

PROFESSIONAL DEVELOPMENT OF SCIENCE TEACHERS THROUGH PARTICIPATION IN EDUCATIONAL RESEARCH

The purpose of this study is to gain insight into the professional development of science teachers and teacher teams, which were partners in the Austrian development project IMST². It categorizes 24 teacher reports about specific school innovations in a cross-case analysis. The changes in professional attitudes and performances were evaluated by means of a set of twelve criteria. Common features of these reports were the science teachers' growing interest and efforts in (a) interdisciplinary teamwork with colleagues in their own school, (b) networking with university researchers and with other teachers of their subject, (c) involvement in school organization, (d) comparing their teaching priorities with state-of-the-art scientific literacy concepts. These findings were re-examined in two case studies using qualitative research methods in a "triangulation" procedure. Action research methods were introduced to the teacher teams, who then carried out additional investigations concerning their students' understanding of science. The results of these complementary investigations were analysed, yielding relevant information about the teachers' priorities. The work with these teachers had a considerable effect on their beliefs and self-esteem. The findings of this study are a part of the overall evaluation of the IMST²-project. The set of twelve criteria proves to be a powerful tool for reflection about one's own professional growth.

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Defining the scope of research on teachers' professional development

This study is part of IMST² (Innovations in Mathematics, Science and Technology Teaching), a large scale development project involving more than a hundred upper secondary schools and teacher training institutes in Austria in the years 2000-2004 (Krainer et al. 2002, Krainer 2005a). The main goal of IMST² was to improve the quality and efficacy of mathematics and science teaching by initiating teachers investigations into their own teaching supported by scientists.

Teachers who were IMST²-partners developed innovative ways of teaching and learning, used action research methods to collect, analyse and interpret data, and eventually wrote and published reports. They worked mostly in teams, sometimes combining several subjects (biology, chemistry, mathematics, physics). They were free to make use of workshops and individual coaching by specialists and to pursue and investigate their practical classroom work.

The study was carried out in order to identify domains of significant professional development through participation in educational research. The investigation focused on two key questions:

1. In which ways do teachers' investigations into their own teaching practice supported by researchers affect their professional development?

2. Which set of criteria offers a profound description of the professional development of science teachers?

The answers to both questions were expected to supply data for the evaluation of the IMST²-project and information for the design of IMST³ (Krainer 2005b) as a nationwide support system for schools cooperating with each other and with universities in local and regional networks.

Combining constructivism and systems theory with action research

Professional development is understood as a continuous extension of competencies through systematic self-study (Stenhouse 1974). It is the capacity to learn and draw consequences from experience and thus balance the complementary dimensions of action and reflection as well as autonomy and networking (Altrichter & Krainer 1996). A main indicator for the success of IMST² is that teachers extend their pedagogical content knowledge as well as their methodological skills in evaluating their teaching, in collaborating with colleagues and in reflecting about educational goals. The central hypothesis of the study is that the importance of reflection and networking is steadily growing in modern school systems (Krainer et al. 2002). A consistent set of criteria for professional development must therefore contain a great variety of aspects of reflection and networking.

In order to describe and analyse a complex intervention into the educational system and its effects on students, teachers, the school setting and on the external research partners, the following theoretical approaches are used:

- Systems theory (focus on interrelations between individual growth, team processes and organizational frameworks; on individuals, teams, schools etc. as “learning systems”)
- Action research (teachers as “reflective practitioners”: learning from experience; sharing knowledge; taking responsibility; empowering students)
- Constructivist theories about cognition (subjective patterns of knowledge and understanding, learning as a social activity).

Research design and procedure

In the first part of this study 24 science teacher reports written for the IMST²-project in the years 2002/03 and 2003/04 about specific innovations in different school environments were analysed in order to gain insight into teachers' professional growth. The features of major changes in teacher performance and attitudes described in these reports were categorized according to the four dimensions action and reflection, autonomy and networking mentioned above. Then these features were clustered and subcategories were established. The temporary result of this procedure was discussed in a workshop of the research team, which finally agreed upon twelve criteria for professional development:

ACTION AND AUTONOMY Innovative teaching and learning methods (learning environments, heterogeneity) Knowledge of current developments in science and science education Provision of adequate learning conditions (resources, atmosphere) Appreciation of students' perspectives	
REFLECTION Evaluation of the effects of the teacher's actions Consciousness of increases in competencies Rethinking of attitudes and beliefs Critical ideas about math. & scientific literacy	NETWORKING Teamwork within school Cooperation with people from other institutions Organizational development Public relations

The original set of criteria was a tentative answer to the second key question and was slightly modified in the course of the study. It was used to specify the domains in which the most frequent and most striking improvements in attitudes and performance were found. On the other hand the criteria were used in IMST²-related workshops as reflective tools for teachers who were interested in self-diagnosing their strengths and weaknesses as professionals and defining goals for their in-service education.

In the second part of the study these findings were re-examined in detailed case studies. Two teacher teams were selected by chance, and their individual progress was studied by qualitative research methods using a "triangulation" procedure, i.e. classroom observation, student questionnaires and teacher interviews. Data from three perspectives were thus made available, which could be weighed against each other in order to gain a comprehensive and differentiated view (e.g. about student interest, participation and understanding). The results were not only used to validate the prior findings, but also to give the two teacher teams specific feedback. The two teams were further included in the research process by introducing them to action research methods so that they could acquire additional data on their own. These were compared to the findings of the case studies, yielding additional information about the teachers' subjective priorities, but also about aspects they ignored, but which turned out to be important for their students.

The micro scale investigations (about two teacher teams in two classrooms) supported the validity of the findings on the macro level (IMST²-project with more than a hundred teachers and schools). They also contributed to new insights for the teacher teams. For ethical reasons they retained the ownership of all data concerning their work and were finally asked for permission to publish the case studies. They were also given opportunity to use them for their own reports. The quality of these findings was highly dependent on the mutual trust and credibility of the university researchers and the cooperating teachers, based on sharing knowledge and undergoing similar procedures of reflection and critical self-assessment (Stern & Krainer 2003).

Findings

The cross-case analysis of reports about innovations in their school yielded characteristic features of the professional development of every teacher team. All of them could easily

be related to one of twelve criteria. The most common features of all 24 reports were the science teachers' growing interest and efforts in

- a. interdisciplinary teamwork with colleagues in their own school,
- b. networking with university researchers and with teachers of their subject in other schools,
- c. involvement with school organization in order to improve working conditions,
- d. comparing their teaching priorities with state-of-the-art scientific literacy concepts (e.g. OECD's PISA 2004).

In 80% of their reports the teachers documented significant gains in expanding their competencies in at least two of these domains. A closer look at two teacher teams added additional data about their exemplary accomplishments (Stern 2002f).

The first case study explored and assessed the changes in the classroom routines and attitudes of a team of four teachers. Their teaching project was about measurement in mathematics, geography and physics. Their most conspicuous progress was the growing awareness of important learning goals like understanding interrelations between different subject domains (d. scientific literacy), and secondly that to their surprise they began to enjoy and appreciate the extra work hours while planning together and learning from each other (a. teamwork).

A second case study investigated the progress made by two young female teachers, one for physics and the other for chemistry. They let their students perform experiments about electricity instead of making them watch the usual demonstrations in the laboratory. They expected a great improvement in their students' learning achievements, but the test results were disappointing as usual. On the other hand the interviews of the teachers showed amazing changes in other fields: the appreciation of sharing subject-specific knowledge by preparing experiments together (a. teamwork), and the growing self-esteem after intense discussions about learning goals and teaching priorities (b. collaboration with researchers).

These data coincided with the prior findings of the analysis of the two teacher reports, but yielded plenty of extra information which proved valuable for the teachers' planning.

As presumed in the central hypothesis, the findings showed a shift towards reflection and networking in most teachers' innovative activities. The set of criteria for professional development offers a differentiated and complex picture. The study answers the first key question by identifying four domains in which teachers are challenged to expand their competencies. But at the same time it shows that outside support is vital for success – especially by incentives for teacher investigations that are most effective in promoting educational change (Fullan 1999).

What the study leaves unanswered are methodological questions about the legitimacy of the action research approach, which does not deny its character as a serious intervention into the system it analyses, but tries to keep record of possible side effects and to reflect carefully on its repercussions. Another unsolved problem is how to raise the quality of many teachers' reports, which are not always driven by the desire to gain insight, but rather to account for what was achieved.

An outline of future research

In December 2005 another investigation of teachers' professional development was launched within the context of the enlarged IMST project. IMST3 replaces IMST² since 2004. It is an even more ambitious grand scale and long term project in Austria and connected to the EU-program "Education and Training 2010". IMST3 (see e.g. Krainer 2005b) aims at providing an overall support system for schools by establishing national centres for mathematics and science education at university institutes, creating regional school networks, train coordinators and stimulate closer collaboration between teachers of every school. One of seven suggested measures is the creation of the "MNI fund" (fund for mathematics, natural and information sciences). It offers financial support and counselling for school-based research & development projects, which numbered 130 in the beginning and 160 in the second year 2005/06. The professional development of cooperating teacher teams is regarded as a key indicator for the success of the project.

In a qualitative study three school-based projects were chosen for a comparative analysis using the results of the previous case studies, viz. the set of 12 criteria. The recent study has three goals, namely carrying out and comparing three more case studies of good practice, building partnerships between university researchers and teachers, and contributing to the evaluation of IMST3. Several features of the new study go well beyond the scope of the former ones:

- More elaborate instruments for inquiry were developed and are being used. Two interviews are carried out with the teachers at the beginning and at the end of their project. It is expected that they yield information about possible changes in teachers' beliefs about learning processes, professional attitudes and patterns of classroom interaction. A questionnaire is applied to students participating in the innovative teaching projects. We are also interviewing students, some teacher colleagues ("critical friends") and the headmaster in order to corroborate and validate the findings.
- The concept of "tension fields" (Krainer, Posch & Stern 2004) is used as an addition to the criteria for professional development, both for analysis of data and for reflection about processes. While criteria are often understood as liabilities or principles that ought to be followed, tension fields are pairs of conflicting claims, and a professional has to decide which one is important in a specific situation. Examples are "learning from experience" vs. "participating in in-service teachers training"; or "acting independently" vs. "coordinating teamwork". Both are necessary, none should be neglected. If one is dominating the other, good reasons should be given. Reflecting along the lines of this set of 12 "tension fields" promises to be a useful instrument for teachers who wish to reflect systematically about the successes and shortcomings of their professional development.
- The action research approach is substantiated by an agreement between the researchers and the teachers concerning the common ownership of the data, the modes of collaboration when developing questionnaires or interview guidelines, and the validation of the study outcomes. Furthermore, the students are partners in the investigation, the collection of their statements concerning their views of

changes in the classroom routines and of the teachers' teamwork are shown to them and are being discussed in order to gain knowledge about potential improvements of the current practice.

The case studies are expected to yield not only further insight into both the needs and accomplishments of mathematics and science teachers in rapidly changing school environments, but also substantial information on how to further improve their support within the IMST3-framework.

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