The Role of Formative Assessment in Enhancing Independent Learning and Reflective Teaching: Some Results of the Austrian IMST-Project

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IMST (Innovations in Mathematics and Science Teaching) is a long term research and development project aimed at establishing an effective support system for Austrian schools. In this framework three case studies of secondary school innovations are analysed, in which the students learned independently and new forms of assessment were introduced. These small scale innovations triggered a series of changes in the classroom and on the school level and led the teachers to question some of their fundamental beliefs. By investigating their practice, reflecting about teaching priorities and sharing their thoughts with colleagues, they were embarking upon a process of self-directed professional development which needed little outside support. Their creativity and problem-solving competencies raise hopes that their knowledge and experience might be valuable resources for the imminent reform of the Austrian school system.

Background, Objectives, Significance of the Study

Since the fast growing globalized economy is increasingly dependent on the development of new technologies and fundamental research, it is a main goal of educational policy worldwide to improve learning outcomes of students in science and mathematics. Austrian educational policy is slow in drawing conclusions from the disquieting results of the two international comparative studies TIMSS and PISA (Mullis et al., 1998). PISA showed that a disproportionately large number of Austrian students (nearly a third of the 15-year-olds) have only limited abilities in mathematics and science. Their average motivation and interest in mathematics and science is significantly lower than in most other OECD-countries. Moreover, success in Austrian schools depends heavily on the economic background and social status of the parents (OECD 2004, OECD 2007). For many reasons schools in Austria do not succeed as well as for e.g. in Finland, Sweden or the Netherlands in compensating social inequality and individual disadvantages (Haider & Reiter, 2004). But in recent years many reform measures have been put under way, among them the design and implementation of educational standards which aim at ensuring comparable learning outcomes for all students. The national project IMST (Innovations in Mathematics, Science and Technology Teaching) is in its third stage now. It is providing an effective support system for innovative schools and teachers while at the same time boosting educational research in universities all over the country. One of seven measures is the establishment of the IMST-fund. About 160 teacher teams per year are encouraged to submit proposals for their classroom innovations, to evaluate processes and outcomes and to write reports for internet publication. In return they receive intensive individual counselling and some financial remuneration, and they are invited to participate in workshops.

A review of more than 400 school projects within the last three years shows that three main trends in science education are promising to contribute to an overall improvement of the quality of teaching and learning.

- Students in a growing number of science classes are offered opportunities to carry out inquiries that crudely resemble scientific procedures like finding a research question or testing a hypothesis by drawing conclusions from experimental data.
- Teachers' interest in formative assessment is steadily increasing. They seem to want more reliable information

about the effectiveness of their instruction and about the individual learning progress of every student (http://imst.uni-klu.ac.at/wiki).

- Collaboration in teams as well as support within the school framework strengthen the teachers' motivation and encourage them to try out new ways of instruction and assessment, which eventually also lead to an increase in the students' engagement in science and mathematics (Mueller et al., 2007).

The goal of the present paper is to give an overview of national and international research results on these trends, evaluate their relevance for classroom practice and for the school system and investigate some examples of school projects in which teachers engage in both inquiry based student activities and innovative forms of classroom assessment. The impact on their self directed professional development is a main aspect of these case studies.

Systems Theory, Action Research, Constructivism

Three theoretical approaches were used and combined:

- Systems theory (focus on interrelations between individual development, team processes and organizational frameworks; on schools 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).

Societal changes, school reform and teachers' professional development are seen as closely related and interdependent. Teachers are key players in the classroom, in the schools and – as a professional group – on the societal level. On none of these levels can educational reform measures be effective and successful without their active participation. Teachers on the other hand often suffer from multiple pressures by institutional changes that are out of their control. Systems theory provides a framework which describes the mutual dependence of teachers and other stakeholders and their interrelations in times of change (Krainer & Pegg, 2008).

Action research offers methodologies for investigating teachers' practice by cooperating with them as research partners. The aim is not only to gain a better insight into characteristics of good teaching and successful learning, but also to empower teachers to make use of research procedures in order to improve their understanding of the classroom situation and thus of their teaching. What is unique in this approach is that it promotes an investigative attitude of the teachers, who collect data about their students' learning, interpret evidence and communicate with their colleagues in a professional way (Altrichter, 2005).

Constructivist learning theories regard prior knowledge as the most important determinant of learning processes (Ausubel, 1968). Therefore efficient teaching should start with identifying the students' preconceptions and investigating their ways of thinking and understanding. Otherwise newly acquired knowledge would soon be forgotten and replaced by preconceptions that are deeply rooted in non-scientific notions. These have to be taken seriously, discussed carefully, confronted with experimental evidence in order to be proven inconsistent and be replaced by new conceptual constructions (Driver, 1989; Duit & Treagust, 2003). Similar strategies prove successful in teachers' professional development as well. Teachers do not change their practice if told to try new instructional methods or alternative ways of assessment. Their routines are the result of both personal experience and beliefs. Only an analysis of their insufficiency or limitations can persuade a teacher to change his or her mind and become really innovative.

Summative and Formative Assessment

Assessment has always been a crucial issue, because of its close links to student learning and to organizational school development. Assessment has two important but contradictory functions. Firstly, it measures the final results of the learning process, and it is thus the basis for decisions, e.g. whether a student qualifies for continuing studies (summative assessment). Secondly, it measures the intermediary results of the learning process so as to give the students individual feedback about their progress as well as the necessary efforts for future success. It also informs the teacher about the effects of the instruction and how it might be improved (formative assessment). A main asset of formative assessment is that it offers teachers a chance to probe into their students' ways of thinking, analyze their preconceptions and misunderstandings, and thus be prepared for constructivist teaching methods.

Both kinds of assessment have strong repercussions on the learning processes. Summative assessment needs to be strictly objective, reliable and valid, in order not to be unfair and perhaps discriminatory. Because of its sometimes drastic consequences ("high stakes") it is in permanent danger of entailing strategies of "teaching and learning to the test" instead of better understanding. On the other hand formative assessment, especially if it is integrated into the teach-

ing and learning process and thus continuously generates information for feedback, has been proven to be a most powerful didactical means to improve learning results (Black & Wiliam, 1998).

In some countries like Austria, teachers are responsible for both kinds of assessment. Research suggests that summative assessment is taken more seriously, and formative assessment is therefore neglected. This is one of the reasons why external testing is suggested as a substitute or supplement for classroom assessment. Another argument in favour of external testing is that what teachers demand from their students and how they assess their tests is differing widely and is a cause for inequity. How much students learn and how their achievements are acknowledged is highly dependent on their teachers' sometimes limited abilities and subjective judgements.

In the USA, national standards for educational science were formulated as early as 1996 (NSES, 1996) in order to "provide criteria against which to judge the quality of assessment practices". They cover five areas:

- The consistency of assessments with the decisions they are designed to inform.
- The assessment of both achievement and opportunity to learn science.
- The match between the technical quality of the data collected and the consequences of the actions taken on the basis of those data.
- The fairness of assessment practices.
- The soundness of inferences made from assessments about student achievement and opportunity to learn. (NSES, 1996)

A later publication elaborates on how teachers are supposed to implement these assessment standards (Atkin, Black & Coffey, 2001). Some of the "key points are:

- Professional development becomes a lifelong process directed towards catalyzing professional growth.
- Assessment offers fertile ground for teacher professional development across a range of activities because of the close integration of assessment, curriculum, teaching and learning. There is no 'best' place to start and no 'best' way to proceed.
- Professional development should be rooted in real world practice.
- Regular and sustained reflection and inquiry into teaching is a start towards improved daily assessment.
- Collaboration is necessary, as is support at the school and broader systems level." (Atkin, Black & Coffey, 2001, p. 96).

The second of these statements was the starting point of the current research; the others are in perfect agreement with the findings of our earlier study (Stern & Streissler, 2006).

Research Design and Procedure

A cross-case examination of several school projects focuses on new ways of assessment that allow the students to some extent to choose their own topics and to keep track of their individual learning progress. In all three cases inquiry-based teaching and learning strategies are combined with innovative methods of assessment. The aim is to find out how teachers can possibly cope with so many challenges simultaneously, what kind of creative solutions to their specific problems they devise, and how they develop personally and professionally.

The research questions are:

a) What new methods of (both formative and summative) assessment do teachers use in order to tune in with instructional innovations and self-directed learning? What influence does this have on the motivation and learning outcomes of the students? How does it affect the teacher-student-relation?

b) Which criteria for good assessments are important for the teachers? How do they try to improve their practice in respect to these? What kind of competencies do they develop, and how does their professional growth influence their attitude towards their profession?

In an exploratory approach the characteristics of the teachers' innovations in assessing their students' understanding were examined and compared. In order to appraise the facets of the teachers' professional development, a scheme of twelve criteria was used. These criteria encompass competencies that are important for the teaching profession on three levels: classroom, school and society. They had been developed and refined in a preceding study (Stern & Streissler, 2006; Stern, 2006).

In order to provide sufficient data for a broad overview as well as a deep insight into the professional development of the teachers, various methods (analysis of teachers' reports and reflective papers, interviews, observations) and a triangulation of perspectives (teachers, students and external

researchers) were used.

By sharing the data and discussing the results of their analysis the cooperation of the researchers and the teachers was of mutual benefit. It also improved the validity of the findings. The teachers were research partners: They also got support for their self evaluation.

Results

The three case studies were chosen to be different in most aspects (region, type of school, subject). But some features turned out to be similar. In the beginning the teachers only had some crude ideas about how to change their assessment practice in order to support independent inquiry-based learning, and in all three cases many other changes ensued.

- Two high school mathematics teachers wanted to include more than the usual calculating skills into the assessment of their 12-year-old pupils' mathematical proficiency, especially their reasoning capabilities and their personal reflections about the importance of mathematics for their daily life. One task was to write down examples of "encounters with mathematics" on a normal day. One boy just recorded numbers: of pieces of clothes he put on, of teeth he brushed, of cups of milk he drank. A classmate wrote down which geometrical concepts or object she encountered: the angle between the upper and lower part of her body, when she sat up in her bed; spherical oranges; cylindrical tea cups, prismatic milk packs …The teachers gave them feedback and advice how to reformulate some of their examples. Many of the kids were excited about this exercise and said they were surprised to find that the world around them was full of mathematics. The pupils were also asked to collect diagrams from newspapers or magazines, and try to explain their meaning. Another task was to invent mathematics problems, illustrate them with poster drawings and present them to their classmates. One girl asked how many half-pint glasses of water it would take to fill up a swimming pool of 33m x 10m x 1.5m. A boy suggested calculating the time he would need to circle around the globe with his bicycle. Analyzing the originality and sophistication of these tasks and the quality of the answers was challenging, but turned out to be an excellent assessment instrument, because it informed better than the results of routine calculations about the pupils' mathematical knowledge and their level of understanding. In addition it was fun for most of them. And it was also a basis for reflections in the classroom about the relevance of mathematics. Both teachers have later been invited by the educational ministry to share their knowledge in an expert group on standards in mathematics education.
- A physics teacher in an upper secondary school designed a crash course on astronomy for his 16 year old students in order to prepare them for a special project. First he collected opinions and discussed with them about the minimum knowledge every educated person should have about astronomy. Then he let them choose their own fields of interest and sum up what is known about our planetary system, the stars and galaxies, and cosmology. They were also supposed to get acquainted with the astronomical telescope on the roof of their school building and learn how to handle the automatic control panel. The aim of the project was to enable the students to offer guided tours for interested visitors. During the "science week" every day another group of students stayed in school until the evening, waiting to inform the visitors about basic astronomical facts and to let them have a glance through the telescope on to the moon or Jupiter (12.5" f:15 Cassegrain reflector, 756 x enlargement). One group of students compiled a paper containing a short introduction to astronomy, another group interviewed the visitors and wrote about their opinions, a third group described the general idea of the project for a brochure. The teacher and the two colleagues, who collaborated with him, added their personal reflections. They noted that they were impressed by most students' zeal to accomplish excellent results, which lead some of them to work and discuss among themselves about astronomy hours after school was over. Since they had learned more about astronomy during this project than in most other periods, many of them could upgrade their marks for the yearly school reports. Including results of independent learning into summative assessment touched off a thorough re-evaluation of how to recognize the students' achievements. Their self-assessment was also taken into consideration. But what turned out to be even more momentous for the further development of the teachers' practice was a main insight: formative assessment during their learning process, i.e., giving the students credit for their achievements and advice on how to improve, had a strong positive effect on their attitudes and learning outcomes. Discussions with teacher colleagues on how to modify their assessment practice later proved to be the key to their professional development. Some of the astronomy projects were awarded national or international prizes and gained attention in the school. There were heated discussions in the teachers' conferences on how extraordinary achievements of students ought to be acknowledged as compared to regular test results. In the long run this had a remarkable impact on school development.

- Two teachers in a vocational school for future kindergarten workers decided to radically change their chemistry instruction. Instead of teaching the subject according to the curriculum in the usual way, they requested their 17-year old students to search for simple but interesting exemplary investigations of chemical properties and reactions of substances everybody knows and uses in daily life. They then ought to demonstrate and explain these to small groups of kindergarten kids in such a way that they could understand, have fun and learn from it. Several difficulties had to be overcome:
  - convincing the students that this course in chemistry was valuable for their future vocation;
  - gaining the support of colleagues and the school principal;
  - and finding new ways how to assess the students' individual achievements.

The two teachers decided to clarify the learning goals, to ask the students to collect evidence of their learning progress in portfolios, and to work out criteria on how to discern good from mediocre quality. But apart from finding new methods of giving the students credit for their overall performance (summative assessment), they put more and more emphasis on feedback procedures and encouragement during the learning process (formative assessment). They also started to organize in-service seminars for colleagues in their school and partners in the experimental kindergartens.

In each of the case studies the teachers put on record how they perceived the effects of their classroom innovation, and their data were compared with student answers in questionnaires and interviews with principals and colleagues. In one case there was some resistance by the principals and colleagues, and the teachers had to try hard in order to succeed and get at least some recognition in the end. The other two cases were examples of how important it could be to get support from the principal. The triangulation method not only helped to validate the findings by corroborating some self-appraisals of the teachers and refuting others, but in general also provided additional information for continuing their innovations.

The cross-case analysis of the three teacher teams shows that promoting self-regulated learning not only compelled the teachers by and large to look for unorthodox methods of summative assessment, but also induced the idea of enhancing the learning processes of their students through formative assessment. Changing their assessment practices proved to be closely connected with a thorough re-evaluation of their teaching priorities, of their beliefs about learning and of their personal perspectives and ambitions as teachers. These changes turned out to have an especially strong impact on many aspects of their professional development and were accompanied by in-depth reflections on professional standards.

Discussion

The overall results of the case studies were compared with a set of twelve criteria for teachers' professional development. In earlier studies (Stern & Streissler, 2006; Stern, 2006) it was found that an innovative approach to any specific aspect of the teaching profession tends to cause changes in several other aspects as well. All the teachers involved had deepened their understanding of the relevance of organizational development for the improvement of teaching and learning. And they had also engaged in a more systematic reflection and professional communication about teaching priorities and standards with colleagues both within their school and outside.

These findings were confirmed by the three new case studies. Projects intending to develop new ways of assessment and to use them for improving both the motivation and the achievements of their students, led the teachers to question their previous instructional habits and to reconstruct their role as teachers. They now put more emphasis on listening to individual students, giving them purposeful advice and stimulating their self-directed learning. Moreover they started to share their knowledge with others and founded or joined new networks of professional collaboration.

A common feature of all case studies was the creativity of the teachers involved. They were in no way dependent on suggestions on how to improve their assessments, but had their own ideas and were satisfied just to be encouraged and backed by educational scientists when they pursued their own goals and designed their projects.

Their progress in professional development was a consequence of autonomous activities, which were neither initiated nor driven but only minimally supported by the framework of the IMST-fund.

Perspectives for Future Research

The school system in Austria like in many other countries is in a stage of transformation. Mathematics and science education is regarded as essential for technological, economic and social progress. One of the imminent changes will be the introduction of educational standards and of centralized tests in order to measure the learning outcomes. Most teachers are suspicious, because they fear a depreciation of their

assessment competency. On the other hand their competencies are badly needed to combine classroom assessments and external tests to get reliable judgments of students' achievements (Harlen & Deakin Crick, 2003).

How do teachers stand up to the twofold challenge of innovating their classroom assessment and of adjusting to external standardized tests? Will they have a voice in the upcoming controversies about educational standards, which might include teaching and assessment standards? Answering these questions is high on the agenda for educational research not only in Austria in the next few years. Case studies like the ones presented here could prove to be valuable for a better understanding of how teachers cope with these tasks and how reform measures can retain their cooperation and support, which are vital for success.

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