ORIGINAL ARTICLE

Ways of promoting the sustainability of mathematics teachers' professional development

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Abstract This paper deals with the sustainable effectiveness of professional development programmes. Based on a review of literature and research findings, the following questions are raised: What is regarded as an effective way of promoting mathematics teachers' sustainable professional development? Which levels of impacts are aimed at? What are the factors promoting the effectiveness of professional development programmes? Regarding these questions, the article links theoretical considerations with research findings from a case study. A secondary mathematics teacher, taking part in a teacher professional development programme in 2002, was revisited in 2005 and 2010 to gather data regarding the sustainable impact of the programme. The case study's results provide information about the teacher's professional growth and lead to a discussion of implications for mathematics teachers' professional development and teacher education in general.

1 Introduction

Effective ways of promoting mathematics teachers' professional development are of great interest, in particular for both the participating teachers and facilitators. In this context, the question of sustainable impact is of outstanding relevance. Despite its central importance, research on sustainable impact is generally lacking within the educational disciplines (Datnow, 2005; Rogers, 2003). This paper addresses this question by providing results of a case study with a secondary mathematics teacher taking part in a teacher professional development programme in 2002. This teacher was revisited in 2005 and 2010 to gather data regarding the sustainable impact of the programme.

The objective of this research is not to evaluate the respective professional development programme (which was not explicitly designed to have sustainable impact, but to support teachers at the time of participation). Rather, the case study aims to analyse why some impacts are sustainable, while other effects disappear after the programme's termination. In other words, the particular professional development programme is not the focus, but rather the frame of this case study.

2 Literature review and theoretical framework

In this section, we give a short overview regarding the theoretical background of the paper's central notions and concepts.

2.1 Professional development

Teachers are considered to play a central role when addressing professional development programmes: "Teachers are necessarily at the centre of reform, for they must carry out the demands of high standards in the classroom" (Garet, Porter, Desimone, Birman, & Yoon, 2001, p. 916). Ingvarson, Meiers, and Beavis (2005) sum up: "Professional development for teachers is now recognised as a vital component of policies to enhance the quality of teaching and learning in our schools. Consequently, there is increased interest in research that identifies features of effective professional learning" (p. 2).

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2.2 Impact

Goals and outcomes of professional development programmes are of great interest, in particular for both the participating teachers and the facilitators. In this context, the question of possible levels of goals and outcomes is important: Which levels of goals and outcomes are possible?

In most papers that emphasise on the question of goals (and thus the potential outcomes) of teachers' professional development, *teachers' learning* is the main focus (see e.g. Guskey, 2000; Lipowsky, 2004, 2010; Sowder, 2007; Zehetmeier, 2008). From a holistic perspective (according to Pestalozzi's idea of learning by head, heart, and hand; e.g. Brühlmeier, 2010), the major indicators for describing teachers' learning are their knowledge, beliefs, and practice: There is an ample body of literature discussing the mutual relationship between any two of them (e.g. Da Ponte & Chapman, 2006; Liljedahl, 2008; Song & Koh, 2010) or three (Carrington, Deppeler, & Moss, 2010; Ernest, 1989; Haslauer, 2010; Zehetmeier, 2008).

However, the situation is rather complex since each of these notions can be defined in different ways. *Teachers' knowledge*, for example, can be differentiated into content knowledge, pedagogical knowledge, and pedagogical content knowledge (Shulman, 1987); but it can also be regarded as knowledge about learning and teaching processes, assessment, evaluation methods, and classroom management (Ingvarson et al., 2005); yet other foci are expressed by the notions of attention-based knowledge (Ainley & Luntley, 2005) or the knowledge quartet (Rowland, Huckstep, & Thwaites, 2005).

Similarly, *teachers' beliefs* can include different aspects of beliefs about mathematics as a subject, and its teaching and learning (Leder, Pehkonen, & Törner, 2002). It includes also the participating teachers' perceived professional growth and satisfaction (Lipowsky, 2004), perceived efficacy (Ingvarson et al., 2005), and opinions and values (Bromme, 1997). In addition, also teachers' attitudes (e.g. to which extent primary teachers like or dislike mathematics and how this probably changes) and interests (e.g. in specific topics, questions to investigate in their own teaching) would be worthy of consideration. At the *teachers' practice* level, the focus is on classroom activities and structures, teaching and learning strategies, methods, or contents (Ingvarson et al., 2005).

Zehetmeier (2008) points out that the complexity of possible impact is not fully covered by this taxonomy. For example, results of an impact analysis (Zehetmeier, 2010) in the context of the Austrian IMST^2 project (Innovations in Mathematics, Science and Technology Teaching, see below and Krainer, 2008) show that the project made impact also on students' knowledge and beliefs or on other—nonparticipating—teachers' practice. So the taxonomy of levels of impact needs to be extended.

Zehetmeier (2008) highlights that the categories *knowledge, beliefs*, and *practice* are suitable to cover the impact at the teachers' and students' level; however, the three categories are also relevant at the level of colleagues, principals, and parents for gathering possible levels of impact. In addition to these *in-school* levels, also *beyond-school* levels need to be considered when analysing the impact of professional development programmes: e.g. other schools, media, policy, or scholarship. For example, "knowledge of other schools" refers to schools as learning organisations and the resulting knowledge. Figure 1 shows a grid of possible levels of impact (for more detailed description of the grid's respective cells, see also Zehetmeier, 2008):

2.3 Fostering factors

What are the factors promoting and fostering the impact of professional development projects? Literature and research findings concerning this question point to a variety of factors. In particular, the factors fostering the effectiveness of professional development programmes are of central importance. However, these factors are rather manifold and complex. This is also true for the underlying theoretical concepts. If we would have to reduce this complexity to a few dimensions, these could be (see Krainer, 2006; see also Stein, Smith, & Silver, 1999; Lachance & Confrey, 2003; Llinares & Krainer, 2006; Sowder, 2007; Krainer & Wood, 2008):

- *content* (high level and balance of subject-related action and reflection);
- *community* (high level and balance of individual and social activities, in particular fostering community building within and outside the professional development programme);
- *context* (high level and balance of internal and external support).

In the following sections, a succinct synopsis of literature concerning the factors fostering the impact of professional development projects is provided and categorised with regard to these "three Cs" (a more detailed review of literature is provided in Zehetmeier, 2008).

2.3.1 Content

The content should *fit* into the context in which the teachers operate and provide direct *links to teachers' curriculum* (Mundry, 2005). It should focus on *content knowledge* and use *content-specific material* (Garet et al., 2001; Ingvarson et al., 2005; Maldonado 2002), and should provide teachers

	In-School Levels					Beyond-School Levels			
	Teachers	Pupils	Colleagues	Principals	Parents	Schools	Media	Policy	Scholarship
Knowledge									
Beliefs									
Practice									

Fig. 1 Levels of impact (Zehetmeier, 2008, p. 197)

with opportunities to develop both *content* and *pedagogical content knowledge* and skills (Loucks-Horsley, Stiles, & Hewson, 1996; Mundry, 2005). Moreover, an effective professional development programme includes opportunities for *active* and *enquiry-based learning* (Garet et al., 2001; Ingvarson et al., 2005; Maldonado 2002), authentic and readily adaptable *student-centred mathematics learning activities*, and an open, *learner-centred implementation* component (Farmer, Gerretson, & Lassak, 2003). Further factors fostering the effectiveness and sustainability of the programme are: *prolonged duration* of the activity (Garet et al., 2001; Maldonado 2002), ongoing and *follow-up support opportunities* (Ingvarson et al., 2005; Maldonado 2002; Mundry, 2005), and continuous *evaluation, assessment,* and *feedback* (Ingvarson et al., 2005; Loucks-Horsley et al., 1996; Maldonado 2002).

Rogers (2003) highlights that the diffusion of an innovation depends on different characteristics: *Relative advantage, compatibility, complexity, trialability*, and *observability*. Fullan (2001) describes similar characteristics (*need, clarity, complexity, quality,* and *practicality*) influencing the acceptance and impact of innovations. Relative advantage includes the perceived advantage of the innovation (which is not necessarily the same as the objective one). An innovation with greater relative advantage will be adopted more rapidly. Compatibility and need denote the degree to which the innovation is perceived by the adopters as consistent with their needs, values, and experiences. Complexity and clarity include teachers' perception of how difficult the innovation is to be understood or used. Thus, more complex innovations are adopted rather slowly, compared to less complicated ones. Trialability denotes the opportunity of participating teachers to experiment and test the innovation (at least on a limited basis). Innovations that can be tested in small steps

represent less uncertainty and will be adopted as a whole more rapidly. Quality and practicality make an impact on the change process. High quality innovations that are easily applicable in practice are more rapidly accepted. Observability points to the claim that innovations which are visible to other persons (e.g. parents or principals) and organisations are more likely to be rapidly accepted and adopted.

2.3.2 Community

The increasing awareness of the crucial impact of the social dimension in mathematics teacher education is reflected in a special volume of the First International Handbook of Mathematics Teacher Education (Krainer & Wood, 2008). For example, Lerman and Zehetmeier (2008) highlight that *community building* and *networking* represent further factors fostering sustainability. This claim is supported by several authors and studies, even if the categories used to describe these activities are sometimes different: Clarke (1991) and Mundry (2005) point to cooperation and joint practice of teachers, Loucks-Horsley et al. (1996) and Maldonado (2002) highlight the importance of learning communities, Wenger (1998) and McLaughlin and Mitra (2001) identify supportive communities of practice, Arbaugh (2003) refers to study groups, and Ingvarson et al. (2005) stress professional communities as factors contributing to the sustainability of effects. In particular, providing rich opportunities for *collaborative reflection* and *discussion* (e.g. of teachers' practice, students' work, or other artefacts) presents a core feature of effective change processes (Clarke, 1991; Farmer et al., 2003; Hospesová & Tichá, 2006; Ingvarson et al., 2005; Park-Rogers et al., 2007; Zehetmeier, 2008).

If the teachers are involved in the conception and implementation of the programme, they can develop an affective relationship towards the programme by developing *ownership* of the proposed change (Clarke, 1991). They can be *empowered* to influence their own development process (Harvey & Green, 2000). Teachers should be prepared and supported to serve in *leadership roles* (Loucks-Horsley et al., 1996). An "*inquiry stance*", taken by the participating teachers also fosters the sustainability of impact (Farmer et al., 2003, p. 343): If teachers understand their role as learners in their own teaching process, they can reflect and improve their practice. Cochran-Smith and Lytle (1999) also use this notion for describing teachers' attitude towards the relationship of theory and practice: "Teachers and student teachers who take an inquiry stance work within inquiry communities to generate local knowledge, envision and theorise their practice, and interpret and interrogate the theory and research of others" (p. 289).

2.3.3 Context

The context is of particular importance regarding the sustainability of innovations and change processes (e.g. McNamara, Jaworski, Rowland, Hodgen, & Prestage, 2002; Noddings, 1992; Owston, 2007). Teachers need *administrative support* and *resources* (McLaughlin & Mitra, 2001). *School-based support* can be provided by students and colleagues (Ingvarson et al., 2005; Owston, 2007) and, in particular, by the *principal* (Clarke, 1991; Fullan, 2006). To foster sustainability not only at the individual (teacher's) level but also at the organisational (school's) level, Fullan (2006) proposes a new type of leadership that "needs to go beyond the successes of increasing student achievement and move toward leading organizations to sustainability" (p. 113). In particular, these "*system thinkers in action*" should "widen their sphere of engagement by interacting with other schools" (p. 113) and should engage in "capacity-building through networks" (p. 115). *Support from outside the school* (e.g. by national or district policies or by collaborations with research teams from universities) is also an important factor fostering the programme's impact (McLaughlin & Mitra, 2001; Nickerson & Moriarty 2005; Owston, 2007).

2.4 Sustainability

The expected outcomes of professional development projects are not only focused on short-term effects that occur during or at the end of the project, but also on long-term effects that emerge (even some years) after the project's termination. Effects that are both short term and long term can be considered to be sustainable. So sustainability can

be defined as the lasting continuation of achieved benefits and effects of a project or initiative beyond its termination (DEZA, 2002). As Fullan (2006) points out, short-term effects are "necessary to build trust with the public or shareholders for longer-term investments" (p. 120). Besides these short-term effects also long-term effects need to be considered; otherwise the result could be to "win the battle, [but] lose the war" (ibid.). Hargreaves and Fink (2003) state, "Sustainable improvement requires investment in building long-term capacity for improvement, such as the development of teachers' skills, which will stay with them forever, long after the project money has gone" (p. 3). Moreover, analysis of sustainable impact should not be limited to effects that were planned at the beginning of the project; it is also important to examine unintended effects and unanticipated consequences that were not known at the beginning of the project (Rogers, 2003; Stockmann, 1992).

When analysing sustainable impact, it is not only important to define the notion sustainability; to better understand this concept and to fully recognise the importance of this issue for the discussion of professional development programmes' impact, it is worthy to know more about the evolution of this notion.

The notion *sustainability* is mainly part of ecological and economical wording, but is also increasingly used in the educational realm. Without using this notion explicitly, already in 1657, Comenius dedicated a chapter of his opus "didactica magna" to the "foundations of lasting teaching and learning" (Flitner, 1970). In the twentieth century, the notion "institutionalisation" was used to describe changes that were stable over time. During the 1970s, institutionalisation was seen as the third and final phase of change processes in schools: (1) mobilisation, (2) implementation, and (3) institutionalisation (Anderson & Stiegelbauer, 1994, p. 280). Anderson and Stiegelbauer (1994) define institutionalisation as "a phase after initial implementation when an innovation either got 'built in' to ongoing use and organizational structures or was discontinued due to such factors as the loss of funding, staff turnover, competing practices, and low administrator or teacher commitment" (p. 280). Fullan (2006) defines sustainability when discussing educational change as "the capacity of a system to engage in the complexities of continuous improvement consistent with deep values of human purpose" (p. 114). Hargreaves and Fink (2003) highlight that sustainability is more than a temporal matter: "Sustainability does not simply mean whether something will last. It addresses how particular initiatives can be developed without compromising the development of others in the surrounding environment now and in the future" (p. 30). In fact, it is important to generate impact which enables individuals and institutions to foster innovations and change—even after the project is terminated and the project resources are not

available anymore. The main goal is empowerment. In this sense, sustainability means that individuals and institutions (a) are able to react autonomously on changing conditions and (b) create and use processes and products to meet these conditions.

The common ground of all these definitions of sustainability is the focus on durable continuation. At the same time, the extent of this duration remains open. It is unclear whether sustainability means, e.g. 3 months or 10 years of continuation. "If the time limit of sustainability is not set exactly (in some cases unlimited), the verification of sustainability is not possible" (Stockmann, 1992, p. 27). So each analysis of sustainable impact has to define the time frame for sustainability.

3 The Austrian IMST[2] project

The initial impulse for the IMST[2] project in Austria came from the 1995 TIMSS achievement study (Third International Mathematics and Science Study). In particular, the results of the Austrian high school students (grades 9–12 or 13) in the TIMSS advanced mathematics and physics achievement test shocked the public. The responsible federal ministry launched the IMST research project (1998–1999) to analyse the situation (see Krainer et al., 2002).

This research identified a *complex picture of diverse problematic influences* on the status and quality of mathematics and science teaching: For example, mathematics education and related research was seen as poorly anchored at Austrian teacher education institutions. Subject experts dominated university teacher education, and other teacher education institutions showed a lack of research in mathematics education. Also, the overall structure showed a picture of a fragmentary educational system of lone fighters with a high level of (individual) autonomy and action; however, there was little evidence of reflection and networking (Krainer et al., 2002; see summarised in Pegg & Krainer, 2008).

The analyses mentioned above led to the 4-year project IMST[2] (2000–2004). The project (Krainer et al., 2002) focused on the upper secondary school level and involved the subjects: biology, chemistry, mathematics, and physics. The two major tasks of IMST[2] were

- The initiation, promotion, dissemination, networking, and analysis of innovations in schools (and to some extent also in teacher education at university); and
- recommendations for a support system for the quality development of mathematics, science, and technology teaching.

To take systemic steps to overcome the "fragmentary educational system", the approach of a "learning system" (Krainer, 2005) was taken. It adopted enhanced *reflection* and *networking* as the basic intervention strategy to initiate and promote innovations at schools.

Besides stressing the dimensions of reflection and networking, "innovation" and "work with teams" were two additional features. Teachers and schools defined their own starting point for innovations and were individually supported by researchers and project facilitators. The IMST[2] intervention built on teachers' strengths and aimed at making their work visible (e.g. by publishing teachers' reports on the Web site). Thus, teachers and schools retained ownership of their innovations. Another important feature of IMST[2] was the emphasis on supporting teams of teachers from a school.

Teachers' participation in IMST[2] was voluntary. They could choose among several priority programmes (e.g. "basic education" or "teaching and learning processes") according to major challenges concerning mathematics and science teaching. In general, teachers in these priority programmes were supported by mathematics and science educators and experienced teachers. The priority programmes can be regarded as small professional communities that not only supported each participant to proceed with his or her own project, but also generated a deeper understanding of the critical reflection of one's own teaching, by means of actions research methods.

4 Method

4.1 Research design

This research follows a case study design (Stake, 1995; Yin, 2003), because this approach is particularly suited for analysing the impact of innovations: "The usual survey research methods are less appropriate for the investigation of innovation consequences. [...] Case study approaches are more appropriate" (Rogers, 1995, p. 409). Similarly, Hancock and Algozzine (2006) state: "Trough case studies, researchers hope to gain in-depth understanding of situations and meaning for those involved" (p. 11).

The case study presented here is *historic* (Merriam, 2001), *intrinsic* (Stake, 1995), and *explaining* (Yin, 2003), since it analyses the teacher's development over time, focuses on the particular teacher's case, and quests for his professional developments' fostering conditions.

4.2 Former research

This analysis is based on the results of a former research project. In 2005, 11 case studies were generated to describe and explain specific aspects regarding the impact of the IMST[2] project (Benke, Erlacher, & Zehetmeier, 2006; see

also Krainer, 2005). These case studies' results pointed to different levels of impact of the IMST² project, for example, teachers' mathematical knowledge, beliefs, or teaching practice.

4.3 Current research

In 2010, the idea was born to revisit these case studies and to analyse the project's impact after 5 more years, from an ex-post perspective (Zehetmeier, 2011, in preparation). For this purpose, semi-structured interviews were again conducted with the teachers who formerly took part in the IMST² project; interviews were also conducted with the teachers' respective colleagues, school principals, and former project facilitators. The data gathered in 2010 were analysed and contrasted with the 2005 case studies' results.

This combination of former and current research projects resulted in a set of quasi-longitudinal case studies. This paper provides the findings of one of these case studies.

4.4 Research questions

This paper's focus is on the impact of a professional development project 8 years after the project's termination: The teachers participated in the project from 2000 to 2002. A comparison of the 2005 results with recent data from 2010 allows a thorough discussion of the following questions: Which of the 2002 and 2005 impacts are still effective in 2010? Which impacts did disappear? Which are the respective factors that fostered or hindered the sustainability of impact?

4.5 Data

The case study includes data from various sources and time periods to gain validity by "convergence of evidence" (Yin, 2003, p. 100): Collection of data was done during 2001 and 2010 and contains documents (teacher's written project report; 2002) and archival records (first author's artefacts; 2001–2004). Moreover, interviews were conducted with the teacher, his colleagues, and principal in 2005 and 2010.

The 2005 interviews were semi-structured. This means, the interview structure was based on document analysis of existing data, which identified various levels of impact. The 2005 interviews were designed to both enquire the sustainability of identified impact and reveal other types of impact which were not already coded by the researchers. Therefore, the questions were both closed (e.g. is the impact you described in the 2002 project report still effective?) and open (e.g. which other impact of the IMST² project is still effective?).

The 2010 interviews were semi-structured, too. The interviews should both work out which of the 2005 impacts were still effective (or not) in 2010 and identify other types of impacts which were not realised by research until 2010. Therefore, the interviews were based on document analysis of the existing data (including the findings of the 2005 case studies) and were designed accordingly.

4.6 Analysis

Data analysis included both, inductive and deductive elements (Altrichter & Posch, 2007). In a first step, all data from before 2005 were analysed and—according to the research questions—coded inductively. The second step included deductive analysis of the 2005 data: interviews and case studies were coded according to the theoretical framework (e.g. the teacher's and his colleagues' knowledge, beliefs, and practice) to analyse both the impact and the respective fostering (or hindering) factors. The 2005 case studies' results were validated by means of member checking. Then, the 2010 interviews were planned, conducted, and analysed. Here, the data were again coded both inductively and deductively to be able to combine and contrast these recent results with the former ones.

Data were analysed by qualitative content analysis (Mayring, 2003) to identify common topics, elaborate emerging categories, and gain deeper insight into the teacher's professional growth over time.

4.7 Validity

Creswell (2007) identified eight verification procedures for qualitative studies and recommends that at least two of them should be given to ensure validity. Four of these verification procedures were present in this study: *prolonged engagement, triangulation, negative case analysis*, and *rich description*: The contact with the teacher spanned more than 1 year in the contexts of the project, and the time span under research lasted for more than 8 years (*prolonged engagement*). Data came from a variety of sources (*triangulation* by convergence of evidence; see above). Research results were refined with regard to disconfirming evidence until any disagreements among the findings were eliminated (*negative case analysis*). Finally, the case study provided detailed information on all persons and activities relevant to this research (*rich description*).

5 Results

This paper presents findings from a case study related to a secondary mathematics teacher's professional development. Within this case study, one teacher is in the focus:

Andy.[1] The following sections provide the teacher's case study with a particular focus on Andy's professional development's impact and the factors that fostered or hindered the sustainability of this impact.

5.1 The case of Andy

Andy is a secondary mathematics teacher with a 32-year teaching experience in 2010. From 2001 to 2002, he participated in the IMST^2 project for one school year. His starting point was a particular interest: he wanted to "provide and perform mathematics teaching which is efficient and appropriate for pupils" (Andy, 2002, project report, p. 1). To meet this goal, he intended to get feedback from the pupils regarding his teaching practice. Therefore, he conducted an action research project to find out more about his "pupils' preferences and aversions" (Andy, 2002, project report, p. 6). The results of Andy's action research project pointed to various positive aspects of his teaching. However, one particular issue was evaluated rather critically by the pupils: In many cases, Andy urged pupils to calculate on the blackboard. While his intention was to support and encourage the pupils, they perceived these situations as taking an examination and being exposed to observations by his classmates. Inspired and surprised by this finding, Andy tried to analyse this issue more deeply. So he conducted another questionnaire with a particular focus on calculating on the blackboard. Additionally, he kept a research diary to record his and his pupils' behaviours and moods during the phases of blackboard calculations.

Another consequence of Andy's action research project was his desire to know more about his teaching. Thus, he gathered feedback not only from his pupils and project facilitators, but also from his colleagues regarding his teaching practices. "It was very important for him to receive external perspectives regarding his explication of intentions. So he initiated a system of mutual classroom observations with two colleagues" (Andy's project facilitator, 2005, interview).

In the next sections, the impact of Andy's participation in the IMST^2 project is provided. In particular, the 2005 results are contrasted with the recent 2010 data. This allows discussing the question, which of the 2005 impacts was still there in 2010.

5.1.1 Andy's knowledge

Andy's participation in IMST^2 brought him *new knowledge*: He realised the importance of clearly and explicitly

explaining his intentions to the pupils, particularly whenever pupils had to perform in front of the class. This knowledge was still active in 2005: Henceforward, Andy explained his objectives before urging pupils to calculate on the blackboard, "to eliminate the threatening aspects of this situation" (Benke et al., 2006, p. 43).

This impact was sustainable. In 2010, Andy stated: "One of my particular concerns is still the calculation on the blackboard. These situations should be burdened as little as possible. This is sustainable knowledge which will be important until my retirement" (Andy, 2010, interview).

During his participation in the IMST^2 project, Andy had the opportunity to network with several teachers from other Austrian schools: IMST^2 organised several 2- to 5-day seminars with the aim to foster mutual exchange and cooperation between the participating teachers and schools. During these seminars, Andy presented his activities and ideas to these colleagues and gained *new knowledge* regarding other teachers' projects, ideas, and innovations. Andy described this exchange: "I met so many colleagues; each of them offered some new and unique ideas. So this really broadened my horizon" (Andy, 2005, interview).

This short-term impact could not be sustained. Since, after the project's termination, there were no more organised meetings offering time and space for networking, Andy could no longer exchange his ideas with and learn from other colleagues. "After IMST^2, this was over. There was no more broadening the horizon" (Andy, 2010, interview).

5.1.2 Andy's beliefs

The 2005 data pointed to some *changes in Andy's beliefs*: In particular, the teacher's self-esteem was enhanced. He did not have to guess, he rather could know, for example, that his teaching was regarded as good by his pupils. "This allowed him to plan and implement innovative teaching practices in a very self-confident manner" (Benke et al., 2006, p. 42).

This impact could be sustained. In the 2010 interview, the open question was posed: "Which impact is still effective, almost ten years after the project's termination?" Andy's first answer was: "Definitely, the courage to go my way and to advance the things I do" (Andy, 2010, interview). Andy stated that his participation in the project "laid the basis for my self-esteem. I dare, I try, and I still have a good feeling" (ibid.).

5.1.3 Andy's practice

In 2005, as a result of his participation in the IMST^2 project, Andy fostered a rather pupil-centred teaching style: For this purpose, he clearly separated open and closed

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[1] Teacher's name is a pseudonym.

classroom practices, where either the pupils' engagement, problem solving, and creativity or the teacher's guidance, experience, and expert knowledge were central aspects of the respective teaching culture. In particular, Andy engaged and involved the pupils in discussions about teaching quality. He used several methods to evoke the pupils' perspective on this issue: Pupils wrote short essays regarding their perspectives on mathematics instruction. In addition, Andy used some questionnaires and video analyses to get more information regarding teaching quality. Moreover, Andy wrote down his own observations and collected these notes in a research diary. Therefore, he was able to contrast the pupils' answers with his own perceptions: "The pupils dared to frankly state what they didn't like. We were in permanent dialogue about good mathematics teaching" (Andy, 2005, interview).

The 2010 data showed that this *innovative practice* was still effective. Eight years after the project's termination, Andy was still examining his pupils' opinions: "Yes, this is something I learnt during the project. Now I tell my recent pupils about the great benefits my project class and I could gain from this practice – and then my pupils write some short essays on topics like 'why I don't like maths' or something similar" (Andy, 2010, interview). Andy continued to foster the dialogue with his pupils on teaching quality by conducting questionnaires and surveys regarding his pupils' perspectives. Moreover, Andy still wrote his research dairy: "This is sustained impact" (ibid.).

5.1.4 Andy's colleagues' practice

Andy's participation in IMST^2 initiated a culture of mutual feedback and evaluation at his school. While at first only two of his colleagues engaged in this *new practice*, later on more and more colleagues joined this feedback group. In 2003, the whole teaching staff decided to establish a school-wide evaluation system: each teacher conducted a questionnaire or took part in a quality circle of two or three teachers, visiting each other, giving mutual feedback, and discussing regularly about teaching and instructional quality. "All this began with a small questionnaire in my mathematics class, and now we have this feedback system with 120 teachers participating enthusiastically" (Andy, 2005, interview).

In 2010, this system of mutual feedback has been persisting. However, the number of participating teachers peaked off, because "now, this immediate need is no longer given. The most important and interesting things are already said" (Andy, 2010, interview). There are still about ten active quality circles. In particular, the school's novice teachers gladly make use of this opportunity to learn from their experienced colleagues.

5.2 Influencing factors

This section provides findings regarding the factors which fostered or hindered the sustainability of impact. All factors which arise from the case study are described and referred to the factors presented above (Sect. 2.3). Within the category "content", the following factors turned out to be effective in this case study: *observability, relative advantage, need,* and *compatibility*. Within the category "community", the following factors were effective: *empowerment, ownership, community building,* and *networking*. Within the category "context", the following factors were found: *school-based support* and *administrative support*.

5.2.1 Content factors

Observability: One major fostering factor was Andy's professional environment: The colleagues, as well as the principal and the parents, gave repeatedly positive feedback. "This continued even in the aftermath of the IMST^2 project" (Andy, 2010, interview). In particular, the pupils' reactions on teachers' activities fostered the sustainability: "They are working highly concentrated; they have fun and are motivated; they make positive experiences in mathematics lessons. All this is very important" (Andy's colleague, interview, 2010).

Relative advantage: Another factor fostering the sustainability of impact represented the direct usability of innovative practices. For example, Andy collected information for feedback purposes and could react immediately on current classroom conditions. He stated: "I simply like this feedback, which is anonymous, authentic and honest. I don't want to miss this" (Andy, 2010, interview). Additionally, Andy experienced personal benefit, which also made the impact last after the project's termination. He stated: "Even after two years, this system of mutual classroom visitations is still in progress – without being imposed by the principal or school administration, just because we all know its value" (Andy, 2005, interview). He concluded: "This is still effective" (Andy, 2010, interview).

Lacking relative advantage, need, and *compatibility*: A hindering factor was the decreasing collegial engagement. During Andy's participation in IMST^2, his colleagues were highly interested and keen to cooperate with him. As time went by, this engagement decreased due to several reasons: On the one hand, the novelty was gone: "By and by, an innovation is no longer new; it is no longer something special; rather one thing among others" (Andy's colleague, 2010, interview). On the other hand, teachers who were not interested from the very beginning enforced articulating their opposite perspectives: "There are always some colleagues, who don't think much of things like that; not

everybody likes mutual classroom observations and feedback groups" (Andy's colleague, 2010, interview). So the impact on the colleagues' practice level decreased over time.

5.2.2 Community factors

Empowerment and *ownership*: Both the teacher and the principal highlight the role of the IMST[2] project facilitator as a fostering factor. This person not only supported the teachers' activities, but also acted as a "critical friend": she introduced an external perspective, gave professional oral and written feedback, and provided alternative interpretations regarding the teachers' classroom practices. In particular, she supported the teacher individually according to his needs (see Jungwirth, 2005). At the same time, the teacher could act independently and autonomously: he was empowered to teach his own way and possessed ownership regarding his professional development.

Community building and *networking*: Yet another fostering factor was represented by the IMST[2] workshops and seminars. These events enabled Andy to communicate and network with colleagues from other schools, which was very important for his professional development: "Each of these meetings was both a source of good ideas and a clear confirmation of my own work" (Andy, 2010, interview).

Lacking community building and *networking*: One of the factors that hindered the sustainability of impact was the absence of network structures beyond the school level. As long as IMST[2] provided organised meetings and workshops for the participating teachers, Andy could benefit from these events. As soon as IMST[2] was over, these structures were gone and the impact disappeared.

5.2.3 Context factors

School-based support: One of the central factors that fostered the sustainability of impact was the engagement of the school's principal. She had great interest in Andy's activities: she asked him on a regular basis about his experiences, or about his professional development activities; when returning from IMST[2] seminars or workshops, he felt "like coming home where you are welcome with all your positive and negative feelings" (Andy, 2010, interview); the principal enabled the teacher to present his ideas in several school boards and committees: "I reported in conferences and staff meetings, so my colleagues could become acquainted with my activities and ideas. And so all this could be developed and sustained" (Andy, 2005, interview). One of Andy's colleagues stated: "The principal must not only tolerate the teachers' activities; a fostering principal has to promote and emphasise professional development – again and again" (Andy's colleague, 2005, interview).

Administrative support: The school had an efficiently organised management structure, which represented another fostering factor. These structures allowed innovations to be disseminated among the teachers, provided access to information and examples of good practice, and facilitated particular working groups by providing time and space for their respective members. "We had a vivid working group of mathematics teachers who actively strove towards high quality teaching" (Principal, 2005, interview).

6 Discussion

6.1 Discussion of results

Andy achieved impact on his knowledge, beliefs, and practice level, as well as on his colleagues' practice level. Most, but not all, of this impact was sustainable.

In detail, Andy generated new *knowledge* regarding his pedagogical content knowledge (pupils' blackboard calculations) and concerning innovative teaching practices (of colleagues from other schools). Here, the first impact was sustainable, due to the factors *relative advantage* (Rogers, 2003), *compatibility* (Rogers, 2003), and *need* (Fullan, 2001). The second impact was not sustainable and disappeared, due to *lacking community building* and *networking* (Lerman & Zehetmeier, 2008).

Andy's *beliefs* changed regarding his self-esteem in a sustainable way, due to the factors *empowerment* (Harvey & Green, 2000), *ownership* (Clarke, 1991), and *inquiry stance* (Farmer et al., 2003). Andy was involved in the conception and implementation of his own professional development, so he could develop an affective relationship towards the project. He also was able to influence his own development process by using methods of action research.

Concerning his *practice* level, Andy used various evaluation methods to gather different perspectives on the quality of mathematics teaching. This impact was sustained, due to the factors *evaluation, assessment,* and *feedback* (Ingvarson et al., 2005; Loucks-Horsley et al., 1996; Maldonado 2002), as well as *inquiry stance* (Farmer et al., 2003).

On the level of Andy's *colleagues' practice*, the impact regarding a culture of mutual feedback could not be sustained to a full extent, due to *lacking relative advantage* (Rogers, 2003), *need* (Fullan, 2001), and *compatibility* (Rogers, 2003).

Even though the teacher's project was not explicitly designed to have sustainable impact, the case study's findings show that more often than not the effects could be sustained over 8 years. Some other levels of impact disappeared as the professional development project was over.

One explanation for this finding is that some of the respective fostering factors are tightly bound to the existence of the professional development project, while others are not. For example, the availability of organised meetings and workshops was a prerequisite for fostering factors *community building* and *networking,* which were crucial for Andy's new knowledge about other teachers' innovative ideas. These meetings were organised by IMST[2], and so they were gone as soon as the project was terminated. Other fostering factors—like *relative advantage*, *need*, or *observability*—were not as dependent on the IMST[2] project.

Therefore, if professional development projects must be designed to have sustainable impact, it is reasonable to carefully examine the factors which can foster (if they are present) or hinder (if they are lacking) the sustainability. If some of these factors are highly interconnected with and dependent on the existence of the project, then these could be substituted with alternative ones that are less or not at all connected to the professional development project's existence. This highlights the significance of fostering factors which are (as far as possible) temporally independent from the professional development project. Moreover, this also points to the importance of the factor *follow-up support opportunities* (Ingvarson et al., 2005; Maldonado 2002; Mundry, 2005), which should be considered in the conception of professional development projects.

This case study's results point to the outstanding relevance of context factors. For example, the principal could be described as *system thinker in action* (Fullan, 2006): She made a commitment to both short-term and long-term results on various levels, and she fostered networks and deep learning. Similarly, Nickerson and Moriarty (2005) analysed an urban school initiative aimed at teachers' professional development with the goal of increasing teachers' mathematics content knowledge and helping them improve their practice. Nickerson and Moriarty could show that organisational conditions like teachers' relationships with the school administration and other teachers are highly relevant for the development of good teaching at schools. This case study's results lead to implications for the design and implementation of sustainable professional development projects: On the one hand, the teacher of this case study took part in a professional development project, which was based on ideas of action research (e.g. Altrichter & Posch, 2007). He integrated several elements of action research into his teaching (e.g. evaluation methods, triangulation, critical friends, etc.). On the other hand, action research as a method in professional development projects covers many fostering factors per se (e.g. empowerment, ownership, link to teachers' curriculum, networking, reflection, assessment, evaluation, relative advantage, inquiry stance, compatibility, teachers as researchers, etc.).

Therefore, to gain sustainable impact, it could be reasonable to integrate elements of action research into the design of professional development projects (see also Zehetmeier, 2010).

Research regarding the sustainability of professional development is a rather complex issue, and this is also true for the underlying theoretical concepts. This complexity is particularly reflected in the factors fostering the sustainability of impact. This paper both (a) points to and highlights this complexity and (b) at the same time reduces this complexity by using already introduced categories (the three Cs). In sum, this paper intends to open and foster discussion on this issue.

Some of this paper's findings were already suggested by literature review (e.g. the influence of the professional development's context on its impact; see above). The provided case study now both supports these suggestions and highlights their significance—not only regarding the short-term impact, but also notably concerning the question of sustainability. In particular, the findings identify methods of action research to be highly relevant for sustaining professional development's impact.

6.2 Discussion of limitations

The data of this case study include Andy's self-reports, both in written form (Andy's project report) and in narrative forms (interviews). There is no control group. This can be discussed as a limitation of this study. One may pose the question, whether the described impact is really due to the particular professional development project, or due to some other sources (which may be the case). We tried to deal with this issue by taking various measures: On the one hand, we explicitly asked the teacher to frankly inform us concerning this question. For this, we clearly explained that evaluation of the IMST[2] project (in the sense of producing success stories) is explicitly not the objective of the interview series. Rather, the goal is to gather data for dealing with the study's research questions. Andy (and the other interview partners) agreed and stated to frankly bear in mind this issue when providing data. On the other hand, we used several methods to enhance the validity of our results (see also the Sect. 4.7 above): e.g. triangulation by contrasting various perspectives or negative case analysis by identifying impact that is not (only) due to the IMST[2] project. All these measures enhance the probability to "get it right" (Stake, 1995, p. 107).

Moreover, as Supovitz, Mayer, and Kahle (2000) clearly lay out, there are also research findings regarding the strength of surveys to gather accurate data on teaching practices: For example, Porter et al. (1993) analysed the consistency between survey responses regarding instructional style and teacher logs describing actual lessons. They concluded that

there existed substantial overlap. Burstein et al. (1995) used interviews, observations, daily teacher logs, and classroom artefacts to validate survey data. They found that survey data could depict instructional strategies validly.

At the same time, this limitation can also be interpreted as a special feature of this research: the results were found without possible distortions of teachers' motivation (to participate in this study) and without pre-set categories of possible impact; this allowed a completely inductive analysis of the initial data (see above). So, one of this study's strengths is the opportunity to complement quantitative "efficacy-studies" working with randomised control groups to—in sum—enhance our knowledge base.

6.3 Discussion of generalisation

This qualitative study is not intended to be generalised. In particular, when using case studies, "researchers are not necessarily interested in examining or creating theories or in generalizing their findings to broader populations" (Hancock & Algozzine, 2006, p. 32). It is rather important to provide extensive information and a deep insight into the specific structure of the particular case: "The intent in qualitative research is not to generalize the information […] but to elucidate the particular, the specific" (Creswell, 2007, p. 126). In this sense, the case study's results can be generalised in a "naturalistic" way: "Naturalistic generalisations develop with a person as a result of experience. They form the tacit knowledge of how things are, why they are, how people feel about them and how these things are likely to be later or in other places with which this person is familiar" (Stake, 1980, p. 69). Stake (1995) further states: "We do not choose case study designs to optimise production of generalisations. More traditional comparative and correlational studies do this better, but valid modification of generalization can occur in case study" (p. 8).

6.4 Discussion of implications

Each professional development project has its own and particular objectives, participants, facilitators, contents, methods, and environments. So each project has to carefully consider its respective fostering and hindering factors regarding the sustainability of impact. Inversely formulated: for professional development projects to be sustainable, it is crucial to carefully consider the fostering and hindering factors. This implies knowing these factors and being sensible about them. Considering and facilitating these fostering factors (and at the same time avoiding the hindering factors) when designing and implementing professional development projects is one important step on the journey to sustainable in-service teacher professional development.

The next step should be to enhance further research and evaluation to get new results regarding the relevance of these factors. These findings should be again integrated into the conception of future projects. In sum, this can lead to a virtuous circle towards the goal of effectively promoting the sustainability of in-service mathematics teachers' professional development.

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