

## Women's leadership in chemistry education: An interview with Rachel Mamlok-Naaman

Ron Blonder 

The Weizmann Institute of Science, Israel  
Ron.Blonder@weizmann.ac.il

### Abstract

Dr. Rachel Mamlok-Naaman, from the Weizmann Institute of Science in Israel, is a distinguished researcher in chemistry education. This paper presents an interview that was conducted in light of her achievements and in recognition of her receiving the IUPAC 2021 award for Distinguished Women in Chemistry or Chemical Engineering.

### Keywords

Women in science, women in chemistry, chemistry education

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### Dr. Rachel Mamlok-Naaman's activities and involvement in chemistry education

I am looking back, trying to reflect upon my accomplishments, as well as the professional experiences and insights that I gained over the years as a: (1) chemistry teacher, (2) regional consultant for chemistry teachers, (3) deputy of the chief chemistry teachers' superintendent, (4) head of the National Center for Chemistry Teachers, and (5) researcher.

It gives me a great pleasure to be involved in a variety of facets regarding the educational system – practice and research: students' misconceptions; the history of science; education for sustainable development (e.g., relevant issues and industrial chemistry); the gender gap in science; and chemistry teachers' professional development models. I would like to focus on each of the above topics, and especially on one of my main research and practice interests: chemistry teachers' professional development models, in which I utilized my experience with all the above topics.

### Students' misconceptions

I was a high-school chemistry teacher for 26 years, immediately after finishing my military reserves service in the framework of academia. I had no experience in teaching, despite my teaching certificate, but my love for chemistry, which became stronger during my BSc, helped me to cope with the challenges encountered by a novice teacher. I found out very quickly that teaching the wonders of chemistry to young people, noticing their enthusiasm, and supporting

their development in scientific issues gave me great satisfaction. However, there were many students who had difficulties in understanding the language and concepts of chemistry. It was obvious that I needed to determine the source of their difficulties and misconceptions. I held a few discussions in class in which I tried to diagnose misconceptions, especially regarding structure and matter, as well as energy issues. Unfortunately, at that time, in the early 1970s, there were neither professional development courses, nor supporting centers for chemistry teachers.

However, I did my best to tackle these problems myself, and over time, I found that I was not the only one who had to cope with the diversity of students' misconceptions in chemistry regarding many topics. I realized this when I was invited to join Ben-Zvi and Silberstein, who developed a new curriculum for high-school chemistry students, in order to cope with students' misconceptions in chemistry: "*Chemistry – A Challenge*" (Ben-Zvi and Silberstein, 1984). I served as an experimental teacher, disseminated diagnostic questionnaires before and after teaching the new curriculum, helped analyze them, and implemented the curriculum in my own classes. This research process promoted my knowledge as a teacher, and it was the beginning of my profession as a researcher (Ben-Zvi, Silberstein, and Mamlok, 1993).

Students' misconceptions became part of my research interest, and I continued with this topic in co-advising Levy Nahum and Yayon in their PhD dissertation work (Levy Nahum, Hofstein, Mamlok-Naaman and Bar-Dov, 2004; Yayon, Mamlok-Naaman and Fortus, 2012). A Systems Thinking project in which I participated, and was initiated by IUPAC ([https://iupac.org/projects/project-details/?project\\_nr=2020-014-3-050](https://iupac.org/projects/project-details/?project_nr=2020-014-3-050)); it enhanced my knowledge of finding ways to cope with the misconception challenges (Chiu, Mamlok-Naaman and Apotheker, 2019). I used this knowledge in meetings with teachers in the framework of professional learning communities (PLCs).

The models of professional learning communities are based on principles of learning that emphasize the co-construction of knowledge by learners, who in this case are the teachers themselves. Creating teachers' professional learning communities is an effective bottom-up way of introducing innovation into the science curriculum and supporting professional development.

### History and philosophy of science

One of my strategies for dealing with my students' misconceptions was to use the historical approach to chemistry teaching and learning. I thought that the historical approach may help me to achieve a better understanding of the essence of scientific phenomena, scientific methodology, and overall scientific thinking; therefore, I integrated scientific developments and historical analyses of scientific events, together with various scientists' projects on a specific subject. Students learned about the development of models from the Greek atomic models, and became familiar with the fact that explanations of different phenomena changed over decades due to new

facts, new technological developments, and changes in the scientific community's perceptions. Students drew timelines and denoted scientific developments together with technological, cultural, and societal developments. They learned that science is an ever-developing entity, and that it is associated with societal, economic, and technological happenings.

I found that using the historical approach to teaching and learning chemistry was fascinating; therefore, I chose it as the topic of my PhD dissertation, which was completed at the end of 1997: “*The effect of a teaching unit: ‘Science: An Ever-Developing Entity’ on Students’ Perceptions and Attitudes towards Science and Science Learning*” (Mamlok-Naaman, Ben-Zvi, Hofstein, Menis, and Erduran, 2005). The dissertation was based on “*Science: An Ever-Developing Entity*” (Mamlok, 1996), a module (a teaching unit) aimed at 10<sup>th</sup> grade non-science-oriented high-school students. It deals with aspects of science, technology, and society, related to the development of the concept “structure of matter.” The module's objectives were as follows:

1. To enable students to familiarize themselves with the nature of the scientific enterprise.
2. To enable students to better understand the interplay between science and technology.
3. To change students' attitudes towards science in general and more specifically, towards science taught in school.

In summary, my students claimed that the concepts and their significance in various periods helped them achieve a better understanding of the scientific endeavor. Many students also remarked about the variety of teaching methods, the new experiments that simulated ancient experiments, as well as films, articles, and projects that they had prepared and presented to their peers and teachers, which greatly contributed to the learning and comprehension of the material. The students found the instruction strategies to be enjoyable, increasing their interest in science in general, and in the area of historical aspects in particular (Blonder and Mamlok-Naaman, 2019).

### Education for sustainable development

Chemistry educators in Israel developed and researched learning materials for high-school chemistry studies by incorporating inquiry-type socio-scientific issues from the chemistry industry and from green chemistry. The goal was to educate for sustainable development and environmental awareness using science inquiry learning, e.g., asking questions, postulating, drawing conclusions, and using argumentation (Taitelbaum, Mamlok-Naaman, Carmeli, and Hofstein, 2008). These learning materials were developed both for students and for teachers, integrating chemistry with environmental, health, economic, and societal aspects. As a high-school chemistry teacher, I always tried to incorporate relevance, context-based, and inquiry-type socio-economic issues in my teaching. The students were asked to follow articles in daily

newspapers in Hebrew, and each week one of them presented an article about sustainable issues. The discussions that followed the presentations included debates and controversial opinions.

Over the years, relevant issues, environment, and sustainability became an elective part of the high-school chemistry curriculum (Stuckey, Hofstein, Mamlok-Naaman and Eilks, 2013). Mandler (2006) developed two modules about the environment, on which she based her PhD dissertation; she was advised by Professor Avi Hofstein and myself (Mandler, Blonder, Yayon, Hofstein, and Mamlok-Naaman, 2014). Two European projects in which I was involved (including development, implementation, and research), also dealt with these issues (Blonder, Kipnis, Mamlok-Naaman, and Hofstein, 2008; Bolte, et al., 2011). All the projects mentioned above involved conducting professional development workshops for teachers, in order to support them in implementing these interdisciplinary subjects. Recently, I accumulated my data about sustainability in a chapter published in an ACS book (Mamlok-Naaman and Mandler, 2020).

### Gender Gap

The gender gap was always one of my main concerns. I always admired women who managed to follow their dreams, and succeeded to achieve great results. It was my pleasure to accept Professor Mei-Hung Chiu's invitation 10 years ago, and to write a chapter: One hundred years of women in chemistry in the 20<sup>th</sup> century: Sociocultural developments of women's status (Mamlok-Naaman, Blonder, and Dori, 2011). I continued to wonder about women's situation in Israel, especially in academia and in Israel, and I wrote about it in a paper (Mamlok-Naaman, 2021).

Three years ago, I became a member of the IUPAC Gender Gap Committee (<https://iupac.org/member/rachel-mamlok-naaman/>). The committee initiated a global approach to the gender gap in 2018 for mathematical, computing, and natural scientists. Over 32,000 answers were collected from women and men. Analysis of the survey contributed to better understanding this phenomenon and in identifying the various factors that cause it. The recommendations address a variety of groups: instructors and parents of girls in primary, secondary, and higher education; educational organizations; scientific unions and other worldwide organizations (A global approach to the gender gap in mathematical, computing, and natural sciences: How to measure it, how to reduce it? 2020 available at <https://gender-gap-in-science.org/>). The project is now in its second phase. A database of good practices for girls and women were developed to provide information on how to encourage females to be interested in science and mathematics. Such a database could be best used by policy makers; it consists of a query of the results of the Gender Gap project survey to further elucidate the situation with respect to chemistry, an additional study of the publication patterns in chemistry journals, and it identifies good practices in chemistry.

### Professional development of chemistry teachers

One of my main research interests over the years was the field of chemistry teachers' professional development. I was introduced to it as a regular research interest, as a regional consultant for chemistry teachers, and as the deputy of the chemistry teachers' inspector. My research on this topic can be described as a *spiral* procedure, referring to the diverse facets of chemistry education, which are integrated into each other. My experience as a chemistry teacher, and the findings on student learning and motivation guided (and will continue to guide) me in designing and revising curricular materials and continuous professional development (CPD) programs for chemistry teachers, since they are the key to any success with their students, implementation of new curricular materials, or reforms in education. More specifically, the professional development programs and models that I developed, implemented, and researched over the last 30 years in the Jewish and Arab sectors in Israel, as well as in USA, Georgia, Germany, Singapore, Taiwan, Estonia, Japan, Tanzania, and other countries are based on research findings related to my topics of practice and the research that I mentioned above, as well as inquiry-based skills, e.g., argumentation, asking questions, postulating (Blonder, Rap, Mamlok-Naaman and Hofstein, 2015; Cai and Mamlok-Naaman (Eds.), 2020), laboratory skills (Mamlok-Naaman and Barnea, 2012), and cultural aspects (Dkeidek, Mamlok-Naaman and Hofstein, 2011; Markic, et al., 2016; Blonder and Mamlok-Naaman, 2019; Mamlok-Naaman and Taitelbaum, 2019).

One project to which I was especially attached was "*Preparing biology teachers to become chemistry teachers in the Upper Galilee in Israel*", sponsored by the JOINT, due to a shortage of chemistry teachers in the Upper Galilee. The program was implemented between 1989 and 1991. The teachers met each week for eight academic hours (224 academic hours per year). The program consisted of intensive coursework that included teaching the content of the high-school chemistry curriculum at the basic and advanced levels, activities, diversifying teaching methods, and pedagogical strategies. As a result, the number of chemistry teachers and students increased dramatically (Mamlok, Hofstein and Ben-Zvi, 1995).

My experience helped me in my task as the head of the National Center for Chemistry Teachers at the Department of Science Teaching, the Weizmann Institute of Science, between 1996 and 2020, with an interruption of two years when Dr. Dvora Katchevich replaced me (2016-2018). The first head of this center was Professor Avi Hofstein (1996-2000). The Chemistry Teachers Center is one of 10 academic science centers in Israel. For example, its activities consist of CPD workshops, a one day per year meeting of chemistry teachers, a magazine aimed at chemistry teachers (published twice a year), and a website. Over the years, it has become a sort of home for chemistry teachers, who felt that they can always get support and answers to their questions by the center's staff (<https://chemcenter.weizmann.ac.il/>).

The National Center for Chemistry Teachers was established in 1996, aiming to provide a strong framework for life-long-learning (LLL) for each chemistry teacher (Figure 1). Its objectives are

as follows: (1) designing standards and models for effective professional development, based on academic research and development, (2) conducting long-term professional development programs for leading teachers, (3) working collaboratively with the chief chemistry superintendent, (3) providing professional consulting based on scientists and science education experts in each discipline, (4) offering prototype courses and teaching/guiding materials, and (4) supporting regional professional development frameworks.



**Figure 1.** The Annual Conference of the National Center of Chemistry Teachers, 2015.

One of the models that I use for continuous professional development is action research. I have been using this model since 2000, and I keep recommending it, and collaborating on its use with colleagues in Israel and abroad (Laudonia, Mamlok-Naaman, Abels and Eilks, 2017). Action research is an inquiry by teachers into their practice and their students' learning, enabling them to gain a sense of ownership towards their teaching, pedagogical content knowledge (PCK), and increasing their self-efficacy (Mamlok-Naaman and Eilks, 2012). From one cycle to another, the workshop's instructions as well as the research design have been improved. We (the researchers): (1) Observed the teachers following the action research stages (identifying the general problem, planning the research including developing the research tools, data collection and analysis, implementing changes, evaluating, and reflecting), and (2) interviewed them at the

end of the workshops, and distributed questionnaires to them and their students in order to learn about the action research's contribution. The results showed that teachers are the best researchers of their own students, and by sharing their ideas with colleagues, they create a community of practice of effective and professional teachers. I am always happy to share my enthusiastic attitudes about the action research models at conferences and seminars to which I am invited, for example at the "Project-based Education Conference" (on-line) in Prague, on November 5, 2020.

I also try to convey this model to chemistry teachers who participate in professional learning communities (PLCs). Teachers in a professional learning community meet regularly to (1) explore their practices and the learning outcomes of their students, (2) analyze their teaching and their students' learning processes, (3) draw conclusions, and (4) make changes in order to improve their teaching and their students' learning. PLC workshops for chemistry teachers were initiated in Israel in 2016. These workshops were supported by the Ministry of Education and sponsored by the Trump Foundation, the Weizmann Institute of Science, and the National Center of Chemistry Teachers at the Weizmann Institute. A leading team of researchers (including myself), headed by Professor Ron Blonder, guides a group of teachers who will become leading teachers and will coordinate regional communities of teachers "Professional learning communities close to home". So far, there are eight regional communities of chemistry teachers in Israel, consisting of Jewish and Arab high-school teachers. Each "Professional learning community close to home" is coordinated by two leading teachers who participate in the PLC workshop (Mamlok-Naaman, 2018, 2020).

### Collaboration with colleagues in Israel and abroad

In the field of education, it is very difficult to reach meaningful achievements without collaboration. For me, as a chemistry teacher, a chemistry regional consultant, a deputy chief chemistry superintendent, and later also a researcher, it would be impossible. When I finished my PhD (1998), I was invited by Professor John Penick to come for 3 months to North Carolina State University (NCSU) at the Department of Education as a Visiting Professor. I gave and attended seminars, and was involved in studies and conducted my post-doctoral studies about scientific socio-economic issues (Mamlok-Naaman, Hofstein and Penick, 2007). A few months later, I traveled to Ann Arbor, MI, USA, to do my post-doctoral studies at the University of Michigan with Professor Joe Krajcik. The main topic of my work was "*Design-based science education*" (Fortus, Dershimer, Krajcik, Marx, and Mamlok-Naaman, 2004). This was the beginning of my academic collaboration: (1) traveling to conferences in Israel and abroad, e.g., the National Association for Research in Science Teaching (NARST), the European Science Education Research Association (ESERA), the European Conference on Research in Chemistry Education (ECRICE), or EuroVariety, (2) being invited to give key-note or plenary lectures, e.g., ACS PacificChem meetings, ECRICE in Krakow, Poland, July 2010; Jyväskylä, Finland, July 2014; the Gordon Research Conference, June 2015; Barcelona, Spain, July 2016; at ICCE in Malaysia; at

the 3rd Conference in Teaching and Dissemination of the Sciences in Portugal, July 7<sup>th</sup> 2018; the 2<sup>nd</sup> International Conference on Science, Mathematics, Entrepreneurship, and Technology Education in Turkey (online), and (3) involvement in research on collaborative research projects, such as the following three consecutive projects of the European Union - EU (2008-2017) in the framework of FP7, which ended with Popularity and Relevance in Science Education and Scientific Literacy, PARSEL (Blonder, Kipnis, Mamlok-Naaman, and Hofstein, 2008), Professional Reflection-Oriented Focus on Inquiry-based Learning and Education through Science, PROFILES (Bolte et al.), and Teaching Enquiry with Mysteries Incorporated, TEMI (Peleg et al.). Professor Avi Hofstein and Professor Ron Blonder from the Department of Science Teaching were also involved in these projects, together with Drs. Dvora Katchevich and Malka Yayon.

Currently, I am involved in another EU project together with Professor Ron Blonder: Addressing Attractiveness of Science Career Awareness – SciCar, in the framework of Twinning of research institutions, financed by Horizon 2020. Our partners are Professor Miia Rannikmae from Tartu University in Estonia, and Professor Jari Lavone from the University of Helsinki. Lately, I have become an external evaluator of different EU projects such as ARTIST, DISSI, and LOVE regarding enhancing the professional development of science teachers.

I would like to elaborate on two specific projects:

- Participating at Malta Conferences which is initiated by Professor Zafra Lerman and held biennially (see **Figure 2**) (*Frontiers of Science: Research and Education in the Middle East*, 2014 <https://www.maltaconferencesfoundation.org/about>). These series of conferences bring together about a hundred scientists from more than a dozen Middle Eastern countries, including Israel, Jordan, Iran, Egypt, and Saudi Arabia. Topics range from materials science, nanotechnology, and medicinal chemistry, to environmental issues of concern to the entire region, such as the scarcity of freshwater, alternative energy, and air pollution.
- Acting as part of an exhibit created for the Museum of the Civilizations of Europe and the Mediterranean Sea, which was inaugurated in Marseille – the city named the European Capital of Culture for 2013. The exhibit, created for the museum's opening, and attended by France's former President, François Hollande, was called Citizenships and Human Rights. The exhibit featured nine women from different walks of life and nationalities, who have made significant contributions to society (see **Figure 3**). In the exhibit, each of the women told her life story and described her philosophy in a filmed monologue; the films are continuously screened on a wall in the museum.



**Figure 2.** Dr. Mamlok-Naaman addressing the audience at the 2017 Malta Conference.

I was one of these women; I explained in the film the importance of science education, which spans borders and cultures, and advances humankind as a whole: “Learning science is an inseparable part of general education – not just a subject for future scientists, but knowledge that is crucial to all citizens of the globe, who want to understand the world around them or even make rational choices in their lives. A broad education that includes science may not be the quickest route to economic success, but it is a sure one, and one that enriches the spirit of humanity. It is the essence of what makes us human”.



**Figure 3.** Dr. Mamlok-Naaman among the nine women who have made significant contributions to society at the Museum of the Civilizations of Europe and the Mediterranean Sea exhibition, 2013.

### Describe a venue of impact from your activities, and its contribution to science education

Currently I have served as chair of the chemistry division of the European Chemistry Society (EuChemS DivCED) from September 2019 (<https://www.euchems.eu/divisions/chemical-education-2/>), and as the representative of the Israel Chemical Society to various international chemistry education organizations, including serving as a senior (titular) member of the IUPAC committee on chemical education - CCE (<https://iupac.org/member/rachel-mamlok-naaman/>). I am also a member of some IUPAC Committees – *Standards in Chemistry Education*, *Gender Gap* (already mentioned), and *Systems Thinking* (<https://iupac.org/member/rachel-mamlok-naaman/>).

It is a great honor for me to be a co-editor of "*Chemistry Teacher International*" (<https://www.degruyter.com/journal/key/CTI/html>), and a member of the editorial and advisory boards of several journals and organizations on science education in general and chemistry education in particular (e.g., *International Journal of Science and Mathematics Education*). I learn a lot from my colleagues in the committees, as well as from the variety of papers submitted to the journals in which I am involved. I myself am the author and co-author of 5 refereed articles on chemistry and science education peer-reviewed journals (3,485 citations since 2015); 28 book chapters on chemistry and science education; 16 book chapters in the framework of European projects (mentioned above); the lead author of a book on the professional development of chemistry teachers Mamlok-Naaman, Eilks, Bodner, and Hofstein, 2018); chemistry textbooks in Hebrew for high-school chemistry students (Mamlok, 1992, 1998), and items in Hebrew encyclopaedias (Mamlok, 1992, 1998).

Last but not least, I would like to mention my continuous involvement in the activities of the Science Teaching Department at the Weizmann Institute of Science, such as taking part in the PLC leading researchers' group, or acting as an advisor for different projects led by scientists and their students.

### What are your main achievements?

I feel that my main achievements lie in combining research and practice. I am happy that I had an opportunity to serve as a chemistry teacher for 26 years, and that I was able to conduct research studies on teaching and learning chemistry. My research, which followed programs, workshops, and courses, were followed by research, conducted together with graduate students whom I co-advised, as well as with colleagues in Israel and abroad, as mentioned in the previous sections. Below are a few examples of research conducted with graduate students:

(1) Models and modeling in high-school chemistry: Researching the teaching and learning of the concept "bonding and the structure of molecules" (Levy Nahum, Mamlok-Naaman, Hofstein, and Taber (2010), (2) Continuous professional development (CPD) of high-school chemistry teachers (Taitelbaum, Mamlok-Naaman, Carmeli, and Hofstein, 2008), (3) Inquiry in the

chemistry laboratory: The case of the Palestinian population (Dkeidek, Mamlok-Namman and Hofstein, 2012), (4) Environmental chemistry (Mandler, Blonder, Yayon, Hofstein, and Mamlok-Naaman (2014), (5) Argumentation in the chemistry laboratory (Katchevich, Hofstein, and Mamlok-Naaman, 2013), and (6) conceptual and modeling frameworks for understanding Chemical Bonding (Yayon, Mamlok-Naaman, and Fortus, 2012).

As a practitioner and educator, I learned to know several important facets regarding the Ministry of Education through my projects, as well as due to my roles as a regional consultant for chemistry teachers, and as a substitute for the chief inspector of chemistry. My experience in the education system helped me in planning and conducting professional development programs in cooperation with science educators in Israel and abroad. I felt the importance of stressing the point of education through science / chemistry, and not just teaching or learning chemistry. It gave me a much satisfaction to work with teachers from all over the world, and to try to influence their attitudes towards the way in which chemistry should be taught, as well as their motivation to perform changes in their teaching strategies (e.g., planning lessons in which every individual student will be able to express himself / herself, and get an opportunity to better understand chemistry).

### You received many awards (Figure 4). From your experiences what would be your suggestions to young female researchers?

- **2021** IUPAC 2021 Distinguished Woman in Chemistry or Chemical Engineering
- **2018** Awardee for the ACS-CEI Award for Incorporation of Sustainability into the Chemistry Curriculum
- **2006** Maxine Singer award for outstanding scientists at the Weizmann Institute of Science
- **1999** Award for an excellent dissertation, The Schnitzer Foundation for Research on the Israel Economy and Society
- **1996** Headmaster Award, Municipal High School, Jaffa (focusing on my work between 1970 and 1996 with disabled students in this area, who face a low socio-economic situation).
- **1984** The Avner Bar-Ner award for excellence in teaching chemistry, Weizmann Institute of Science

**Figure 4.** Awards and Recognitions of Received during the career of Dr. Rachel Mamlok-Naaman.

My experience over the years convinced me that loving my profession and believing in what I am doing are the main components for success. The passion for research in a domain in which I am involved with both my mind and my soul has helped me to continue my work, even when I faced difficulties and problems. Science education research in general, and chemistry education, in particular, are composed of many different aspects: curriculum, teachers, students, policy makers,

and more. It is always recommended to focus on not too many aspects. However, a researcher should be acquainted with the other components. The process may include hardships that have to be overcome, and I faced many challenges, including personal family constraints. However, I was persistent, loved my research and my practical work, developed self-efficacy, and believed in my ability to make positive changes. As a result, I was elected by IUPAC as one of the 2020 *twelve distinguished women in chemistry*.

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