However, it is important to note that the modules are part of the curriculum. They encompass theoretical and practical components that together make up the curriculum learning. This is very important, as 'education through science' (Holbrook & Rannikmae, 2007) is an intention in all science curricula in all countries. All school curricula are educational in intent.

Reference

Holbrook, J. & Rannikmae, M. (2007). Nature of Science Education for Enhancing Scientific Literacy. International Journal of Science Education, 29(11) 1347-1362.

OECD. (2005). The Definition and Selection of Key Competencies; Executive summary. Retrieved (20th June 2012) from: http://www.oecd.org/dataoecd/47/61/35070367.pdf

3.7 Action Research for Innovations and Continuous Professional Development (CPD) in Science Education

Ingo Eilks – Universität Bremen, Germany;
Rachel Mamlok-Naaman – Weizmann-Institute of Science, Israel;
Franz Rauch – Alpen-Adria-Universität Klagenfurt, Austria

Introduction

Teachers have been repeatedly identified as the key if any sustainable innovation in educational practices is expected to be successful. This is why extensive, dynamic and long-term continuous professional development (CPD) of science teachers has been demanded inside the framework of science education reforms in order to assure sustainable learning among teachers (Loucks-Horsley & Matsumoto, 1999). Working within such a framework, teachers require guidance and support in all stages of their training when it comes to implementing curriculum changes or in bettering their teaching methods and styles (Loucks-Horsley & Matsumoto, 1999). Under such circumstances teachers have generally proven themselves to be excellent learners, who are interested in trying to teach new curricula and improve and enrich their personal teaching methods (Joyce & Showers, 1983).

One set of medium to long-term strategies to connect both research and practice – including the practitioners thereof – to one another is the wide variety of methods of Action Research (e.g. Feldman, 1996; Parke & Coble, 1997; Bencze & Hodson, 1999; Eilks & Ralle, 2002; Altrichter, Feldman, Posch & Somekh, 2008). Each of these methods has a different focus and employs a different strategy, however, all of them include strong bottom-up, teacher-centered components (e.g. Mamlok-Naaman & Eilks, 2011).

Within the wide span of possibilities for teacher professional development, Action Research is seen either as a practitioner-oriented inquiry into teachers' work and their students' learning in the classroom (Feldman & Minstrel, 2000) or as the development of new educational strategies oriented on teachers' and students' deficits or personal interests (Eilks & Ralle, 2002). Within both ways, the first goal of Action Research is not to generate new knowledge - whether local or universal - but rather to improve and change classroom practices and contributing teachers CPD (Feldman, 1996). 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 (Eilks & Ralle, 2002). In the end, the cyclical 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.

This paper presents three cases of using Action Research's potential for innovation in science education, coming from Israel, Germany and Austria. The case from Israel focuses on building professional competencies in a group of teachers when it comes to reflecting upon and developing their own individual professional practices by carrying out small-scale, individual research projects. The case from Germany describes a ten-year-old cooperation of a group of teachers from different schools accompanied by an educator from the university focussing on the joint development of new curricula and lesson plans for wide dissemination. The Austrian case uses Action Research for subject oriented school development and thus integrates science education with other subjects and the development of the school as a whole. This paper links the three examples leading to a joint reflection.

Three countries – three cases

Israel

This project (e.g. Dass, Hofstein, Mamlok, Dawkins & Pennick, 2008) focused mainly on allowing teachers to develop their own individual practices by enabling them to conduct small scale Action Research studies in their schools. A workshop structure was established to build the teachers' confidence in the area of conducting Action Research as a part of their CPD. Action Research was selected as a topic within this program in order to: (1) provide teachers with a powerful tool for enhancing their professional expertise by performing small-scale research projects, (2) improve opportunities to practice the technique in the teachers' schools, and (3) create a professional community of corroborating teachers.

In planning the program, it was assumed that the teachers needed to improve their content knowledge, PCK, and leadership skills in order to become professionals. Action Research was assumed to offer potential solutions for reaching all of these goals using a joint approach. The Action Research segment of the program was structured around a series of workshops teaching the methodology and research tools necessary for data collection and evaluation. This was carried out by coupling workshop phases with Action Research activities performed directly in the teachers' school environments. In between the workshops, the teachers were asked to both discuss the content of the workshop with their school colleagues and to apply the learned strategies and methods to several aspects of their own practice.

Twenty-two teachers participated in the program. All participants were experienced secondary school teachers having at least 10 years of experience teaching high-school chemistry. They were identified as potential candidates for becoming chemistry coordinators.

The program involved weekly meetings and consisted of a total of 450 hours. The Action Research course consisted of eight meetings. The workshop syllabus encompassed making the participants familiar with backgrounds in both chemistry content and pedagogy, but also with knowledge and skills about performing educational research by qualitative research techniques in general and Action Research in particular.

The workshop was accompanied by a study about its effects (Mamlok-Naaman, Navon, Carmeli, & Hofstein, 2004; 2005). The participants' reacted very positive regarding how the Action Research workshop contributed positively to their work. Most of the teachers expressed satisfaction with the workshop. This was particularly true with respect to their personal interest in conducting Action Research in their own classrooms, and in becoming part of a community of practice. Many teachers stressed the fact that they had learned the importance of reflecting upon their work using Action Research. Some of them continued conducting Action Research with their students, stating that their pupils raised very good points which contributed to their work.

Germany

In this project a group of roughly ten secondary school teachers from different school types, accompanied by a science educator is working together for more than 13 years now (Eilks & Markic, 2011). The focus of the group's work looks at the development, testing and evaluation of alternate teaching approaches for science education based on new curricular structures, pedagogies and media.

The project is based upon Participatory Action Research (PAR) for education research as described in Eilks and Ralle (2002). PAR in this sense attempts to improve teaching practices through the close cooperation of university science education researchers and in-service teachers. It seeks to develop new curricular and methodological approaches and analyze them in authentic teaching situations, thus leading to an evidence-based understanding of the effects of newly-developed teaching approaches. The model also aims at sustainable changes in the fields touched by these innovations and seeks contributing the CPD of all participants involved. To achieve such research-based innovation, a cyclical model of brainstorming, evaluation, reflection and revision is applied. Any ideas for classroom innovation are continually compared to the evidence available from empirical research. In order to connect these two areas, relevant research evidence is presented to the teachers by the university researcher in a group discussion format. Empirical results are also compared to actual teaching experiences in the classroom and examined with respect to the needs and wishes expressed by teachers for their day-to-day situation in school.

From the accompanying research on teachers' CPD one can see that over the years a continuous shift in the teachers' attitudes and views on practice-research relations could be observed (Eilks & Markic, 2011). In the first year, the teachers viewed themselves mainly as technical supporters of innovation. The reason for this was uncertainty about the level of trustworthiness and security to be found in the newly-developed curricular and methodological approaches. Nevertheless, all of the teachers expressed a feeling after the initial year that the new approaches had proven themselves better than the old ones. At the end of the first year it was readily apparent their point-of-view had begun to change. This was even more the case in year two and three. The discussion shifted towards self-reflection among the teachers. The group started reflecting upon the meaning of the process for the individual on their own initiative. The teachers said that the long-term cooperation had led to increasing openness inside the group and a tendency to self-confidently and offensively bring their own criticisms and ideas into play. Many of the teachers described an increasing feeling of being able to competently reflect upon their own teaching. The participants expressed changes due to their own professionalization, with a focus on a totally different view towards methodological variety. Individual practitioners began to start their own initiatives for the group, with an even larger jump seen in the third project year. Finally, discussion led over to the teachers feeling more self-confident in stretching the regulations set up by circumstances when implementing student-oriented and student-active chemistry teaching practices. Some of the teachers enthusiastically accepted the offer of becoming members of a team of textbook authors to implement and widely disseminate their work and ideas.

Austria

The nation-wide project 'IMST' (Innovations Make Schools Top) aims at improving instruction in science, IT, mathematics, German language and related subjects. The focus is on students' and teachers' learning in the context of the whole school (www.imst.ac.at). Innovations are not regarded as singular events that replace an ineffective practice but as continuous processes involving teacher teams and the whole school with the aim to lead to a further development of practice. Most of the participating schools develop cross-curricular labs which foster experimental and inquiry-based learning. Teacher teams at schools have ownership of their innovations. These teacher teams research, reflect and document their experiences in a systematic way (Action Research). They are facilitated by a university team. As a support the schools are offered seminars (i.e. on Action Research methods; about experimental teaching and learning settings), writing workshops; network meetings to exchange experiences among teachers and schools; a pool of advisors, and financial gratification for the documentation of the innovations (Rauch & Kreis, 2007). The participating schools use the instrument of a school development plan. This is a framework to develop and sustain a culture of continuous quality development and self-evaluation at school and should also allow to credibly demonstrate that the school cares for quality (Posch, 2003).

A joint reflection

This paper described three examples applying Action Research to science education. All three have a completely different character. The first was an interactive course design, which successfully qualified experienced teachers to use Action Research in innovating and reflecting upon new practices in their own individual school environments. It also taught them the skills necessary to become innovative leaders with the ability to inform their school colleagues and to implement Action Research beyond their own classrooms. The second project created a network of teachers from different schools, accompanied by a university science educator. This group learned how to develop and research innovative curricula and methodological approaches in chemistry education with the goal of generating both curricular structures and teaching materials which could be widely disseminated. It also contributed to changing individual teaching practices and to promoting teachers' ongoing professional development via the Action Research process. Within the third project teams of teachers developed cross-curricular science labs. In a whole school approach these teachers negotiated with colleagues and the headteachers which changes necessary in the curriculum eventually should be accepted by other subject groups (i.e. languages, humanities) at the school (Rauch & Senger 2006). With time different models of science labs were developed, reported upon via Action Research and published on the internet, in the IMST newsletter and in books (www.imst.at). The ongoing reflection and reporting as well as the exchange among teachers from different schools turned out to be very supportive to overcome obstacles at their own schools. This was made possible by networks on a local (school district) and regional level involving not only teachers but also local school authorities, teacher education and research institutions as well as businesses (Rauch & Erlacher forthcoming). In terms of reflection and documentation so called "writing workshops" offering three days of intensive reflection, writing and sharing were seen as very helpful.

All three projects can be considered successful in their own individual ways. The advantage of the Israeli case study is the workshop structure. The necessary contact time with the accompanying researcher and the overall duration of the project are limited and can therefore be repeatedly applied to several different groups of teachers simultaneously. This allows the process to reach a relatively large number of teachers and schools. On the other hand, this approach has limited potential for constructing more wide-reaching innovation projects, which focus on multiple schools or on changes within an entire curriculum. The advantages of the second project is that it aims on long-term-cooperation and widespread dissemination. Due to the ongoing, long term cooperation there is continuous input from the research side towards the teachers. The results were also able to be widely disseminated in various arenas, up to and including school textbooks to be marketed all over the country. However, the main limitation of this model is caused by the need of the intense, long-term accompany by the university researcher. Advantages and limitations in the third project are that learning is not restricted to a certain subject lesson but involve teachers from different subjects and reflect learning as a phenomenon of the whole school. Cross-curricular activities (i.e. labs) offer the possibility to more authentic and relevant science learning for students. But it requires the internal support by a school culture which values distributed leadership, co-operation, quality development and learning in the sense of a learning organisation as well as external support (i.e. facilitation in networks). To meet the challenge of complexity of a whole school approach Action Research offers an efficient methodology as well as instruments.

All the three projects can be considered successful when it comes to aiding teachers' CPD. The participants achieved higher levels of professionalism by taking ownership of new strategies for better reflecting upon and improving their teaching practices. It can be hoped that this will make them better able to cope with their own practices and help contribute to their future development.

References

Altrichter, H., Feldman, A., Posch, P., & Somekh, B. (2008). Teachers investigate their Work. London: Routledge.

Bencze, L., & Hodson, D. (1999). Changing practice by changing practice: toward more authentic science and science curriculum development. *Journal of Research in Science Teaching, 36*, 521-539.

Dass, P., Hofstein, A. Mamlok, R., Dawkins, K., & Pennick, J. (2008). Action research as professional development of science teachers. In I. V. Erickson (ed.), *Science education in the 21st century* (205-240). Hauppauge: Nova.

Eilks, I., & Ralle, B. (2002). Participatory Action Research in chemical education. In B. Ralle & Eilks, I. (eds.): *Research in Chemical Education – What does this mean?* (pp. 87-98). Aachen: Shaker.

Eilks, I. & Markic, S., (2011). Effects of a long-term Participatory Action Research project on science teachers' professional development. Eurasia Journal of Mathematics, Science and Technology Education, 7(3), 149-160.

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*, 513-540.

Feldman, A., & Minstrel, J. (2000). Action Research as a research methodology for study of teaching and learning science. In A. E. Kelly & R. A. Lesh (eds.), *Handbook of Research Design in Mathematics and Science Education* (429-455). Mahwah: Lawrence Erlbaum.

Huberman, M. (1993). Linking the practitioner and researcher communities for school improvement. *School Effectiveness and School Improvements, 4*, 1-16.

Joyce, B., & Showers, B. (1983). Powers in stuff development through research on training. *Ch. 3 – Attacking the Transfer Problem.* Alexandria: Association for Supervision & Curriculum Development.

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

Mamlok-Naaman, R., & Eilks, I. (2012). Action research to promote chemistry teachers' professional development – Cases and experiences from Israel and Germany. International Journal of Mathematics and Science Education published online first July 01, 2011.

Mamlok–Naaman, R., Navon, O., Carmeli, R. & Hofstein, A. (2004). A follow-up study of an Action Research workshop. In B. Ralle & I. Eilks (eds.), *Quality in Practice-oriented Research in Science Education* (63-72). Aachen, Germany: Shaker.

Mamlok-Naaman, R., Navon, O., Carmeli, M., & Hofstein, A. (2005). Chemistry teachers research their own work two case studies. In: K. M. Boersma, O. De Jong & H. Eijkelhof (eds.), *Research and the Quality of Science Education* (141-156). Heidelberg, Germany: Springer.

Parke, H. M., & Coble, C. R. (1997). Teachers designing curriculum as professional development: A model for transformational science teaching. *Journal of Research in Science Teaching, 34*, 773-790.

Posch, P. (2003). Action Research in Austria: a review. *Educational Action Research, 11 (2),* 233-246

Rauch, F., & Erlacher, W. (forthcoming). Networking in the Project IMST: Concept, experiences and reflections. *Cambridge Journal of Education.*

Rauch, F., & Kreis, I. (eds.) (2007). Lernen durch fachbezogene Schulentwicklung. Innsbruck: Studienverlag.

Rauch, F. & Senger, H. (2006). Schulentwicklung im Umbruch: Der Unterricht rückt in den Mittelpunkt. Klagenfurt: IMST.

3.8 IBSE Experiments

Josef Trna and Eva Trnova – Masaryk University, Czech Republic

Experiments in Science Education

Science experimentation plays a crucial role in science education. The reasons are the decisive role of experiments in science research and the cognitive importance of experiments in science education (Haury & Rillero, 1994). That is why science teachers' professional competence to use science experiments in teaching/learning science is a very important part of their pre-service and also in-service training. Teachers' experimental skills play a crucial role in the acquiring of students' scientific and educational skills (Trna et al., 2010) and thus experience in the use of science experiments is an integral part of the individual pedagogical content knowledge of every science teacher (Royer et al., 1993). Crucial aspects of science teachers' professional competence to use experiments are their motivation, experience and professional training in experimentation.

Experiments in IBSE

Inquiry-based science education (hereinafter IBSE) has proved its efficacy in increasing students' interest and at the same time stimulating teacher motivation. IBSE is effective with all types of students from the weakest to those most able and supports the improvement of the gifted.

Very importantly, students´ experimental activity is included in all four levels (identified later) of inquiry-based science education. Implementation of experiments is necessary for IBSE, although these need to be meaningfully incorporated in carefully chosen teaching/learning methods, which is the main task for the science teacher.

It is not easy to transform science content into an IBSE format. Just as students cannot immediately switch from traditional methods of learning to inquiry-based learning, so teachers must also "learn" how to implement IBSE. For this, it is important for teachers to be able to use certain experiments in all corresponding IBSE levels. In this workshop, we present characteristics of each of the four levels of IBSE and examples of implementation of experiments (Trnova & Trna, 2011; Trna, 2011).

Confirmation inquiry

The outcome of this level is confirmation of the knowledge of principles, concepts and theories. The results of experiments are usually known in advance. Confirmation inquiry is useful in beginning IBSE so as to develop students´ experimental skills. Students can gain practice in specific inquiry skills, such as collecting and recording data.

- *Oxidation-reduction 1 (chemistry):*
  In the frame of curriculum content on oxidation-reduction, students confirm the sequence of metals in the electrochemical series.They choose one of the metals and insert it into different aqueous solutions of metal ions. They observe whether there is a chemical reaction and changes to the metals. They summarize all their observations in a table and analyze their results. On this