Professional Learning Communities (PLCs) of Chemistry Teachers

Rachel Mamlok-Naaman

*Weizmann Institute of Science, Rehovot 7610001, Israel*

**Abstract:** The models of Professional Learning Communities (PLCs) are based on principles of learning that emphasize the co-construction of knowledge by learners, who in this case are the teachers themselves. Teachers in a PLC meet regularly to explore their practices and the learning outcomes of their students, analyze their teaching and their students’ learning processes, draw conclusions, and make changes in order to improve their teaching and the learning of their students. It was found that participation in a PLC influences teaching practice, so teachers become more student-centered. Moreover, the teaching culture improves as the community increases the degree of cooperation among teachers, and focuses on the processes of learning rather than the accumulation of knowledge. This enables students to be innovative, creative, and critical. In addition, trust is developed among the participants, which enables them to discuss and analyze their students’ cognitive and affective problems, misconceptions, and learning outcomes.

**Key words:** Teachers’ professional development, professional learning communities (PLCs), professional learning communities close to home, action research, diagnostic questions.

1. Teachers’ Professional Learning Communities (PLCs)—Theoretical Framework

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 bringing innovation into the science curriculum and professional development. Teachers in a professional learning community meet regularly to explore their practices and the learning outcomes of their students, analyze their teaching and their students’ learning processes, draw conclusions, and make changes in order to improve their teaching and the learning of their students [1]. The concept of PLC arose in the field of education in the context of workplace-based studies conducted in the 1980s that addressed teachers whose professional relations were characterized by continuous striving for improvement, focused on student learning, and who collaborated and explored their work. Such relationships differ from the norms used in the teaching of a more individualistic culture, which typically characterizes schools as a place of work [2].

In 1982, Little conducted an anthropological study of six primary and secondary schools in four counties in the western US. He found that schools with norms of collaboration, collegiality, and research could respond better to the pressures of external changes and education initiatives. This finding was reinforced by Rosenholtz [3], who combined surveys and interviews with 78 primary schools. She distinguished “rich” and “poor” schools with respect to learning. The learning-rich schools were more likely to establish norms of cooperation and continuous improvement.

Newmann [4] argued that a professional community of teachers offers a supportive environment in which teacher learning can occur. For example, the Center for Organizing and Building in Schools at the University of Wisconsin conducted systematic research on 24
primaries, junior high, and high schools in which structural and organizational changes were carried out, with an emphasis on the quality of instruction in mathematics and social sciences. It was found that aspects of a school’s professional community that include common norms and values, a focus on student learning, reflective dialogue, transformation of teachers’ practice in public classes, and a focus on collaboration, are linked to robust teaching and support for teacher learning.

In a series of articles based on analysis of the NELS:88 databases, Lee et al. [5] argued that more organized schools produce higher levels of teacher satisfaction, positive student behavior, problem-solving pedagogy, and understanding and learning in mathematics and science. “Our results indicate that when there is a professional community of teachers—when teachers are taking responsibility for the success of all their students—more than learning is occurring”[5].

Shulman [6], in his lecture at the Mandel Institute in Israel, spoke enthusiastically about the idea of both teacher communities and student communities. Shulman argued that since a single teacher can never possess perfect knowledge of pedagogical content, we must continue to create conditions in which a teacher can collaborate with other teachers and be part of a community of teachers facing difficult teaching challenges. In other fields, no one expects a single professional working alone to solve an important problem, because complex, real-world problems require “distributed expertise”—the sharing of highly specialized professionals in dealing with common challenges.

Bryk et al. [7] identified professional communities, along with a work culture oriented [8], toward improvement and access to professional development, with elements of “professional capacity” associated with improvements measured in primary school achievement in Chicago over a period of 6 years in the 1990s. A recent study by Kraft and Papay [9] reinforced this important insight. These researchers used a measure for the professional environment that was composed of the responses of teachers to a survey in North Carolina combined with a national test in mathematics and elementary school reading. They found that teachers who work in a supportive environment, compared to those who work in a less supportive one, have increased effectiveness over time.

PLC workshops for chemistry teachers were initiated in Israel 2 years ago. 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. The workshop operates on a cascade model: a leading team of researchers guides a group of teachers who will lead communities of teachers in regional communities “professional learning communities close to home” (see Fig. 1).

A leading team of researchers guides a group of teachers who will become leading teachers, and 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. The Tira community of chemistry teachers will serve as an example to a community “close to home”.

2. Tira “Professional Learning Community Close to Home”

Fifteen (15) teachers of the “Tira professional learning community close to home” (TPLCCH), met once in three weeks, coordinated by 2 leading teachers. Each meeting consisted of:

- An opening activity aimed at creating social and personal relationships among the members of the group, as well as openness and trust to strengthen the cooperation among members of the community, and enable them to gain a sense of ownership.
**PLC -Cascade Model**

![Diagram](image_url)

**Leading team of researchers**

**Leading teachers’ workshops**

**Communities of chemistry teachers “close to home”**

- Students
- Students

**Fig. 1** The PLC cascade model [10].

- “Our corner”—one or two teachers share an experiment or an interesting activity with their colleagues—a short, stimulating and thought-provoking activity that can be applied in the classroom. It can be an experiment, a demonstration, a discussion question, an interesting video clip, or a technological innovation in education.
- A discussion referring to a content and pedagogical subject, e.g., diagnostic questions, misconceptions, unclear questions, or alternative assessment methods.
- Sharing lesson plans regarding new curriculum materials.
- A reflection of each teacher at the end of the meeting, referring to the meeting’s topics.

The teachers develop activities and pedagogical teaching strategies with the leading team of researchers (a “bottom-up” approach), and implement them in their own classes before they disseminate them among the communities of teachers in their regions. Following are three examples of major activities.

### 2.1 Diagnosis of Students’ Ideas and Difficulties

Teachers are usually surprised to find out that their students have learning difficulties and misconceptions. Therefore, diagnosis of students’ misconceptions is a very important activity. During the meetings, the Tira community teachers reflect upon their teaching methods, and discuss how to use different strategies to cope with these difficulties, how to implement the change and then collect and analyze their students’ assignments. Major misconceptions have been encountered in topics such as bonding and structure, acids and bases, energy, and equilibrium.

The following example is based on a study conducted by Ben-Zvi Eylon and Silberstein [11]. The study consisted of three stages: (1) a diagnostic investigation of students’ views of structure in chemistry, (2) development and implementation of a program designed to prevent some of the misconceptions identified in the first stage, and (3) an evaluation of the new program. The diagnostic investigation of students’ views of structure in chemistry consisted of a questionnaire administered to eleven 10th-grade classes in different high schools in Israel (about 300 students, average age 15 years). All students had studied chemistry for at least half a year. The question relevant to the atomic model was:

A metallic wire has the following properties: (1) conducts electricity, (2) brown color, and (3) malleable. The wire is heated in an evacuated vessel until it evaporates. The resulting gas has the following properties: (4) pungent odor, (5) yellow color, and (6) attacks plastics.

- Suppose that you could isolate one single atom from the metallic wire. Which of the six properties...
would this atom have?

- Suppose that you could isolate one single atom from the gas. Which of the six properties would this atom have?

Most of the teachers at TPLCCH who disseminated this question among their students reported that their students could not differentiate between macro and sub-micro concepts. The interventions which they decided upon in order to cope with the misconceptions consisted of: using models; computerized interactive programs; video clips; games, etc. The process of dealing with the misconceptions which were diagnosed was based on the Action Research rationale (see below).

2.2 Lesson Plans Referring to Sustainable Education

A few lesson plans shared at the TPLCCH, dealt with issues of sustainable development, as suggested by the two leaders of the community. Issues of sustainable development have been suggested as a way to contextualize chemistry learning for relevant chemistry education [12]. If this is implemented from a Socio-Scientific Issues (SSI)-based perspective [13], controversial issues from the sustainability debate can be used to motivate chemistry learning within the context of a societal perspective. The issue of alternative fuels can be used as an example [14].

In recent years, a group of teachers in Israel developed a lesson plan that was called “Can used oil be the next generation fuel?” [15]. This lesson plan focuses students’ learning on traditional and alternative fuel sources. The students learn about the advantages and disadvantages of each of the different suggested technologies: fuels from crude oil, recycling of used oils, or producing biodiesel from vegetable oil.

The lesson plan uses a structure that starts with the SSI, involves learning about the content behind the issue, and then turns to questions of evaluation and reflection on the issue from different perspectives and in the foreground of the societal discourse. The lesson plan starts with exposing students to information about the world’s energy crisis and its consequences. Discussion of this information activates prior knowledge and raises questions to be answered. The idea that teachers should convey to their students is that sustainable mobility is a worldwide problem and not just a scenario for the science classroom. Furthermore, there are several proposed solutions to this challenge, but these solutions often introduce new problems.

Students undertake different activities to investigate and compare the different fuel types in order to decide on various options for providing fuels for mobility. In one activity, the students are asked to inquire into the chemistry of the use of different fuel types, one of which is biodiesel. Comparative activities require students to select criteria such as enthalpy of combustion values or the release of emissions. The teacher then introduces the student to an experiment that compares the energy released by the combustion of different fuel types. By measuring the mass of the fuel needed to increase the temperature of a certain volume of water by 30 degrees Celsius, students can compare the caloric values of different fuels. They can also investigate the level of pollutants emitted from the burning fuels with a special board called the “Ringelmann scale”, which determines the concentration of soot particles produced by the flame. Students are then asked to decide which the best fuel is. Before making a final decision, there is an attempt to involve students emotionally and from an ethical perspective by creating a conflict regarding the use of biodiesel. This activity is based on viewing pictures that highlight the use of crops for fuel instead of using them as a food source for the world’s ever-growing population. Students’ decisions should be based on arguments, but first there should be agreement within the group about the assumed meaning of the term “best fuel”. This discussion leads to understanding that a thorough comparison requires more criteria beyond the limits of chemical behavior. These criteria
include price, environmental behavior, production methods, and societal impact. An open discussion about which technology has the most promising potential for sustainable development is used to end this lesson plan.

Within this lesson plan, the students learn about an authentic sustainability issue and the complexity of its solution. On one hand, they learn that there is neither “best fuel” nor any “best solution” to many sustainability problems. On the other hand, they learn that making use of used oil or biofuels is not “the ideal solution”. Other ways might better protect the environment because less waste is produced and fossil resources are saved. However, the students also learn how complex such evaluations are and how many dimensions need to be taken into consideration before an overall decision can be made.

2.3 Action Research Activities

During the meetings, the teachers at TPLCCH conducted Action Research activities, referring to issues which bothered them. The teachers dealt with content issues as well as pedagogical issues such as: “Can we change students’ attitudes toward science by integrating relevant, everyday issues into their science curriculum?” The activities consisted of: (1) identifying the general problem and their own research question, (2) planning the research including the development of the research tools, (3) data collecting and analyzing, (4) implementing, (5) data collecting and analyzing, and (6) evaluating and reflecting. The various stages are presented in Fig. 2.

Action research is regarded either as a practitioner-oriented inquiry into teachers’ work and their students’ learning in the classroom [16], or as the development of new teaching strategies oriented on teachers’ and students’ deficits or personal interests [17]. According to Feldman [18], the first goal of action research within such a framework is not to generate new knowledge—whether local or universal—but rather to improve and change classroom practices. Nevertheless, this point may be viewed differently depending on the action research mode chosen and depending on the objectives negotiated within the group of practitioners and researchers [17]. In the end, the development of individual practices and generation of results of general interest can be understood as two sides of the same coin, with both having equal importance. A further objective of the action research activities was to enhance the chances of creating a professional community of chemistry teachers [19]. The participants in the Tira community had many opportunities to enhance their social skills through collaboration and cooperation with their peers. They

![Fig. 2 The various stages of action research [10].](image-url)
shared ideas, consulted with each other, and maintained good social and professional relations with the others. The PLC meetings enabled them to consult with each other and exchange information and ideas as often as they wished. The cooperation between the teachers in the group was fruitful and helped promote their teaching strategies, as well as their professional development [20].

3. Evaluation of the PLC Workshop

Data were collected for two years from a variety of sources: video records of the teacher-leaders’ PLC meetings; reflection questionnaires; e-mail correspondences; interviews; portfolios; additional data from questionnaires sent to teachers in the “professional learning communities close to home”, as well as to their students.

The data analysis revealed that the PLC workshops were accompanied by an evaluation study that consisted of questionnaires and interviews. To date, the teachers who have participated in the PLC workshops for chemistry teachers have claimed that the professional community environment improved their self-efficacy and enhanced their ability to share teaching difficulties with their colleagues. The teaching culture improves, as the community increases the degree of cooperation among teachers: trust, ownership, friendship [1]. They said that during the meetings, a feeling of trust was developed among the participants, which enabled them to discuss and analyze their students’ cognitive and affective problems, misconceptions, and learning outcomes. In addition, the fact that they could share ideas, lesson plans and interesting experiments was an asset in itself. They were encouraged to develop ownership of innovations in education, becoming more student-centered [10].

The PLC community has an impact on teaching practices, and served as a perfect environment for preparing and encouraging teachers to conduct changes—towards gaining pedagogical content knowledge in conveying important issues in education, and preparing the future citizen in a mixed cultural society, focusing on the processes of learning rather than the accumulation of knowledge, in order to enable students to be innovative, creative, and critical.

References
[1] Tschannen-Moran, M. 2014. Trust Matters: Leadership for Successful Schools. John Wiley & Sons.
[2] Lortie, D. C., and Clement, D. 1975. Schoolteacher: A Sociological Study. Chicago: University of Chicago.
[3] Rosenholtz, S. J. 1989. Teachers’ Workplace: The Social Organization of Schools. Addison-Wesley Longman Ltd.
[4] Newmann, F. M. 1996. Authentic Achievement: Restructuring Schools for Intellectual Quality. San Francisco: Jossey-Bass.
[5] Lee, V. E., Smith, J., and Croninger, R. 1997, “How High School Organization Influences the Equitable Distribution of Learning in Mathematics and Science.” Sociol. Educ. 70: 128-50.
[6] Shulman, L. S. 1997. Communities of Learners & Communities of Teachers. Jerusalem: Mandel Institute.
[7] Bryk, A. S., Gomez, L. M., and Grunow, A. 2010. Getting Ideas into Action: Building Networked Improvement Communities in Education, Carnegie Foundation for the Advancement of Teaching. Stanford. http://www.carnegiefoundation.org/spotlight/webinar-bryk-gomez-building-networked-improvement-communities-in-education.
[8] Markic, S., Mamlok-Naaman, R., Hugerat, M., Hofstein, A., Dkeidek, I., Kortam, N., and Eilks, I. 2016. “One Country, Two Cultures—A Multi-perspective View on Israeli Chemistry Teachers’ Beliefs about Teaching and Learning.” Teachers and Teaching: Theory and Practice 22 (2): 131-47.
[9] Kraft, M. A., and Papay, J. P. 2014. “Can Professional Environments in Schools Promote Teacher Development? Explaining Heterogeneity in Returns to Teaching Experience.” Educational Effectiveness and Policy Analysis 36: 476-500.
[10] Mamlok-Naaman, R., Eilks, I., Bodner, A., and Hofstein, A. 2018. Professional Development of Chemistry Teachers. Cambridge: RSC Publications, 76-80.
[11] Ben-Zvi, R., Eylon, B. S., and Silberstein, J. 1986. “Is an Atom of Copper Malleable?” Journal of Chemical Education 63: 64-6.
[12] Eilks, I., and Hofstein, A. 2014. “Combining the Question of the Relevance of Science Education with the Idea of Education for Sustainable Development.” In Science Education Research and Education for
Sustainable Development, edited by Eilks, I., Markic, S., and Ralle, B. Aachen: Shaker, 3-14.

[13] Eilks, I., Ralle, B., Rauch, F., and Hofstein, A. 2013. “How to Balance the Chemistry Curriculum between Science and Society.” In Teaching Chemistry—A Study Book, edited by Eilks, I., and Hofstein, A. Rotterdam: Sense, 1-36.

[14] Mamlok-Naaman, R., Katchevich, D., Yayon, M., Burmeister, M., and Eilks, I. 2015. “Learning about Sustainable Development in Socio-scientific Issues-Based Chemistry Lessons on Fuels and Bioplastics.” In Worldwide Trends in Green Chemistry Education, edited by Zuin, V. G., and Mammino, L. Cambridge: RSC, 45-60.

[15] Ezra, L., Skolnick, B., and Aghbariya, G. 2012. Can Used Oil Be the Next Generation Fuel? Unpublished Module Developed in the Framework of the PROFILES Project Funded by the European Community’s 7th Framework Program.

[16] Feldman, A., and Minstrel, J. 2000. “Action Research as a Research Methodology for Study of Teaching and Learning Science.” In Handbook of Research Design in Mathematics and Science Education, edited by Kelly, A. E., and Lesh, R. A. Mahwah, NJ: Lawrence Erlbaum, 429-55.

[17] Eilks, I., and Ralle, B. 2002. “Participatory Action Research in Chemical Education.” In Research in Chemical Education—What Does This Mean? Edited by Ralle, B., and Eilks, I. Aachen, Germany: Shaker, 87-98.

[18] Feldman, A. 1996. “Enhancing the Practice of Physics Teachers: Mechanisms for the Generation and Sharing of Knowledge and Understanding in Collaborative Action Research.” Journal of Research in Science Teaching 33: 513-40.

[19] Mamlok-Naaman, R., and Eilks, I. 2012. “Different Types of Action Research to Promote Chemistry Teachers’ Professional Development—A Joint Theoretical Reflection on Two Cases from Israel and Germany.” International Journal of Science and Mathematics Education 10: 581-610.

[20] Laudonia, I., Mamlok-Naaman, R., Abels, S., and Eilks, I. 2017. “Action Research in Science Education—An Analytical Review of the Literature.” Educational Action Research 26 (3): 480-95. https://doi.org/10.1080/09650792.2017.1358198.