Teachers' beliefs on teacher training contents and related characteristics of implementation – the example of introducing the topic study method in mathematics classrooms[1]

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Abstract: *So-called "bottom-up" strategies for implementation based on mathematics teachers' own developmental activities are considered to be a powerful approach when encouraging teachers to introduce alternative instructional practices. For evaluational research of in-service teacher training programs using "bottom-up" implementation strategies, the way how teachers implement contents of the teacher training is at the centre of interest. As the teachers' active role in the implementation process is necessary, their individual beliefs on the contents of the teacher training and their expectancies might influence the teachers' implementational activities. These beliefs can be considered as components of professional knowledge and pedagogical content knowledge (Shulman, 1986) in particular.*
For this reason, the study focuses on the development of beliefs on contents of a teacher training program throughout the training on the one hand and relationships with characteristics of implementation on the other hand. We consider the example of introducing a student-centred learning environment, the so-called topic study method, in the teachers' classrooms.
The results indicate that there are interdependencies between beliefs on the teacher training contents and characteristics of implementation.

Kurzreferat: *Vor dem Hintergrund von Evaluationsansätzen zu „Bottom-up"-Implementationsstrategien in Lehrerfortbildungen wird untersucht, wie Lehrkräfte Anregungen der Fortbildungsmaßnahme implementieren. Dabei wird erwartet, dass Erwartungen der Lehrkräfte dem Fortbildungsinhalt gegenüber auch dessen Implementation beeinflussen können. Für das Beispiel von Fortbildungsinhalten zur Rahmenkonzeption der sog. „Themenstudienarbeit" zeigen sich Anzeichen für Zusammenhänge zwischen Erwartungen zur Lernumgebung und Implementationsmerkmalen.*

ZDM-Classification: B59, C79, D49

1. Theoretical background

1.1 Findings on impacts of teacher training projects and strategies of implementation

One of the core goals of in-service teacher training programs is to improve instructional quality in mathematics classrooms. This goal can be described by the notion of *implementation* (cf. Euler & Sloane, 1998), which can be understood as the transfer of teacher training contents into the teachers' instructional practice. It is the teachers who can implement teacher training contents – this is why many teacher training programs focus on their instruction-related knowledge base, which is part of the professional knowledge (Bromme, 1992, 1997) of the participants. Even though full evidence of the relationships between professional knowledge and instructional practice remains lacking (Tillema, 2000; Lipowsky, 2004), a possible interpretation of the results Lipowsky (2004) reports in his overview on research on teacher learning projects appears to be that changes in professional knowledge play a role of necessary but not sufficient condition for changes in the instructional practice of mathematics teachers.

Teacher trainings provide learning opportunities for teachers related to their professional knowledge and practices. There is a widespread consensus that learning is not only a function of learning opportunities, but also of the use of the learning opportunities by the learners, which can be influenced by different factors like e.g. the previous knowledge or convictions of the individuals (cf. Helmke 2003, Fend, 1998). Consequently, in teacher trainings, professional knowledge and instruction-related beliefs in particular are likely to play a mediating role for learning and hence for impacts or for the success of teacher training programs. This mediating role between teacher training contents and implementational activities affecting instructional practice is modelled in Figure 1.

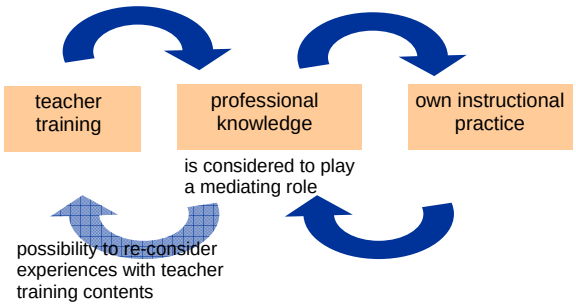

Fig. 1: Model for the role of professional knowledge for processes of implementation

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In order to structure different components of professional knowledge, we refer to Shulman's (1986, 1987) distinction between content knowledge, pedagogical knowledge and pedagogical content knowledge. Especially the third domain contains situation- and content-specific cognitions and beliefs which appear to be potentially very relevant to the teachers' making of instruction-related decisions (Malara, 2003; Escudero & Sanchez, 1999).

What do we know about the success of teacher training programs? Unfortunately, there is not a very broad range of quantitative empirical studies: in his overview, Lipowsky (2004) draws an outline of available research results and characteristics of teacher training programs that have turned out to be successful trainings. Success of teacher trainings can be analysed on four different levels of observation (cf. Lipowsky, 2004; Kirkpatrick, 1979): The first level of observation includes feedback by participating teachers e.g. with respect to the usefulness of the training project or self-reported changes in the teachers' classrooms. On a second level of observation, the development of professional knowledge can be analysed. The third level includes ratings of the teachers' actions in the classroom by external observers. Finally, there are studies treating possible impacts of teacher training programs on student achievement and other data linked to the learners, which can be identified as a forth level of observation. According to these four levels of observation, several properties of teacher training programs appear to be essential for noticeable positive effects: For instance, possibilities of cooperation and active learning in the in-service teacher training, the duration of the training and the content-specific focus are identified as central parameters for a positive development of the self-concept of teachers enrolled in in-service teacher training projects (cf. Garet et al., 2001, p 933). Smylie (1989, cited after Kennedy, 1998) reported in-service teacher trainings as being more effective in the perspective of teachers when the training was combined with own experiences in the classroom and cooperation with other teachers. There are several studies emphasising the role of professional knowledge for characteristics of instructional practice (Fennema et al., 1989; Staub & Stern, 2002; Peterson et al., 1989; Shulman, 1987; Stipek et al., 2001). Within the framework of in-service teacher training, the development of professional knowledge and particularly the change of instruction-related beliefs seems possible (Lipowsky, 2004; Barnett & Sather, 1992; for contrary findings: Tillema, 1995). For the development of professional knowledge, again, an active and cooperative learning role anchored in concrete contents appears to be an important characteristic for observable effects of teacher trainings. Kennedy (1998) and Lipowsky (2004) summarise that in-service teacher trainings concentrating on observable teacher action in the classroom had smaller effects on students' competence development than did have training programs focusing on the development of professional knowledge. This highlights the importance of giving adequate attention to professional knowledge when the implementation of teacher training contents is concerned. Moreover, an active role of the participating teachers combined with elements encouraging implementation in the own classroom seems to be an important characteristic of successful in-service teacher trainings.

A teacher training approach which promises to have effects on mathematics instruction consists in adopting so-called "bottom-up" implementation strategies (Gräsel & Parchmann, 2004). In contrast with "top down" implementation strategies, which consist mainly in the transmission of a given concept in the teachers' classrooms, "bottom-up" implementation strategies are characterised by an active and comparably autonomous role of the participating teachers in the conception and creation of activities of implementation. In the "bottom-up" concepts, the teachers are fostered to develop their instructional practice according to the aims of the teacher training, e.g. to create instructional elements according to the goals of the teacher training program.

Especially when teachers take an active part in the planning of classroom instruction corresponding to teacher training contents, their perceptions and expectancies towards the learning opportunities in the teacher training seem to be of primordial significance. In this manner, professional knowledge is likely to be a prerequisite for experimenting with contents of the teacher training in their classroom practice. If a teacher, for instance, perceives a contradiction between their instruction-related beliefs and contents of the teacher training, they might react differently to the teacher training project than teachers who see their beliefs in line with the aims of the training. If teachers are encouraged to develop and to experiment e.g. with a learning environment, their beliefs and expectations towards this learning environment are likely to have an influence on the way the learning environment is implemented. Such individual expectancies and beliefs are to be regarded as components of professional knowledge and pedagogical content knowledge (Shulman, 1986) in particular. Seen from this perspective, it seems probable that such expectancies are developed on the background of situation- and content-specific instruction-related beliefs of the teacher (Leinhardt & Greeno, 1986; Kuntze & Reiss, 2005) or more gen-

eral convictions about instructional quality (cf. Kuntze, 2004b).

As individual professional knowledge is expected to play an important role, quantitative evaluational research on teacher trainings adopting "bottom-up" implementation strategies encounters the methodological difficulties that, on the one hand, different teachers choose different ways of implementing the contents of the training and, on the other hand, their professional knowledge may develop differently, both according to previously existing instruction-related beliefs. Research on teacher trainings following a "bottom-up" approach often focuses on rather general aspects which are not dependent on the individual domain of implementation. For example, for the German SINUS project, which adopted a "bottom-up" implementation strategy, Ostermeier (2003) reported that participating teachers observed changes in their instructional practice and their professional development.

Summing up, "bottom-up" implementation strategies offer perspectives for success of teacher trainings in the domains of instructional practice and professional knowledge. However, the specificity of individual beliefs and expectancies regarding the teacher training contents as well as individually different domains of implementation activities set considerable limitations for evaluational research on such teacher trainings.

1.2 Implementation of the topic study method in mathematics classrooms as one of the goals of a teacher training project

For a quantitative study on teachers' expectancies and beliefs concerning contents of a teacher training and their role for the teachers' implementation activities, it is particularly useful to focus on a content with which the teachers have had no previous individual experience. In this way, the teachers' expectancies and beliefs are not influenced by previous experiences deriving from personal attempts of implementation of the content. For the teacher training project considered here, we concentrated on the so-called topic study method in mathematics instruction, because we could assume that this was a learning environment which was new to the teachers.

The topic study method is a framework for a student-centred learning environment (Kuntze, 2003, 2005; Kuntze & Ramm, 2005) based on a moderately constructivist learning model (Reinmann-Rothmeier & Mandl, 2001). The central elements of this learning environment are the following:

- The students are confronted with a mostly heterogeneous selection of different documents: short texts, diagrams, solutions of other students, articles, etc. These documents comprise of authentic contexts which are related to a mathematical concept or topic.
- The task of the students is to make sense of these documents, to establish links between them, to explore differences, to compare and to develop a deeper understanding of the mathematical concept in question or the facets of the mathematical topic.
- The students are required to prepare a work in this learning environment, e.g. a written description of what they have learned, a text summarising the topic, a paper or presentation supporting the personal point of view of the students, etc.

The topic study method allows a certain range of different possibilities for realisation in the classroom (cf. Kuntze & Ramm, 2005). When conceiving a topic study learning environment for a specific content and creating corresponding working materials, the teachers have to make several decisions influencing the character of the learning environment. Independent from the mathematical content referred to, there are two central aspects of the topic study method, namely (cf. Kuntze, 2003, 2005):

- The document-based working process of the students should not be pre-structured by small instructional steps within the documents, in order to support their authenticity and the autonomy of the learners.
- The documents being included should constitute a heterogeneous selection of authentically presented aspects, which stimulates comparisons, and even controversial discussion. This material should help the students to establish links between different areas of knowledge and to anchor mathematical concepts in different context domains.

One of the goals of the in-service teacher training project was to encourage the participants to introduce the topic study method in their classrooms and to conceive an own learning environment for this purpose. In this way, the teacher training followed the approach of a "bottom-up" implementation strategy. One of the prerequisites for this approach was the structure of the in-service teacher training project: there were two implementation phases between the three weekends of the training. These weekends were spaced out evenly during one school year. Like this, the teachers had time to develop their own learning environment (first implementation phase) and to collect experiences with this

learning environment in their classrooms (second implementation phase). The structure of the teacher training is shown in Figure 2. More detailed information about the teacher training is given in Kuntze (2004a, cf. also http://www.mathematik.uni.muenchen.de/~kuntze/kuntze/mubil-projekt/index.html).

For the teacher training, we anticipated that the expectancies of the teachers regarding the framework conception of the topic study method would influence its conception for the particular content chosen by the teachers and its implementation in their classrooms. According to the "bottom-up" implementation strategy, the teachers worked on different contents appropriate to the grade and the knowledge of their students. For this reason, the evaluational research concentrated on characteristics of implementation, independent of the mathematical content being treated in the learning environment. Two of these characteristics of implementation, namely "guidance by small-step task structure in documents" and "use of heterogeneous materials stimulating discussion" have been described above.

Summing up, the study focused on different initial beliefs and expectancies of the teachers concerning the topic study method as a content of the teacher training, the development of these beliefs until the time when practical experiences in the classrooms had been made, and characteristics of implementation of the learning environment.

2. Research questions

The study aims at providing evidence for the following research questions:

(i) How do teachers' expectancies regarding the learning environment evolve during the in-service teacher training project?

(ii) How do the teachers implement the topic study method?

(iii) Are there interdependencies between characteristics of implementation and the teachers' initial expectancies regarding the learning environment?

3. Design and sample

The sample of this study consisted of N=35 upper secondary mathematics teachers who answered paper-and-pencil questionnaires at the beginning and after the teacher training. These teachers were from Switzerland and Germany. As we did not find significant differences between the Swiss and German teachers regarding expectancies linked to the learning environment, we considered them as one sample.

The teacher training project had the structure described above. An overview on the structure of the evaluational research concerning the research questions of this study is given in Figure 2. The participating teachers were asked about their expectancies and beliefs concerning the learning environment at the beginning of the teacher training (immediately after having been informed about the conception of the topic study method) and after the teacher training (and its phases of implementation). In the questionnaires, a broad range of possible expectancies was included in order not to presuppose a too narrow perspective. The questionnaire contained indicator-like items for expectancies linked to the topic study method regarding the fostering of conceptual knowledge, the fostering of content-specific self-efficacy, an improved math-related verbal expression of the students, a better rooted and interconnected knowledge of the mathematical content area and the fostering of experiences in student-centred working techniques. The domains of the indicator items are also given in Figure 3. In the second questionnaire, additional Items about the individual implementation of the topic study method and about corresponding experiences were included (cf. Tab. 1; Figures 5 and 6).

Furthermore, at the end of each of the three teacher training weekends, the participating teachers were asked in feedback questionnaires about their overall perception of the practical value of the teacher training contents regarding the topic study method (cf. Fig. 4).

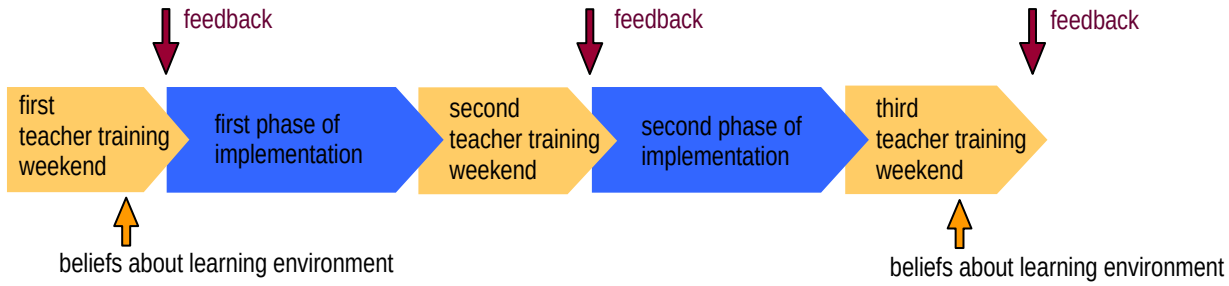

Fig. 2: Design of the study

4. Results

According to the "bottom-up" implementation strategy, the participating teachers developed learning environments for different subjects and different grades and made experiences with their implementation in their classrooms. Learning environments were developed for the following topics:

- Measurement (school year 5-7)
- Diagrams (school year 5-7 and 8-9 resp.)
- Calculation of percentage (school year 6)
- Dependence (school year 6-8)
- Symmetry (school year 7)
- Mistakes (school year 8-10 or 7 resp.)
- Functions (school year 9)
- Growth processes (from school year 10)
- Logarithm (school year 10)
- Limits (from school year 11 on)

In order to give evidence for the research questions, it was necessary to get an overview on predispositions in the domain of situation-specific convictions of the participating teachers. This overview was derived from a cluster analysis based upon the answers to the multi-criteria items on expectancies regarding the topic study method. A two-cluster solution (Ward method) leads to the results presented in Figure 3.

Figure 3 shows that for a smaller group of teachers initially holding slightly more moderate expectancies and beliefs on the learning environment, the expectancies were not as optimistic after the project as they were before the phases of implementation. In contrast, a larger group of teachers very optimistic before the phase of implementation seems to have developed even slightly more optimistic views. After the implementation phases there were highly significant differences between the two groups.

Fig. 4: Feedback on the applicability of the teacher training contents regarding the topic study method after the three teacher training weekends

The teachers' over-all perceptions of the practical value of the contents of the teacher training (focusing on the development of instructional materials, i.e. the topic study materials) are presented in Figure 4. Both clusters show a significant rise in the perceived applicability of the teacher training contents from the first to the third teacher training weekend, reaching on average the level of a "good" applicability.

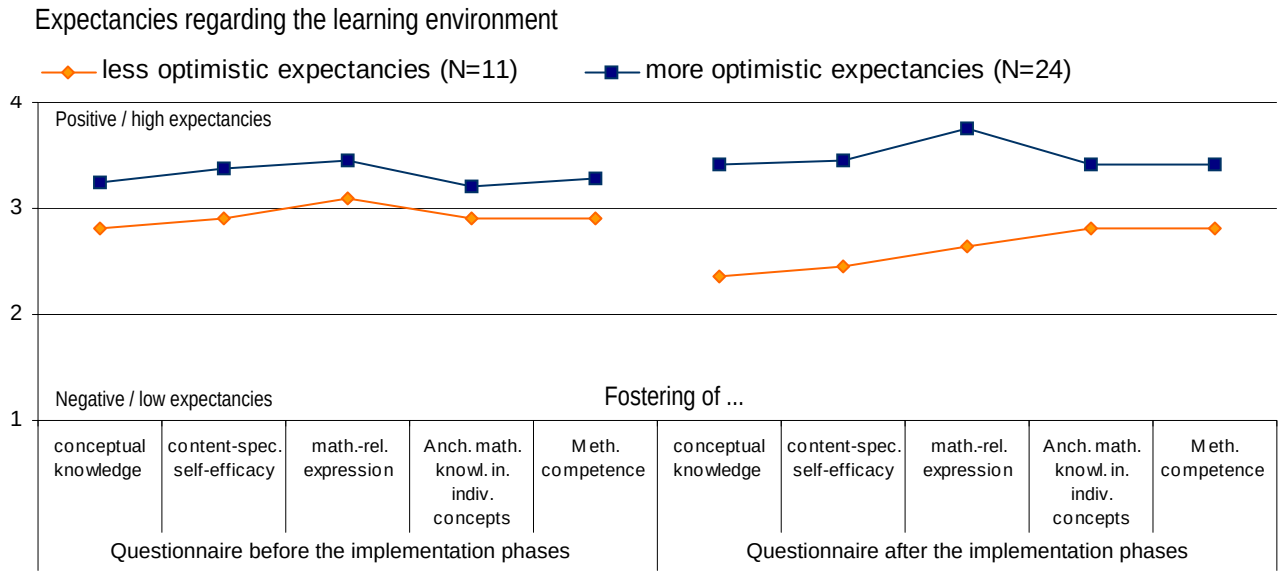

Fig. 3: Expectancies of the teachers (two-cluster solution) regarding the learning environment

The characteristics of implementation independent of math content, which were introduced in section 1.2, namely "guidance by small-step task structure in documents" and "use of heterogeneous materials stimulating discussion", are reflected in the scales contained in Tab. 1. Given the low number of items per scale, the reliability values are acceptable. The scales could also be confirmed by a factor analysis.

Scale	number of items	Cronbach's α
Additional guidance through small-step task structure in documents	2	.59
Use of heterogeneous materials stimulating discussion	2	.47

Tab. 1: Scales for reported characteristics of implementation

Figure 5 presents the results of the two scales for characteristics of implementation for the two clusters. Teachers with more optimistic expectancies reported a significantly more intensive use of heterogeneous materials stimulating discussion than did the less optimistic group of teachers. The less optimistic group of teachers shows a slightly stronger preference of small-step instructional guidance in their reported implementation of the topic study method.

In order to provide a rough insight into additional results regarding some other items concerning classroom experiences the teachers made in the phases of

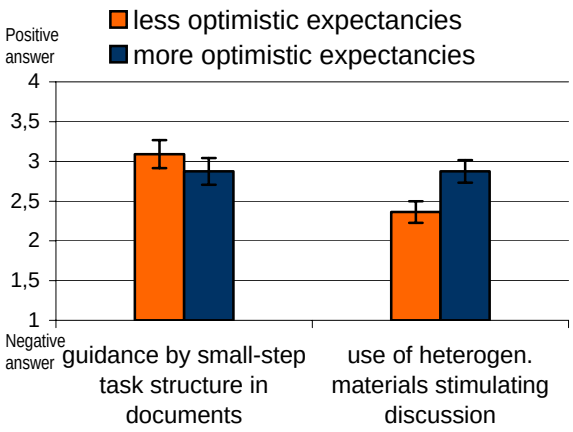

Fig. 5: Reported characteristics of implementation

implementation and views about the individual learning environments, cluster-specific means are shown in Figure 6. The tendencies seem to be consistent with the findings in Figures 3 and 5.

5. Discussion

After the presentation of the topic study method during the first teacher training weekend, the teachers showed moderately positive expectancies regarding these contents of the in-service teacher training project. Although the overall judgements on the applicability of the teacher training contents, i.e. the learning environment continued to improve throughout the training, we observed differential effects: As far as the relationships between beliefs and expectancies about the learning environment are concerned, the results can be interpreted as a

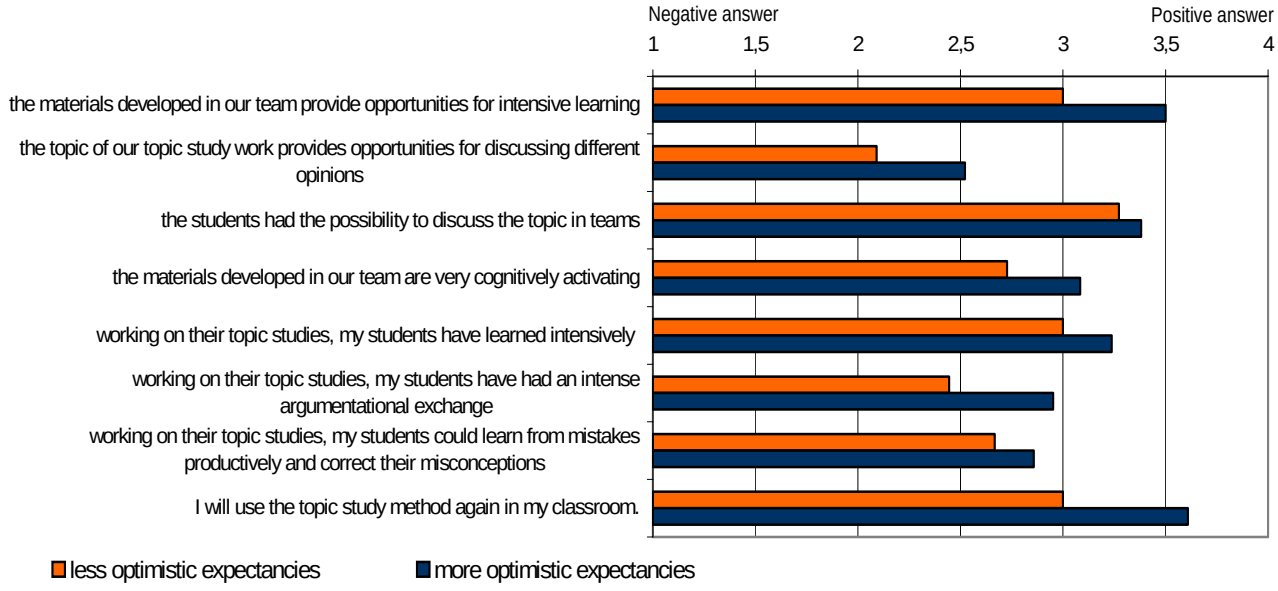

Fig. 6: Experiences regarding the implementation of the topic study method and additional evidence on reported characteristics of implementation (questionnaire at the end of the training)

Matthew effect: the (larger) cluster of teachers initially most appreciating the learning environment seems to have implemented the topic study method more consequently and had very positive beliefs on this content of the teacher training after its implementation. The other (smaller) cluster of teachers showed positive expectations as well, which receded after the implementation phase. It is possible that the teachers of this smaller cluster may have experienced a process, which might have been similar to the possible use of contents of many conventional in-service teacher trainings: initially positive expectations combined with an inconsequential implementation might have lead to a certain readjustment of beliefs, which could have resulted in lower expectancies linked to the learning environment. However, the ratings of the practical value of the teacher training contents (cf. Fig. 4) improved by the end of the teacher training project for both clusters. A possible interpretation could be that the first cluster showed a professional development in terms of a consequent implementation and a positive perception of the potentials of the learning environment, whereas the second cluster consisted of teachers who saw their high expectancies relativated by their experiences with a somewhat less consequent implementation of the topic study method. This second cluster of teachers kept moderately positive beliefs about the learning environment. This orientation might also have lead to the mainly positive answering of the Item, whether the teachers were aiming at using the topic study method again (cf. Fig. 6).

As is the case for many studies based on data from teacher questionnaires, the results have to be interpreted carefully, as the teachers' answers might be influenced by what the teachers assert to be a desired answer. This possible effect has to be taken into account especially when absolute values of the teachers' answering are being discussed. When considering differences between teachers' answers, it seems less probable that the validity of the results would be affected.

Accordingly, the results emphasise the importance of initial expectancies and beliefs for implementational activities of the teachers and for the success of teacher trainings under the condition of "bottom-up" implementation strategies. Further research is needed to explore how such expectancies develop and how they interdepend with other components of professional knowledge. It would be particularly interesting to investigate whether there are more general instruction-related orientations which might influence expectancies regarding particular teacher training contents.

To assist teachers with the implementation of innovations in their classrooms, it could be a central issue to develop the expectancies and beliefs regarding teacher training contents, e.g. in the form of showing them how, in a concrete classroom example, students profited from their work in a particular learning environment. Implementational activities of the teachers could also be supported by a coaching process including a cooperative planning of classroom instruction by a teacher and a trainer (cf. Staub, 2001).

Further research on interdependencies of professional knowledge and characteristics of implementation should also include ratings of implementational activities by external observers. For the data collected in this in-service teacher training project, an extended research, e.g. in the form of case studies, could include analyses of the materials developed by the teachers and their task structure, as well as feedback questionnaires on the learning environments filled in by the students who worked with the learning environment. Such research could help to assess the validity of self-reported characteristics of implementation and lead to more detailed hypotheses, how professional knowledge and instruction-related beliefs could influence the design of learning opportunities by mathematics teachers.

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