2

The IMST Project: Reflections on a Nation-Wide Initiative Fostering Educational Innovations

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The IMST project started in 1998 as a reaction to Austria's disappointing TIMSS 1995 results at the upper secondary level. In its first phase, IMST aimed at fostering mathematics and science education at secondary schools. Later, it was extended to all levels and more subjects. The paper sketches the genesis of the project, including the initial research project and its continuous development. Furthermore, the theoretical framework, the goals and the intervention strategy are outlined as well as the project's approach to evaluation and research. As an outcome of IMST, a national support system was launched. The paper compares the vision of this support system and its implementation. Also, it concludes with some reflections on Austrian students' achievement in TIMSS and other studies over the years.

Keywords: Austrian Students, Educational Innovations, IMST, PISA, TIMSS.

IMPULSE FOR THE INITIATIVE AND CONTEXT

The TIMSS[1]achievement study in 1995 was the first, large international comparative study in the education sector where Austria participated. The results concerning the primary and the middle school (reported in 1997) were rather promising. Media and public saw it as strengthening of the Austrian education system and highlighted the importance of the study. However, when shocking results of the Austrian high school students (grades 9 to 12 or 13), in particular with regard to the TIMSS advanced mathematics and physics achievement test, were reported one year later (1998), a huge public disappointment arose. It evoked discussions on educational practice, research and policy. The ranking lists showed Austria as the last (in advanced mathematics and advanced physics) among other nations (see e.g., Mullis, Martin, Beaton, Gonzalez, Kelly, & Smith, 1998, p. 129, 189). This and other results indicated that the teaching of mathematics and science in Austria needed a shift. Some experts suggested reducing the dominance of teacher-centred instruction and application of routines (by launching specific teacher education initiatives). Other experts saw the necessity to reformulate curricula or to introduce educational standards, and still others argued that teacher education needs to be reorganised, and some indicated that Austria needs an educational reform like other countries (for example, Northern Europe) launched in the last decades of the twentieth century. Anyway, TIMSS 1995 (and later PISA[2]) offered external impulses for reform ideas in Austria. Like in many other countries (e.g., Germany,

[1] TIMSS = originally it is the Third International Mathematics and Science Study (1995, 1999), now known as the Trends in International Mathematics and Science Study (2003, 2007, 2011, 2015).

[2] PISA = Programme for International Student Assessment (2000, 2003, ..., 2015, ...).

European countries in TIMSS) showed a picture of a fragmentary educational system. For example, the data indicated few collaborations among teachers and among teacher education institutions (the latter split into university and non-university teacher education) with a high level of (individual) autonomy and action; however, there was little evidence of reflection and networking (see e.g., Krainer et al., 2002; Krainer, 2003a). All these results became a part of a report for the education ministry and were published and presented to relevant stakeholders.

THE DEVELOPMENT PROJECT IMST² (2000-2004): THEORETICAL FRAMEWORK AND THEORY-PRACTICE-RELATIONSHIP

The analysis sketched above supported the idea that the focus should be laid on enhancing reflection and networking. These two dimensions should not be directed towards the teachers only (as policy often tends to do), but on the whole educational system, including teacher education and research in MINT education[5]. All parts were expected to contribute to the goal of improving students' learning, based on challenging MINT activities and autonomous thinking, again using reflection and networking as an appropriate means to promote their learning.

In order to take systemic steps to overcome the fragmentary educational system, the approach of a ''learning system'' (see e.g., Krainer et al., 2002, p. 26) including the four dimensions: action, reflection autonomy and networking (as mentioned in chapter 1) was taken. This perspective suggests a holistic and integrated view of learning and development.

Often autonomy and actions predominate (leading to lonely fighters, low levels of joint learning and synergy), thus, a particular emphasis on reflection and networking is regarded as crucial. The concept of a "learning system" has been inspired by concepts like "learning schools" or "learning organisations" (see e.g., Marx & van Ojen, 1992, and Rolff, 1994). The concept is also a generalization of ideas generated at the level of students' mathematical learning and teachers' professional learning (see e.g., Krainer, 1993, and Altrichter & Krainer, 1996). The concept of "learning systems" makes use of several theoretical backgrounds, including action research, constructivism, network theory, system theory, and community of practice (see detailed information and references in Krainer, 2005a).[6]

Within IMST, students are seen as inquiry-based learners (IBL), and consequently also teachers should be regarded as such, and should be supported in promoting students' inquiry-based learning (see e.g., Krainer & Zehetmeier, 2013). Furthermore, it is important to view teachers as experts who investigate their own teaching in a systematic

[5] MINT stands for Mathematik, Informatik, Naturwissenschaften and Technik, and is the German equivalent for STEM. Later, when German language (Deutsch) was added to IMST, the abbreviation was extended to MINDT.

[6] The "learning system" can be regarded as an overarching theoretical framework, which needs to be concretized when coming to a specific sub-project. The research projects are diverse in nature (e.g., focusing on students, teachers, school development) and built on their own research questions (e.g., focusing on mathematics teaching, other subjects, general pedagogical issues) and methodologies (e.g., qualitative, quantitative, action research). Research was assumed in all sub-projects, balancing the specific interests of researchers and needed knowledge for further developing the corresponding sub-project.

and self-critical way (action research, see e.g., Altrichter, Feldman, Posch, & Somekh, 2008). This means that educators and researchers working with teachers need to be seen as "critical friends" to teachers (fostering their learning). However, at least equally important, they also need to be seen also as experts reflecting their work with teachers and generating knowledge interesting for them and the teachers, and the scientific community. This proffers a special relationship between educators/researchers and teachers, built on mutual respect and trust, and also gives way to viable ways of negotiating interests and seeking flexible answers to the question how research can enhance both practice and policy (see e.g., Krainer, 2005b).

IMST regards teachers as experts and key agents of change (getting support bycolleagues, teacher educators, etc.) and follows the three assumptions of Reflective Rationality(see e.g., Altrichter et al., 2008): (i) Complex practical problems require particular solutions; (ii) These solutions can only be developed inside the context in which the problem arises and in which the practitioner is a crucial and determining element; (iii) The solutions can rarely be successfully applied to other contexts, but they can be made accessible to other practitioners as hypotheses to be tested in practice. This is in stark contrast to Technical Rationality (see critique by Schön, 1983) which assumes: (i) There are general solutions to practical problems; (ii) These solutions can be developed outside practical situations (in research or administrative centres); (iii) The solutions can be translated into practitioners' actions by means of publications, training, administrative orders, etc.

Goals and Intervention Strategy of the Development Project

The recommendations of the IMST research project directed to the 4-year project IMST² (2000–2004)[7]. This project (Krainer et al., 2002) focused on the upper secondary school level only. The overall goal of IMST was (and still is) to contribute to improving MINT teaching in Austria. However, how should a project with limited funds start in order to aim at this goal in a sustainable way? What made achieving this goal even more challenging was the fact that subject didactics for MINT (as well as in other fields) and related research were poorly anchored at Austrian teacher education and research institutions. This meant there was a severe lack of MINT educators with a strong research background. For example, at that time, Austria had only a few full time professors for mathematics didactics and few associate professors for MINT didactics, all related to secondary teaching[8]. Thus, there was a dearth of sufficient educators in Austria to educate other educators and expert teachers, and to support schools. This meant that the project had to initiate activities for schools, but at the same time take initiatives to establish professorships, to qualify educators and expert teachers in order to enlarge the group of educators and researchers in subject didactics and to involve professors from Germany and Switzerland.

[7] First, the project was financed for one yearonly; later it wasextended for three additional years.

[8] At that time, Austria had no single full or associate professor for primary education in any subject, thus teacher education for primary teachers (and also main school teachers) was done at "Pädagogische Akademien" who had the status of schools (not universities) with hardly any task for doing research.

Therefore, the main goals of IMST were:

- to initiate, promote and make innovations visible, to analyse and to disseminate innovations, with an emphasis on generating ''good practice'' concepts and on supporting teachers in further developing their teaching;
- to take part in setting up a support system for further development of school practice in MINT subjects, particularly by encouraging practice-oriented, scientifically grounded subject didactics.

For *intervention* into a (learning) system, ideas by Willke (1999, p. 12, referring to ideas from Bateson and von Förster) were helpful, who defined *observation* as *noticing* a relevant difference, and *intervention* as *producing* a relevant difference. In IMST, fostering reflection and networking (at all levels of the educational system) were regarded as producing a relevant difference to the status quo of fragmentation.

The project aimed at establishing a *culture of innovation*. This means starting from teachers' strengths, understanding teachers and schools as owners of their innovations, and regarding innovations as continuous processes that lead to a natural development of practice, as opposed to singular events that replace an ineffective practice (for more details see e.g., Krainer 2005a, referring to and further developing ideas from Altrichter & Posch).

However, teachers' (and schools') innovations did not start totally in a bottom-up style. In the years 2000-2004, each school-year about 50 innovative projects at Austrian upper secondary schools (and partially at other organisations, e.g., teacher education institutions) were supported by teacher educators in four *Priority Programmes* according to the challenges extracted from the above-mentioned research project. These programmes were small, professional communities that intended to support each participant to proceed with his or her own project and also generated a deeper understanding of one's own teaching. This means, specifically, that the teachers were free to define the issues they intended to investigate. In addition, this approach would help teacher educators to reflect about how they support teachers during their interventions in order to improve them, or to share new knowledge within the project or within the scientific community.

In addition to supporting innovations at schools, IMST also elaborated a sustainable support system as a proposal for a strategy plan for improving teaching in MINT subjects at secondary schools[9] in Austria. The suggested support system was based on the project's theoretical framework and comprised seven key measures whose main ideas and present status quoare sketched below.

Evaluation and Research within the Development Project

From the beginning of IMST², evaluation was considered systematically. The outcome of IMST² was investigated from different perspectives, in a formative and summative way. Studies focused on students' and teachers' learning, the development at the school and

[9] It was recommended to start with MINT at the secondary level as a pilot, and later to consider extending it for other subjects and levels.

partially at the regional and national level. The main emphasis was put on teachers' professional growth, on effects at schools, and on how IMST² generated the basis for a sustainable support system for MINT teaching in Austria. For example, an external evaluation using a questionnaire for teachers and principals (Specht, 2004) investigated the effects of IMST² at schools after two years. It concludes that the initiative mostly reached active schools and teachers and was regarded as an "important, helpful and effective support for instruction and school development". The study indicates many positive changes (e.g., more readiness for innovations in teaching, increased ability to reflection and self-evaluation, and intensified collaboration) and only a few problematic aspects (e.g., too much work for those who are engaged in many activities, or conflicts among teachers because some colleagues resist to take responsibility).

In order to document and reflect on their activities, teachers were invited to write (action research) reports about their goals, efforts, and results. These evaluations helped them to improve their practice and to better understand it; and also informed the IMST staff about the progress, and the evaluations were used, for example, as data for research on teachers' professional development (e.g., Krainer, 2005c) or on further development of single schools (e.g., Rauch & Kreis, 2007; Rohrer & Senger, 2004). However, research was confined to individual research interests, taking into consideration the available time and resources of team members whose priority was to achieve the goals sketched above. Apart from gaining direct research results, IMST activities in that period also contributed to the improvement of research in an indirect way: many teachers improved in (systematically and self-critically) reflecting their practice, and thus, developed an inquiry stance and increased interest in evaluation and research. In addition, the results of IMST research project 1998-1999, which showed a lack of research in subject didactics in Austria, and the continuous discussions about building a support system, increased the consciousness in ministries and teacher education institutions that an investment in research personnel in that area is necessary.

IMST (2004-2018) AS A NATIONAL SUPPORT SYSTEM

The responsible ministry – supported by the Council for science and technology development – decided to continue IMST (firstly 2004-2006, then 2007-2009, 2010-2012, 2013-2015, and up to now 2016-2018). The initiative was adopted several times (e.g., it was extended to all school levels and types, and subjects like German language were added), partially with fluctuating sub-programmes and contents, changing political context, and the never long-term secured resources (stagnating last years due to state-wide budget problems). However, the main basis was the support system suggested by IMST (see e.g., Krainer, 2005c).

The support system comprises even measures (M1–M7) focusing on various levels of the educational system: local, regional, and national. Specifically, the focus is laid on evaluation and research, and on gender and diversity, which should be integrated into all measures. In order to strengthen gender and diversity in IMST, a special Gender Diversity Network has been implemented since 2013 (a Gender Subproject had already

establishment of such centres and initiated the label Regional Educational Competence Centres (RECC) for M3, fulfilling specific quality criteria.

In 2014, the first 13 RECC had been awarded by the responsible ministry, seven more followed in 2015. An evaluation of subject didactics in Austria (Krainer, Hanfstingl, Hellmuth, Hopf, Lembens, Neuweg, et al., 2012) showed that – in addition to AECC – also regional subject didactics centres contributed largely to further development of the disciplines (however, still having challenges becoming stronger in researchdue to historic and structural reasons).

c. *Support structures for practice (M6, partly M4 – see below):* In order to breed the culture of innovations at schools, it is important to make good practices in challenging MINDT areas visible and accessible to all the teachers. Teachers need to be offered an adequate opportunity where they get informed about good practices and can try out innovations by themselves.

   IMST established a kind of fund (M5), structured in the Thematic Programmes (a further development of the priority programmes sketched above). The design of Thematic Programmes (TP) is based on the idea of a scientific fund, adapted to the needs of schools. The TPs were selected by an independent jury (application of a theme that responds to a current challenge in MINDT teaching by a team of experts from universities, university colleges for teacher education, and practice). Each TP supports about 20 innovation projects a year all over Austria. To get funds, the teachers have to apply for a project (describing e.g., challenge, innovation, goals and evaluation of the project). They get funds after their applications are reviewed and passed successfully by a jury. Apart from individual support for their project and participation in several meetings with colleagues and experts, teachers need to write a paper about their innovation and post it on IMST-Wiki (http://www.imst.ac.at/wiki) for everyone's learning.

   Selected projects are presented at IMST conferences, network meetings, partially at international conferences and in the context of EU-projects (e.g., Fibonacci, Key Co Math, and PROFILES, PARRISE) where IMST is/was involved, or these projects might become winners of the annual IMST award (currently six prizes are sponsored by the State and Economy). About 200 projects are financed per year. Recently, about 100 projects (covering all MINDT subjects and grades) are supported[11].

   The actual nation-wide TPs focus is on competence oriented teaching in the fields of mathematics and science, writing and reading, learning with digital media, and hands-on laboratory.[12] Teachers carrying out innovations within TPs are expected to disseminate their knowledge, and thus, become potential bridge-

[11] Concerning the future, there are visionary plans to implement the Thematic Programmes by establishing an Austrian Educational Fund (as fund for teachers in parallel to scientific funds like e.g., the FWF in Austria, or the DFG in Germany).

[12] In the years 2010-2015, the nation-wide TPs had been supplemented by a regional, economy-sponsored TP in Carinthia, which focused on creative teaching in computer science.

ministries, changing political contexts, budget considerations, etc. Therefore, it was never foreseeable at any time, if, when, and to what extent measures will be established. Often, it was a matter of negotiations, whether a measure should be implemented within or outside the project, and eventually with which partners. It also occurred that new challenges (e.g., the launch of university teacher colleges in 2007) and new measures (e.g., a stronger need for educating-the-educator offers) had to be taken into consideration. In addition, the scope of subjects and school levels changed. Whereas IMST 2000-2004 focused on upper secondary mathematics and science only, IMST 2004-2006 was broadened to all MINT subjects and all secondary schools. IMST 2007-2009 even began to include primary education and to integrate German language projects with a link to MINT (as a consequence of the ministry's decision to initiate an AECC for German language in reaction to bad reading results in PISA). Since 2010, IMST covers all grades and school types, however, with a reduced budget compared to 2004-2006. The invitation to take part in several EU projects also contributed to the complexity of steering IMST, and thus to plan evaluation and research.

Due to the complexity of the whole endeavour, it became obvious that it makes sense to distinguish between different demands of evaluation and research (although, making these distinctions, the boundary between evaluation and research is often blurred):

a. Teachers' action research: Supported by "critical friends", teachers carry out innovations, reflect on them, improve their practice, produce "local knowledge" and document their results as "reflective papers" on the Internet; meanwhile, more than thousand papers by teachers can be read onhttp://www.imst.ac.at/wiki.
b. Self-evaluation of IMST and of its sub-programmes, with the Regional Networks and the Thematic Programmes as the largest initiatives: These evaluations can be formative in the sense of producing knowledge about how IMST and its parts run during the process, with the aim to further develop and optimize measures; they can also be summative, in order to produce knowledge about the impact of the measures and (if possible) to explain why and to what extent certain things occur or not; this can be done for internal documentation, or for publications.
c. Evaluation in the sense of accountability: This kind of evaluation is directed towards the ministry or other ordering parties (for all the goals the project gets resources for), with written reports for each project period (on average 2-3 years). Starting 2010-2012, it was negotiated with the ministry to report the achievement of goals at the basis of a so-called Logical Framework Matrix along three levels of goals (students; teachers; local, regional and supra-regional level), using 45 indicators. Among others, the project reports provide the ministry steering knowledge, particularly related to MINDT teaching in Austria.
d. Research (not necessarily focused on the impact of IMST or its parts)[13]: Since no additional resources for research were included in the project budget after 2009,

[13] The organising institute of IMST, the Institute of Instructional and School development (AECC IUS, founded in 2004), aimed at emphasising on research in IMST specifically, promoting junior researchers (e.g., through doctoral and habilitation theses). This was in line with results from external evaluations of IMST by

Regional Networks (e.g., Rauch & Scherz, 2009) or Thematic Programmes (e.g., Langer, Mathelitsch, & Rechberger, 2015).

INSIGHTS INTO THE IMPACT OF IMST

Here are some exemplary insights into the impact of IMST, differentiating the *local* (schools), the *regional* (federal states), and the *national* level (exemplary contributions to all levels and some general considerations can be found in Krainer, Hanfstingl, & Zehetmeier, 2009).

At the *local level*, the students' and teachers' learning as well as school development are in the foreground. All three IMST-books (Krainer et al., 2002; Rauch & Kreis, 2007; Krainer, K., Hanfstingl, & Zehetmeier, 2009) include examples of successful MINDT teaching at schools, but the reports and analyses reveal challenges as well. Regarding German language, reading, and writing, as well as the link to MINT teaching, a book (Fenkart, Lembens, & Zeitlinger, 2010) and a special issue of a journal for German language didactics (Information enzur Deutschdidaktik, issue 38(2), 2014) is highlighted. The IMST-Wiki (http://www.imst.ac.at/wiki) and further publications (often classified into science-to-public, science-to-professionals, and science-to-science publications) provide interesting insights into the diverse approaches (for sustainability of IMST work at the school level, and some general considerations at IMST, see e.g., Krainer & Zehetmeier, 2013; Pegg & Krainer, 2008). As a support for teachers and schools, IMST produced several booklets (e.g., on examination culture, gender, pre-scientific writing, school development) and IMST Newsletters dedicated to challenging issues of MINDT teaching (see https://www.imst.ac.at/eintraege/newsletterarchiv/bereich_id:50). So far, in the years 2010-2015, 44 Newsletters have been produced and disseminated (e.g. to all schools in Austria).

At the *regional level*, the existence and development of Regional Networks (some of these networks exist for more than ten years) is an important indicator. The impact is also visible in presentations at conferences and in publications (e.g., Rauch, Zehetmeier & Erlacher 2014; Rauch & Kreis 2009; Altrichter, Rauch & Rie ß 2010; Rauch 2013; see the chapter by Schuster, Rauch & Zehetmeier in this book).

At the *national* level, the Austrian Educational Competence Centres (AECC) and the regional subject-didactics centres (most as RECC) turned out as important spin-offs of IMST. Among others, they actively contributed to the introduction of educational standards and of a partly centralized high-school exit exam. IMST supported the MINDT initiatives of several ministries and carried out research and development projects commissioned by the industry (e.g., investigating technical students' motives for studying MINT subjects, see Andreitz, Müller, H., Kramer, & Krainer, 2013), or co-authored a booklet on "MINT 2020". IMST is present with publications and presentations in various relevant environments, including those of scientific community, practice, and policy (e.g., invitations to write chapters in Austria's National Education Reports 2009 and 2012). In 2012, IMST was the winning project of the Austrian Sustainability Award in the category of "Regional cooperation".

Since changes in an educational system are influenced by a variety of aspects, one should be cautious regarding the impacts by particular projects, reform steps, etc. However, the results evoke at least some questions.

Question 1: What effect might Austria's decision to reduce the number of lessons for students at all school levels starting with the school year 2003/04 have on the PISA results in the period 2003-2012?[17] Assuming that most other (neighbouring) countries did not worsen the situation like Austria, it is likely that Austria falls back. However, the fact that Austria did not fall back in mathematics and science, is a positive sign, and since IMST was the leading reform project in MINT, a link between the positive trend of Austria in the above-mentioned studies and the efforts around IMST is plausible.

Question 2: Why does Austria lose ground compared to neighbouring countries (related to both 9-10 year old students, and 15-16 year old students) in reading, but not in mathematics and science? Since items in mathematics and science require meaningful reading of texts, a decline of Austria's results in mathematics and science was to be expected. This, however, was not the case. IMST started in 2000 with a focus on mathematics and science. In contrast, there was no comparable initiative in Austria related to German language. Only in 2007, IMST started supporting first projects with a link between MINT and German language teaching. In the years 2010-2015 such projects were fully integrated; however, in sum, many more projects fully dedicated to mathematics and science were supported than those with a link to German language teaching. Thus, it is plausible that an impact of IMST on PISA 2012 results is much more likely in the case of mathematics and science than in the case of German language.

Question 3: Why is mathematics rather stable, but science developed positively? At the end of the 1990s subject didactics for mathematics was better than science; for example, for mathematics education several university professors were available, but no professors were available for biology, chemistry or physics education. According to this perspective, the initiation of IMST was more important for science than for mathematics teaching. Therefore, the launch of one AECC in mathematics but, three AECCs in science (biology, chemistry and physics) lead to more positions in science didactics at teacher education institutions than in mathematics didactics. The stronger need in science was also mirrored by the fact that more RECCs in science than in mathematics were established and more projects in science teaching were supported by IMST than in mathematics teaching.

Other countries put a lot of emphasis on education by establishing professorships, doctoral programmes, etc. Austria still has strong challenges in subject didactics (see e.g., Krainer et al., 2012). This means there is a lack of young researchers in this field, no adequate support for practice, a lower level of professional advice for policy, and a worse starting point for students' learning at all school levels, as well as for teaching and related research. Therefore, given all the restraints sketched above, the positive

[17] The responsible ministry decided to implement parts of the suggested support system immediately, and to start preparations for the remaining ones. However, at the same time, a decision was taken by the ministry to reduce the number of lessons per student at all school levels. This decision caused many protests (also by IMST), but it was implemented without delay. This measure certainly diminished the impact of IMST.

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