaching at the Weizmann Institute of Science in Israel, has been one of the leading science educators in Israel over the last thirty years. His contributions have had a major impact on science education, in general, and on chemistry education, in particular. Throughout his career, Prof. Hofstein has employed a unique holistic approach to advancing science education - an approach that integrates activities of research, curriculum development, implementation, and teacher development. The interplay between research and practice has contributed to the high quality of his work. On the one hand, the curriculum development, implementation, and assessment, as well as professional development programs provided a context for studying authentic questions in complex environments that led to findings and insights that could not have been found in more artificial settings. On the other hand, his research studies were deemed valid, and were directly applicable to practice, and thus

had an actual impact on the field of science education.

His scientific activities conducted over the years with many members and students from the chemistry group, are:

Development of learning materials for both students and teachers based on our knowledge of how students learn and how teachers teach chemistry and science for all students programs.

- Some products of these developments are students' textbooks, teachers' guides, computer assisted instructional materials, inquiry-type laboratory investigations, and dynamic internet sites.
- Professional development of chemistry teachers in general and leading chemistry teachers in particular.
- Research on classroom and laboratory learning environments (based on students' perceptions), on instructional techniques implemented, and on the ability of the students to develop inquiry-oriented skills.
- Development of learning and teaching strategies (pedagogical interventions) with the goal of varying the classroom learning environment, thus, making chemistry more relevant to the learner, and introducing alternative assessment methods to be implemented by the teachers.

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Professor Hofstein's activities have had a huge impact on science education in Israel. This was done with great collaborations with colleagues, and students within the environment of the Department of Science Teaching at the Weizmann Institute of Science. The Weizmann Institute of Science, located in Rehovot, Israel, is one of the top-ranking multidisciplinary research institutions in the world and noted for its wide-ranging explorations of the sciences. The Institute consists of more than 2,500 scientists, technicians, and research students devoted to adventuring into the unknown in the quest to advance scientific knowledge. In their labs, located in a beautifully landscaped campus environment, they share a common vision: to better understand nature and our place within it. Inquisitiveness is their predominant trait. In the Department of Science Teaching, extensive research and development projects take place, aimed at producing improved and up-to-date learning materials that integrate the use of modern technologies. These materials are later implemented into the Israeli education system. On-going work is based on an underlying philosophy that considers curriculum development and implementation, teacher in-service development, research, and evaluation as an interrelated and continuous long-term activity. Therefore, research related to all aspects of curriculum development and implementation forms an integral part of the process. This research includes evaluation of pilot materials through classroom research, affective and cognitive studies, analysis of students' learning difficulties and the effectiveness of specific learning and teaching strategies, as well as improving student cognition.

The department is composed of groups working in mathematics, physics, chemistry, computer science, earth and environmental sciences, life sciences, and science and technology for junior-high school. In all these areas, there are extensive research and development projects, aimed at (1) studying science and mathematics learning and teaching and their development, (2) producing and implementing improved and up-to-date learning and teaching materials that integrate the use of modern technologies, and (3) providing professional development for teachers, throughout Israel. As mentioned before, research studies focus on cognitive, socio-cultural, and affective aspects of learning, teaching, and learning to teach science and mathematics by using various research methodologies: quantitative, qualitative, and mixed methods.

Currently, the department runs two national centers for science teachers (physics, and science and technology in junior high school and until recently also in chemistry), specializing in developing leadership among science teachers and in continuous professional development for science teachers using effective



Figure 1. One of the Weizmann Institute sights



Figure 2. Avi Hofstein with colleagues and students in September 2006 at the end of an inquiry-type laboratory professional development of teachers at the Weizmann Institute of Science. Standing (from left to right) are students: Dorit Taitelbaum, Iyad Dkidek, and Mira Kipnis. Sitting (from left to right): Rachel Mamlök-Naaman, Avi Hofstein, and Relly Shore (a chemistry teacher and a member of the chemistry group).

models. In recent years, the department has been involved in EU projects aimed at enhancing science education both at the formal as well as the informal levels.

The interview with Professor Hofstein will be divided into three parts: (1) his academic career, (2) his contribution to science and chemistry education in Israel, and (3) his future plans.

Prof. Hofstein talks about his academic career

In 1965 I received my B.Sc. in chemistry and physics from the Hebrew University in Jerusalem, followed later by a master's degree in education from Tel-Aviv University, and a Ph.D in Chemistry Teaching from the Weizmann Institute of Science. In 1968, I joined a group of teachers and young scientists who established the Department of Science Teaching at the Weizmann Institute of Science. Since then (for almost 40 years), I have been part of the chemistry group within this department. I carried out my work in the context of

chemistry teaching and promoted programs ("Science for All") for advancing scientific literacy among high-school students who do not opt to major in any of the scientific disciplines. One of my central concerns (and activities) has been the design of learning environments and instructional strategies that foster the development of understanding and interest in chemistry. I have been one of those who investigated extra-curricular learning environments, and I have advocated the need to bridge the gap between formal and informal settings (Hofstein & Rosenfeld 1995). Ideas that I have suggested and investigated many years ago are now being implemented in other educational settings as promising means for enhancing the interest in and relevance of science studies and for developing scientific literacy (Hofstein & Kempa, 1985; Shwartz, Ben-Zvi, & Hofstein, 2006; Hofstein & Kesner, 2007).

Over a period of more than 30 years, I have studied the area of learning in and from science laboratories (Hofstein & Mamlok-Naaman, 2007). I published two reviews (jointly with Prof. Vince Lunetta) often cited (Hofstein & Lunetta, 1982; 2004) and other research papers focusing on the laboratory as a unique learning environment, assessment of students' performance in the laboratory, attitudes towards and interest in the science laboratory and the development of cognitive and metacognitive skills in inquiry-type laboratories. The studies that I carried out in this area with my group and graduate students has significantly advanced our understanding of the learning that takes (and does not take) place in these environments. In particular, together with the chemistry group, I tried to design a format for inquiry labs that can promote the development of inquiry skills such as asking questions, designing experiments, and improving interpretation. The challenge has been to develop a format that is usable by many teachers (up-scaling), is sustainable, and effective (Hofstein, Shore, & Kipnis, 2004).

Special efforts were directed toward the development of innovative **alternative portfolio-based assessments** that are essential for assessing and supporting the development of such complex skills. This work, performed collaboratively with Dr. Rachel Mamlok-Naaman, was accompanied by extensive research and development of professional development models. One of the recent models has been the "evidence-based" model developed and studied in a collaborative project with colleagues from King's college, leading to new insights regarding how to support teachers in introducing student-centered instructional strategies into classrooms (Taitelbaum, Mamlok-Naaman, Carmeli, & Hofstein, 2008)). This Continuous Professional Research program, conducted concomitantly by the Department of Science Teaching at the Weizmann Institute of Science and the Department of Science Education, Kings College,

London, has been continuing for three years. The main goal of this collaboration is to design an effective evidence-based CPD model for key aspects of science teaching and learning. The CPD program is being developed through collaborative research with classroom science teachers. It focuses on a specific set of characteristics and protocols that individuals can use to achieve evidence-based accomplished practice in science teaching. This three-year project investigated the resulting professional development and practice of teachers. More specifically, the objectives of this program are as follows:

- Identify the specific needs and difficulties of science teachers and the factors that contribute to successful CPD based on the six science teaching areas.
- Produce an enhanced CPD model.
- Design high-quality materials for the professional development of science teachers.
- Design associated-quality assurance procedures to enable physical science teachers to use the enhanced CPD model effectively.
- Develop and implement guidelines and criteria for preparing a teaching portfolio framework that teachers can use to demonstrate accomplished practice in the various domains.

I mentioned the **professional development of teachers**, and I would like to stress the fact that the scientific community realizes that without the teachers' involvement and the teachers' ownership, no reform or innovation could be incorporated into the educational system. Therefore, I was one of the science educators who established in Israel a system involving a national and regional center devoted to providing life-long professional development for science teachers. In particular, in 1995 I established the chemistry national center and have designed innovative strategies for promoting teacher leadership in chemistry. I ran this national center for more than six years, and when I became the head of the chemistry group, Dr. Rachel Mamlok-Naaman from the Chemistry Group replaced me. The overriding goal of this center was to develop a cohort of chemistry teacher-leaders. The idea was that these leading-teachers would eventually serve as agents for change, namely, they will help in bringing about reform in chemistry education in Israel (both in its content as well as in the way it is taught namely the pedagogy). This initiative is part of a more comprehensive report on reform in science education in Israel (Tomorrow 98) that provides directions and actions to be taken in the professional development of science teachers in general, and in the development of leadership among science teachers, in particular. (For more details regarding the reform of professional development and about the national center, see for

example: Hofstein & Even, 2001). Several programs aimed at developing leadership among chemistry teachers were initiated at the National Center for Chemistry Teachers. The program for leading chemistry teachers, which was documented in the literature (Hofstein, Carmi, & Ben-Zvi, 2003), was conducted over a period of two academic years, 450 hours in total. The program was designed around the following three components:

- Developing teachers' understanding about the current trends of chemistry teaching and learning, which include both the content and the pedagogy of chemistry learning and teaching;
- Providing the teachers with opportunities to develop personally, professionally, and socially;
- Developing leadership and the ability to work with other chemistry teachers.

The program was assessed regarding the changes that the teachers underwent as a result of the leadership program. The assessment focused on three interrelated variables, namely:

- Developing the teachers' personal beliefs about themselves, about teaching chemistry, and about becoming a leader;
- Developing their professional behavior and activities in their chemistry classroom;
- Developing leadership skills and activities with other chemistry teachers in and outside their schools (social development).

Another focus of recent years has been the development of "**scientific literacy**" and in particular, chemistry literacy in high-school students (Shwartz, Ben-Zvi & Hofstein, 2006). This work involved a systematic attempt to define the concept of "chemistry literacy" as well as creative approaches to develop learning materials to advance the acquisition of literacy. My work has been accompanied by on-going research on learning and teaching strategies leading to a personally relevant study of science and the development of citizens who master independent learning skills (Hofstein & Mamlok, 2001).

Prof. Hofstein Talks about His Contribution to Science and Chemistry Education in Israel

After finishing my B.Sc. in 1965, I worked as a high-school chemistry teacher until 1970, first in an academic-type agricultural high school and afterwards at the technical high school of Tel-Aviv University, in which I also served as a deputy head master. From 1980 to 1999, parallel to my work at the Weizmann Institute, I served as a coordinating inspector for high-school chemistry; this enabled me to be part of various pedagogical committees that influenced the educational policy in Israel. In addition, I established the National



Figure 3. Prof. Avi Hofstein speaking at a one day meeting of chemistry teachers at the Weizmann Institute in December 2006.

Center of Chemistry Teachers at the Weizmann Institute of Science (1996-2002). As I mentioned before, in addition to my work to improve both the content and pedagogy of high-school chemistry, I became involved in the development, implementation, and research aimed at advancing scientific literacy among high-school students who do not opt to major in any of the scientific disciplines (the "Science for All" program). The "Science for All" program was developed as part of a more comprehensive reform in science education that was launched in Israel (Tomorrow 98, 1992). The key components of this reform were the recommendations regarding the teaching of science for non-science-oriented high-school students. The various activities that were developed to cater to these students were a big challenge for me regarding all the curricular components.

The "**Science for All**" program consists of a set of learning (and teaching) modules (35-40 hours each), all having an STS-type structure and content. Each module focuses on a specific scientific topic (Dori & Hofstein, 2000). Some of the modules that were developed in my department are Energy and the Human Being (Ben-Zvi, 1999); Science: An Ever-Developing Entity (Mamlok, 1996), and Brain, Medicine, and Drugs (Cohen, 2000; Cohen, Ben-Zvi, Hofstein, & Rahamimoff, 2004). Energy and the Human Being tries to clarify some issues concerning many beliefs and misconceptions about energy (for more details, see Ben-Zvi, 1999). Science: An Ever-Developing Entity was designed to develop an understanding of the nature of science by using historical examples. In this way, science is presented as a continuously developing enterprise of the human mind in the context of the historical development of our understanding of science (Erduran, 2001; Mamlok, Ben-Zvi, Menis, & Penick, 2000). Brain, Medicine, and Drugs focuses on several selected aspects of brain research and their relationship to human behavior and emotions. When teaching the modules, the teachers are expected to use a wide range of pedagogical

interventions and instructional techniques in order to cope with a wide range of student abilities, interests, and means of motivation (Hofstein & Kempa, 1986). Moreover, the implementation of such an STS program with a wide spectrum of learning goals necessitates matching to each learning goal its instructional technique as well as an assessment tool to measure students' achievement and progress (Hofstein, Mamlok, & Rosenberg, 2006).

For more than 30 years, my favorite (and central) research area (including my PhD work) was the **laboratory**. During these years, in collaboration with my enthusiastic graduate students and members of the chemistry group, I managed to research almost all the components (and variables) involved in this unique mode of learning (a summary of most of these studies was published in CERP - Hofstein, 2004).

More recently, an Inquiry-type laboratory program was developed by the chemistry group (Hofstein, Shore, & Kipnis, 2004), which I believe, provides an exemplar for enacting inquiry-based science in Israeli high-school science classrooms through providing a context for students to experience authentic scientific inquiry (Abd-El-Khalick, Duschl, Lederman, Mamlok, Hofstein, BouJaoude, Niaz, & Tuan, 2004). I am among those science educators who believe that, when properly developed, inquiry laboratories have the potential to enhance students' constructive learning, conceptual understanding, and understanding of the nature of science (NOS) (Hofstein & Lunetta, 2004; Lunetta, Hofstein, & Clough, 2007). The chemistry laboratory experiences that were developed involve conceiving problems, formulating hypotheses, designing experiments, gathering and analyzing data, and drawing conclusions about scientific problems or natural phenomena. They are especially effective if conducted in the context of, and integrated with, the development of scientific concepts and processes (Hofstein & Walberg, 1995). About 100 inquiry-type experiments were developed and implemented in 11th and 12th grade chemistry classes in Israel (for more details about the development procedure, assessment of students' achievement and progress, and the professional development of the chemistry teachers, see Hofstein et al., 2004). Almost all 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. These experiments have been implemented in the school chemistry laboratory in Israel for the last five years. Moreover, this program has to take into account such variables as the professional development of teachers, the continuous assessment of students' progress in terms of achievement in the laboratory, and the allocation of time and facilities (materials and

equipment) for conducting inquiry-type experiments. An intensive and comprehensive series of studies clearly showed that these types of learning experiences are advantageous as a method to develop students' ability to ask high-level-type questions (Hofstein, Navon, Kipnis, & Mamlok-Naaman, 2005), to develop metacognitive learning skills (Kipnis & Hofstein, in press), and to develop their ability to cope with other inquiry-type skills, which in recent years, are regarded as an important component of scientific literacy (Bybee, 2000). We also found that these experiences are important components for improving the classroom laboratory learning environment (Hofstein, Levy Nahum, & Shore, 2001).

Future Plans

We operate in an era in which many students learn chemistry, although they do not plan to pursue a career in the sciences in general, and in chemistry in particular. I sincerely believe that future development of science education should be aligned to the needs and interests of all the students, as advocated by Harms and Yager, namely, science education for those who are seeking careers in the sciences, for those who are going to utilize science in their profession, and finally for those who are planning to become literate scientists in a scientific and technological community and who will be able to appreciate the contribution of science in their daily life. The learning materials should be more contextualized; more students' centered, and provide opportunities to develop high-order learning skills. In order to achieve these rather ambitious goals, we need to develop varied types of pedagogical interventions and their related alternative assessment tools in order to cater to different student learning styles, abilities, interests, and motivational traits.

My plan is to continue the research and development in the four interrelated areas, namely, curriculum development and implementation including chemistry teachers' professional development, evaluation, and research. In the next four to five years, the chemistry group will be involved in the development and implementation of learning materials based on the new syllabus of chemistry recently published by the Ministry of Education and Culture. The new program will incorporate the findings regarding chemistry students' conceptions and misconceptions. In addition, the main goal of the new program is to develop chemistry-literate students and students who will find chemistry studies relevant and applicable. It is planned to expand research on students' misconceptions and learning difficulties in other areas (e.g., organic chemistry) in which such difficulties were revealed. The results of these and similar studies will then be used to develop learning materials and other remedial methods. It should be

mentioned that we operate in an era in which advanced technologies are emerging in schools. In light of this, we plan to develop more internet sites to supplement the development of the new curriculum. Research will be conducted with the goal in mind of investigating the educational effectiveness of such learning and teaching tools. We intend to apply the model and results of the CPD program to other instructional techniques such as using the internet, using scientific articles in the chemistry classroom, and utilizing distant learning techniques.

Looking back on my career in science education, I feel that even today I would not choose a different area to be involved in. I had opportunities to work as a high-school teacher and my academic involvement helped me work to attain the goal of improving science education in my country. Finally, I was blessed with supportive colleagues: Rachel Mamlok-Naaman, Ruth Ben-Zvi, David Samuel, and Bat Sheva Eylon and other members of the chemistry group and students, who without them, these goals could not be attained. In addition, I would like to thank many friends around the world: Vince Lunetta, Richard Kempa, Bob Yager, Barry Fraser, David Treagust, Jack Holbrook, Herbert Walberg & Wayne Welch who over the years, provided me with new ideas that helped me to construct my research agenda.

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