

## Improving science and mathematics instruction - the SINUS-project as an example for reform as teacher professional development

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**Improving Science and Mathematics Instruction - The  
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**Improving Science and Mathematics Instruction -  
The SINUS-Project as an Example for Reform as Teacher Professional Development**

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## **Improving Science and Mathematics Instruction - The SINUS-Project as an Example for Reform as Teacher Professional Development**

### **Abstract**

This article presents an example of teacher professional development based on a perspective of situated learning and implemented on a large scale. We consider teacher professional development from three perspectives. First, teacher professional development is a key factor in improving classroom instruction. Second, teacher professional development is a vehicle for conveying knowledge from research into classrooms. Third, teacher professional development is an object of research itself. A German project to improve science and mathematics teaching (SINUS) – comprising 180 schools in a pilot-phase and more than 1,700 schools in a second phase of scaling-up – serves as an example of this framework for teacher professional development. Using these three views we describe the foundations of the programme and provide a brief account of the programme's background and its conception. We show how the central elements of the programme (11 modules) are based on an in-depth analysis of science and mathematics education, as well as how those modules structure the professional development of the teachers. Finally, we provide an overview of the evaluation of the programme. A large-scale comparison between SINUS schools and a representative sample of German schools tested in PISA 2003 showed positive effects of the programme with regard to students' interest and motivation as well as competencies in science and mathematics. In the light of these findings, we argue that teachers' learning related to daily pedagogical challenges in the classroom should be central to all professional development initiatives.

## Introduction

Teacher professional development is often discussed as one of the key factors in improving educational systems. Teachers constitute the key group of professionals acting in educational systems. In the following we will consider teacher professional development from three perspectives.

First, teacher professional development plays a crucial role in improving classroom instruction. Teachers are directly involved in designing learning environments for their students. They provide learning opportunities for their students, and thus have a major impact on learning processes and outcomes. Obviously, teachers are the pivotal target group when it comes to improving the quality of schools, instruction, learning and understanding. In this respect the professional development of teachers should be related to professional standards (National Council of Teachers of Mathematics (NCTM), 1991; Oser, 1997). Besides these more or less normal demands, professional development could also foster teachers' competence to deal with and to solve educational problems in classrooms and schools.

Secondly, professional development can serve as a vehicle to convey research-based educational knowledge into classrooms. It must be emphasized that there is no simple and direct way to transfer findings and insights from research on learning, instruction and science and mathematics education into principles for acting in the classroom. Educational research provides background knowledge and tools for instruction. Educational research helps to identify problem areas of learning, teaching and schooling that could serve as a frame for professional development. Additionally, educational research can offer empirically-founded theories as scaffolds when teachers are tackling typical problems of their profession (Hiebert, Gallimore, & Stigler, 2002).

From a third perspective, teacher professional development itself is an important and interesting object of educational research. More or less obvious are the questions of how professional development programmes for teachers are designed, how they can be implemented, and what impact they have on the participating teachers as well as on their classrooms, schools, and students. Besides the research on aspects of implementation and evaluation studies, the effects of professional development on teacher expertise is of special relevance (Garet, Porter, Desimone, Birman, & Yoon, 2001; van Driel, Beijjaard, & Verloop, 2001).

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3 In the following these three views of teacher professional development will be discussed in  
4 more detail. The different perspectives played a decisive role in the design of a recent  
5 professional development programme in the field of mathematics and science instruction. The  
6 aim of the programme was to improve the quality of mathematics and science education in  
7 Germany as a reaction to the findings of TIMSS and PISA. As this programme – called the  
8 SINUS project - has been enlarged during recent years from a pilot study (including 180  
9 schools) to an extensive programme involving over 1,700 schools, it may serve as an example  
10 of a comprehensive attempt to improve the quality of education by means of teacher  
11 professional development. To classify the approach, two general directions of professional  
12 development can be discerned.  
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21 On the one hand, we find professional development programmes offered by institutes  
22 responsible for in-service teacher training. These institutionalized programmes comprise more  
23 or less conventional approaches to professional development and normally characterize the  
24 situation in many countries, including the U.S. or Germany (Sykes, 1996). This approach to  
25 professional development often attempts to transmit knowledge and skills by providing  
26 isolated training seminars dedicated to a specific topic. Often this kind of teacher professional  
27 development is regarded as less effective because it does not take into account the daily  
28 problems of classroom instruction.  
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36 On the other hand, there are professional development initiatives (among them the projects  
37 described in the articles of this special issue) that are related to educational reform (Beeth &  
38 Rissing, 2004; Krainer, 2005; Sykes, 1996; Tytler, 2007). These professional development  
39 programmes are often designed from a perspective of situated learning (Borko, 2004; Borko  
40 *et al.*, 2000; Putnam & Borko, 2000) and aim to relate teacher learning to the daily tasks of  
41 classroom instruction. The quality development programme that will be outlined in the  
42 following is best classified as an example of this second approach as well.  
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### 51 **Improving the Quality of Science and Mathematics Instruction: A Professional** 52 **Development Programme** 53

54 As an example of a programme for professional development that has been designed from a  
55 perspective of situated learning and that relates to reform as a problem-oriented change  
56 process to improve science and mathematics teaching, we will describe one approach taken in  
57 Germany in more detail. We discuss the programme using the three perspectives mentioned in  
58 the beginning:  
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3 First, professional development is considered a key factor for improving classroom  
4 instruction. In this section we will outline the foundations of the programme, give a brief  
5 account of the programme's background and its conception, discuss the role of teachers in the  
6 programme and illustrate how professional development is facilitated in the programme. Also  
7 we will highlight the educational context in which the professional development programme  
8 takes place.  
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14 Second, professional development is discussed as a vehicle for conveying knowledge from  
15 research into classrooms. We will outline how research-based knowledge contributed to the  
16 conception of the programme. We will show how the central elements of the programme, the  
17 eleven modules, are based on an in-depth analysis of science and mathematics education  
18 research, as well as how those modules structure the teacher professional development.  
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24 Third, professional development is regarded as an object of research itself. In this section we  
25 will provide an overview of the evaluation of the programme and of instruments that were  
26 used to assess the effects of the programme. We will address the following five questions: (1)  
27 Are the schools in the programme 'normal' schools? (Control of selection effects), (2) How  
28 did the teachers engage in the programme? (Acceptance studies), (3) What kind of support do  
29 teachers want? (Research on conditions for implementation), (4) What products and  
30 understandings did the teachers develop? (Analyses of products and processes) and (5) What  
31 did the students learn? (Studies of the effectiveness of the programme).  
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### 39 40 *Professional Development as a key to promote Quality Development*

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42 In this section, we give a structured overview of the programme. We will refer to four key  
43 elements of professional development suggested by Borko (2004): (a) The professional  
44 development programme; (b) the teachers, who are the learners in the system; (c) the  
45 facilitators, who guide teachers as they construct new knowledge and practices; and (d) the  
46 context in which the professional development occurs.  
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51 Thus, in the following we will present the background and basic conception of the  
52 programme, discuss the specific and central role teachers play in the programme, give an  
53 overview of the support structure and the people involved in facilitating the professional  
54 development of the teachers, and describe the specific educational context in which the  
55 programme takes place.  
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3 (a) The professional development programme: SINUS  
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5 Before describing the approach to professional development in the following section, we  
6 briefly describe the background of the programme. The responsibility for school teaching in  
7 Germany, as, for example, in the United States of America, lies within the administrative  
8 authority of each of the federal states ('Länder'). The Third International Mathematics and  
9 Science Study (TIMSS) (Beaton *et al.*, 1996a; Beaton *et al.*, 1996b) and German students'  
10 mediocre performance strongly aroused public interest. An effort to tackle the problematic  
11 findings was considered necessary.  
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18 Thus, the German federal government, in cooperation with the federal states, commissioned a  
19 group of experts to develop a framework in preparation for the set-up of a programme to  
20 increase the efficiency of mathematics and science instruction (Bund-Länder-Kommission für  
21 Bildungsplanung und Forschungsförderung, 1997). The programme conception was based  
22 upon an analysis of problem areas of German mathematics and science teaching (Baumert,  
23 Bos, & Lehmann, 1998; Baumert *et al.*, 1997; Bund-Länder-Kommission für  
24 Bildungsplanung und Forschungsförderung, 1997). The major goal of the programme is to  
25 improve classroom instruction in mathematics and science and, in doing so, to foster student  
26 learning and understanding, as well as motivation and interest in those domains. There are  
27 four central characteristics of the programme aimed at achieving those goals.  
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36 First, the programme refers to central problem areas in German mathematics and science  
37 teaching as pointed out, for example, by the TIMSS 1995 Video Study (Stigler & Hiebert,  
38 1997). The problem areas are conceptualized into 11 modules that provide a framework for  
39 improving classroom instruction (Table 1). Schools in the programme had to choose at least  
40 two modules to work on. Modules are not preformed teaching units or whole science or math  
41 programmes. Rather, they outline central aspects of the problem area and provide examples of  
42 how to overcome the identified shortcomings. Modules serve as a starting point and frame to  
43 improve teaching. They also help to categorize the documentation of processes and products  
44 (developed units, materials, etc.) and provide a shared language to facilitate communication  
45 about science and mathematics teaching. The choice of a system of modules also makes  
46 professional development adjustable to the specific local situation and problems at the  
47 participating schools.  
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Second, the programme introduces processes of quality development at the level of the participating schools. The teachers are encouraged to set their specific working goals, to develop new materials or modify existing approaches, and engage in self-evaluation methods that are easily applied to their classroom teaching. To ensure steady and sustainable improvement, teachers first are sensitized to typical problems in mathematics and science teaching. A culture of feedback is considered crucial in order to detect problems in the future and work on them. The programme seeks to draw upon the collective wisdom inherent in the communities of colleagues. In the long run, an enduring system to ensure the quality of teaching should develop at the school level.

Third, the programme's leading principle is cooperation and collaboration on different levels, especially between the teachers participating in the programme. In German schools, cooperation is rather uncommon (Terhart, 1987). Nonetheless, according to school effectiveness research, collaboration among teachers constitutes a main characteristic of effective schools (Sammons, 1999; Scheerens & Bosker, 1997). Also professional development initiatives prove to have the greatest effect if a group of colleagues from one school is engaged in the activities (Garet et al., 2001).

Fourth, the teachers' work is supplemented by support from science and mathematics educators and through research on learning and instruction. Teachers working on modules have access to scientifically-based materials and worked-out examples referring to the modules. There are also various possibilities for consultation and in-service training offered within the programme.

#### (b) Teachers as the learners in the system

Teachers are the one group of professionals who have immediate influence to improve learning environments in classrooms. Therefore, the best chance to increase student competencies and motivation is to devote a programme to the professional competencies of in-service teachers.

Different forms of teacher involvement exist in the programme. The basic level of involvement is the cooperative work of science and/or mathematics teachers at a particular school. That is, the smallest unit of cooperation is the subject department. This can be the physics, biology, chemistry or the mathematics department (or some combination, if two,

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3 three or four departments take part). In addition to cooperating at the school level, teachers  
4 work together across school boundaries. To foster this level of cooperation, the programme  
5 schools are organized into small school networks (school sets) of six schools each.  
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9 Teachers in the programme are seen as the experts in teaching and learning who are capable  
10 and responsible for further developing and improving their own classroom teaching. In order  
11 to do so, they have an array of problem areas (modules) with which they can frame their  
12 work, and they share their thoughts and ideas with their colleagues. The teachers, who are the  
13 learners in the programme, are seen as reflective practitioners (Schoen, 1987) who work in a  
14 self-directed and cooperative way.  
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21 (c) The facilitators, who guide teachers as they construct new knowledge and practices  
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23 The cooperative work of the teachers is supported on different levels. In each school, there is  
24 one person coordinating the programme activities at the school level. In addition, the schools  
25 are organized in small school networks. Each school network has at least one coordinator who  
26 gives technical support and guides and structures the classroom-related work of the teachers.  
27 Besides the coordination of the school networks, several support structures are located at the  
28 level of the participating federal states. Local district authorities and education ministries, as  
29 well as the states' in-service training institutes, serve as valuable assets for the infrastructure  
30 of the programme. Additionally, the people in charge of the programme in each state are  
31 encouraged to cooperate closely with faculty and staff of local universities and to utilize the  
32 knowledge and experience of science and mathematics educators and researchers studying  
33 learning and instruction.  
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43 As a result, staff responsible for teacher training are familiarized with the approach to  
44 professional development suggested by the programme – that is, teachers improving their own  
45 classroom teaching in a collaborative way over a longer period of time within a conceptual  
46 framework related to problem areas (modules) of science and mathematics teaching. Thereby  
47 the existing institutions of teacher training will experience a steady influence in the direction  
48 of a long-term and school-based professional development approach designed from a  
49 perspective of situated learning.  
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57 (d) The context in which the professional development occurs  
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59 The TIMS-study (Baumert et al., 1997; Beaton et al., 1996a; Beaton et al., 1996b) gained a  
60 high level of interest in German public discussion. This has been the most important reason

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3 for developing the programme SINUS. However, the professional development programme  
4 occurs in a special educational context that is characterized by following aspects:  
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8 - The general appreciation of mathematics and science and corresponding school subjects –  
9 or even school and education in general – is rather low in Germany. Often success and  
10 failure in mathematics and science subjects is only attributed to ability. Thus, efforts to  
11 improve one's competencies appear not to be worthwhile from the students' point of view.  
12  
13 - There is a high degree of individualism of teachers in German schools (Terhart, 2000).  
14 Most commonly the teacher is a "lone warrior" who almost never opens her or his  
15 classroom door in order to share teaching experiences with colleagues.  
16  
17 - There are almost no incentives to engage in professional development. Schools and  
18 districts do not have systematic requirements to participate in in-service-training.  
19 However, some federal states have started to make in-service professional training  
20 compulsory.  
21  
22 - Existing support systems tend to offer in-service-training without taking much account of  
23 teachers' needs. Professional development is seldom oriented towards the actual demands  
24 of teachers. Often "one-shot training" is offered that is not part of a coherent curriculum.  
25 Additionally, universities do not play a substantial role in teacher professional  
26 development.  
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38 In conclusion, there is a high level of need for professional development that takes into  
39 account the demands of daily classroom teaching and support systems that are demand-  
40 oriented. Instead of stand-alone training, in-service-training should be embedded into a  
41 classroom-related professional development structure that focuses on continuous  
42 development. The professional development approach outlined above takes those aspects very  
43 seriously and adheres to them in multiple ways.  
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52 *Professional Development as a Vehicle to convey Knowledge*  
53 *from Research into Classrooms*  
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56 The starting point for the teachers' work is the set of 11 modules. Findings from research on  
57 learning and instruction, educational psychology, and science and mathematics education are  
58 the foundations of the modules. Science and mathematics educators are engaged to support  
59 the professional development on various levels. The modules are a frame of reference for  
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3 support. Within the frame of the modules, written materials, in-service training or  
4 consultation is offered to the teachers developing their own classroom instruction. In the  
5 following we choose module 2 “Scientific inquiry and experiments” in order to (1)  
6 demonstrate how scientifically-based knowledge is introduced into the modules and to (2)  
7 show the ways teachers are introduced to the basic ideas of the modules.  
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12 (1) The foundation of each of the modules is a thorough analysis of the current state of the art  
13 of research in science and mathematics education and research on learning and instruction in  
14 general (Seidel & Shavelson, in press). Module 2 “Scientific inquiry and experiments” takes  
15 up the current academic discussion of scientific work and experiments and their effect in  
16 science classrooms (Seidel & Prenzel, 2006). The use of scientific inquiry and experiments in  
17 classroom learning has been studied thoroughly in science education. For instance, White and  
18 Frederiksen (1998) showed that students learning with an inquiry approach improved  
19 significantly on physics as well as inquiry assessments. Furthermore, positive effects on  
20 students’ attitude towards science could be observed (George & Kaplan, 1998). However,  
21 studies focussing on the role of student experiments do not yield such a clear picture. The  
22 mere implementation of student experiments does not seem to have a positive impact. Rather,  
23 the way in which experiments are embedded in classroom instruction and the way in which  
24 science is represented by inquiry and scientific investigations seems to be more crucial to  
25 student learning and attitudes (Harlen, 1999). In order to integrate experiments and scientific  
26 investigation and inquiry in classrooms with the goal of enhancing student thinking and  
27 deeper understanding, some principles can be drawn from research in science education  
28 (Harlen, 1999; Hofstein & Lunetta, 2004; White & Frederiksen, 1998):  
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- 43 - Experiments should be both challenging and thought-provoking. They also should  
44 stimulate students’ interests.
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46 - The students need to have a clear picture about the intention of the experiment.
- 47  
48 - The main objective for employing student experiments is learning and deeper  
49 understanding. Students have to deal with an idea and not just act upon or handle scientific  
50 equipment.
- 51  
52 - Students need to be given the choice to plan and interpret their own experiments.
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55 - Experiments should support students to work in a self-directed manner.
- 56  
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58 - Scientific inquiry and experiments should bring about experiences of competence for  
59 students.  
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3 (2) There are several ways in which teachers are introduced to the basic ideas of the modules.  
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5 Typically the group of teachers at a participating school chooses at least two to three modules  
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7 to work on. The teachers are not directly exposed to the research basis of modules. Rather,  
8  
9 they can access an array of module-specific support measures like basic written module  
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11 descriptions, module-related classroom material and in-service training-workshops.

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13 A first way to get acquainted with the idea of the module is through a basic written module  
14  
15 description. These papers include a very brief introduction to the problem area and its  
16  
17 empirical foundation. A description of possible shortcomings concerning the module is  
18  
19 typically followed by specific examples of how to overcome those problems in classroom  
20  
21 instruction. In module 2, for example, teachers are introduced to the principles concerning the  
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23 use of experiments mentioned above and get exemplary experiments which they can try out in  
24  
25 class and then exchange experiences with colleagues from their subject departments.

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27 Besides the basic module descriptions, there is of course a vast amount of module-related  
28  
29 reform-oriented material available to the teachers. There are many good examples provided  
30  
31 especially by science and mathematics educators from universities and teacher-training  
32  
33 institutes. The internet server of the programme plays a crucial role in managing and  
34  
35 providing this module-related information.

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37 Another important way to introduce teachers to the basic content of the modules is through in-  
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39 service training sessions. These sessions typically start with a brief introduction to the  
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41 module-specific ideas and their research base. A main focus, however, is to offer innovative  
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43 module-related examples that can be applied to classroom instruction. The basic idea is that  
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45 teachers try out new examples – often after adapting them to the specific classroom situation  
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47 they are confronted with – and share the experiences with the group of colleagues at the  
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49 school or school network level.

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51 In summary, modules serve as a frame of reference for teacher professional development and  
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53 support. They are based on current research on learning and instruction, especially in the  
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55 domains of science and mathematics education. Science and mathematics educators, as  
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57 experts on module-related topics, are engaged to support the teachers' work. As a result, a  
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59 network of support is being built throughout the country. Through the set of modules,  
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61 research-based knowledge can find its way into real classrooms. However, the route is not a  
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63 direct one. An important characteristic of the kind of professional development in the SINUS  
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65 programme is that it is oriented towards key problem areas. The teachers can locate their own

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3 crucial classroom-related problems within the frame of the modules and are then supplied  
4 with examples to help solve those problems.  
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8 *Professional Development as an Object of Research:*

9 *Evaluation of the SINUS-Programme*

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12 In this section, we present an overview of the research accompanying the professional  
13 development programme. We used different approaches for evaluation. We will refer not only  
14 to findings from these evaluations, but also to some reports of teachers' experiences with the  
15 programme that help to complete the picture.  
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20 In the following, we present a more problem-oriented overview of the findings of the research  
21 linked to the professional development programme. We will try to answer some questions that  
22 may be critical for the evaluation of the programme:  
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- 25  
26 - *Are the schools in the programme 'normal' schools? (Control of selection effects).* This  
27 question refers to the control of possible selection or sampling effects.  
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30 - *How did the teachers engage with the programme? (Acceptance studies).* The second  
31 question deals with the acceptance of the programme by the teachers. Acceptance is a  
32 necessary condition for success. We are also interested to learn the extent of teachers'  
33 agreement with the programme's philosophy and how they translate the programme into  
34 practice.  
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38 - *What kind of support do teachers want? (Research on conditions for implementation).*  
39 Most interesting for the management of the programme is information about conditions  
40 that foster or hamper the realization of important principles of the programme. For  
41 example we looked at the support the teachers wanted.  
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45 - *What products and understandings did the teachers develop? (Analyses of products and*  
46 *processes).* The success of the programme finally depends on the output. In this respect  
47 we looked at the materials the teachers developed themselves. Finally, an important aspect  
48 of investigation is the effects on the students.  
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52 - *What did the students learn? (Studies on the effectiveness of the programme).* This  
53 question deals with the major goal of the professional development programme: to  
54 increase student competencies and motivation in science and mathematics.  
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3 In the following we refer to these questions in describing the purpose of the investigation, the  
4 design of the study and methods used as well as the results. We end by drawing conclusions  
5 about each of the questions.  
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10 (a) Are the schools in the programme 'normal' schools? (Control of selection effects)  
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12 *Purpose of investigation.* Our first aim was to check the sample of schools. Professional  
13 development programmes may attract schools and teachers who are already more engaged in  
14 innovation than others. In order to disseminate the programme conception to a wider range of  
15 schools, it is important to rule out the hypothesis that the approach only worked because of  
16 more favourable conditions at the programme schools. Thus, we wanted to investigate  
17 whether the participating schools were a special sample with regard to classroom- and school-  
18 related preconditions. Relevant conditions refer to mathematics- and science-specific  
19 cognitive and motivational student variables at the school level, as well as more general  
20 student ratings about the school (e. g. school climate).  
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29 *Design of study.* 171 programme schools were tested in a first study in 2000 to answer these  
30 questions. The instruments were selected from our national extensions of the PISA study so  
31 that a comparison of SINUS-schools to a representative sample of German schools (PISA/E  
32 2000 - an extended PISA-sample) could be made.  
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*Results.* Our data show no meaningful differences between the PISA sample and the  
programme schools in the first assessment (year 2000) (Ostermeier, Carstensen, Prenzel, &  
Geiser, 2004). The schools did not differ with respect to resources, staff, programmes,  
experiences with innovations and school climate. Also we found comparable levels of  
interest, motivation and self-concept. Most importantly the programme schools did not  
systematically show a higher or a lower performance on the mathematics and science  
assessments.

*Conclusions.* Overall, the programme schools did not differ systematically compared to a  
nationally representative school sample. This result is an important prerequisite for the  
dissemination of the programme approach. It is more likely to successfully disseminate an  
approach tested in “normal” schools, whereas it would seem almost impossible to do this with  
an innovation tested only in the most excellent schools. In addition, the data from the first  
study will serve as a baseline for the investigation of changes in student competencies and  
interests towards the end of the programme.

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3 (b) How did the teachers engage in the programme? (Acceptance studies)  
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6 *Purpose of investigation.* The programme has been conceptualized by integrating research  
7 findings on school innovation and reform showing that changes of professional actions are  
8 most likely to occur when they are accepted by the main actors, the teachers. Also new  
9 approaches will work successfully not only if they are accepted, but when they become part of  
10 the professionals' routines (Anderson & Helms, 1999; Brown, 1997; Knapp, 1997; Stake,  
11 Burke, Flôres, Whiteaker, & Irizarry, 1997). Therefore, one goal was to study the extent to  
12 which the programme and its features are accepted by the target group, the teachers.  
13 Information on the acceptance level helps adjust the programme to the needs of the teachers  
14 and schools. So the acceptance study serves as formative evaluation.  
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22 *Design of the study.* Questionnaires were designed containing questions about the degree to  
23 which the teachers accept the programme and its goals. Specifically, items were designed to  
24 study how engaged the teachers are in the cooperative quality development, how the teachers  
25 accept the cooperation, how content they are with programme activities, and how they  
26 perceive the development of their professional competencies throughout the programme. The  
27 teachers were also asked to assess the quality of the support provided as well as to give an  
28 account of their actual use of this assistance.  
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35 Two surveys were conducted during the pilot phase of the programme. In 2000, a total of 557  
36 teachers, and in 2002, 527 teachers completed the questionnaire. Because of data protection  
37 regulations, data from the two points of measurement could not be linked on an individual  
38 level. However, data from both times can be compared using data aggregated at the school  
39 level (Table 2). Although the participating teachers were the main target group of the studies  
40 of acceptance, we additionally included other groups in our study, namely the principals of  
41 the schools, the coordinators, as well as small samples of parents and students from the  
42 schools.  
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49 *Results.* The results of both surveys suggest that participating teachers engage in programme  
50 activities to a high degree. In general, teachers invest a lot of time in cooperative quality  
51 development. The additional time spent on programme-related activities exceeds the amount  
52 of reduction of teaching load to a significant degree.  
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57 Teachers report exchanging programme-related materials, cooperative clarification of goals,  
58 working together on modules, cooperatively reflecting on teaching, and receiving as well as  
59 providing feedback on cooperatively-developed materials. Naturally, the frequency of those  
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3 activities is higher at the level of the schools. Cooperation at the level of the school networks  
4 takes place less often but is still remarkably high, bearing in mind the considerable effort  
5 needed to get together at this level.  
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9 In addition to the frequencies of cooperative quality development activities, we wanted to  
10 obtain indicators of how the teachers accept the cooperation within the programme, about  
11 how content they are with programme activities and about how they perceive developments  
12 throughout the programme. As a next step, we looked at how the teachers' ratings developed  
13 throughout the course of the pilot programme. Table 2 shows results for those three aspects  
14 for the two points of measurement: the surveys in 2000 (N = 557 teacher responses) and in  
15 2002 (N = 527) (Ostermeier, 2004). For comparison of the two points of time, data have been  
16 aggregated at the school level (scales with response categories from 'I strongly disagree' = 1  
17 to 'strongly agree' = 4).  
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26 - *Teachers' acceptance of cooperation.* Three aspects regarding cooperation in the  
27 professional development programme have been assessed (Table 2). Each aspect has been  
28 operationalized by a scale comprising three to seven items, with the first one referring to  
29 what degree teachers experience cooperation as being effective. The second scale includes  
30 items that assess to what extent the participants experience a gain for their professional  
31 work through cooperation. The last aspect deals with issues that could foster or hamper  
32 cooperation and is labelled "Unhampered cooperation". As Table 2 shows, teachers rate  
33 all three aspects rather positively. The ratings even increase in the second survey.  
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- 40 - *Teachers' contentedness with programme activities.* The next step was to study how  
41 content the teachers are with different aspects of the programme. For example, items  
42 referred to collaboratively developing and testing new approaches in classroom instruction  
43 (scale labelled "Appreciation of cooperative quality development") or getting new ideas  
44 for future classroom instruction. Two further scales related to the amount of additional  
45 work load through programme activities and the support and consultation provided by  
46 coordination on different levels. As in the ratings referring to the assessment of  
47 cooperation, teachers' answers were positive. Except for one scale ("Support and  
48 consultation"), the already positive ratings increase significantly in the second survey.  
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- 56 - *Teachers' perceived development throughout the programme.* We also wanted to  
57 investigate which changes the teachers experience throughout the course of the  
58 programme. More precisely, teachers were asked to rate how they perceive the  
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3 development of their own professional competencies, how they perceive improvement  
4 with respect to classroom instruction, and how they perceive the support and approval of  
5 programme activities from parents and colleagues not participating in the project. Again,  
6 ratings are significantly higher at the second measurement point. As in the two former  
7 areas, ratings are also very positive. However, there is one exception in this positive  
8 appraisal. Participating teachers rate the approval and acceptance of the programme  
9 expressed by non-participating colleagues and parents rather low. Although those ratings  
10 are significantly higher in 2002, they are still below the theoretical mean (2.5) of the scale.  
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20 INSERT TABLE 2 ABOUT HERE  
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25 *Conclusions.* In general, findings indicate engaged teachers. The acceptance of the  
26 professional development programme seems to be high. Also acceptance does not decrease  
27 over the course of the pilot phase.  
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30 However, an important group to work on seem to be parents and colleagues who are not or  
31 not yet involved in programme activities. Those groups form a proximal environment for the  
32 programme that might be crucial as an important supportive characteristic that may accelerate  
33 or hamper the professional development at the local level.  
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39 (c) What kind of support do teachers want? (Research on conditions for implementation)  
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41 *Purpose of investigation.* Information from the acceptance questionnaires can be interpreted  
42 as information on conditions for successful implementation of the programme. An important  
43 question in this respect is, for example, how teachers use and appreciate the offered support:  
44 What kind of support do teachers prefer or request? We also used the teacher questionnaires  
45 to ask some questions which could help us to identify conditions of a successful  
46 implementation of the programme. So we were interested to learn which conditions support or  
47 hamper the implementation of the central principles of the programme.  
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54 *Design of the study.* We also used the studies on acceptance in 2000 and 2002 to get feedback  
55 from teachers to optimize the support and for further guidance of the programme. Thus, in the  
56 questionnaires, teachers were asked to rate the extent to which they would need more of the  
57 following aspects: autonomy for programme work, supply of written materials, training  
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3 meetings, possibilities of mutual exchange, precise instructions, and a precise determination  
4 of the goals for the programme work at the school (Ostermeier & Prenzel, 2005).  
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7 *Results.* The requests for support do not point in a specific direction. Nearly one half of the  
8 teachers want more support concerning each item, whereas the other half long for less. The  
9 data structure seemed suitable for running a Latent Class Analysis, looking for different  
10 patterns or types of requests. With LCA we could identify three groups of teachers. Two  
11 groups had in common that teachers wanted to get more material and wished for more precise  
12 instructions and a precise determination of the goals for the programme. The third group  
13 emphasized the need for mutual exchange, whereas the level of request for materials or  
14 precise instructions and goal determination was rather low. This group of teachers seems to be  
15 in line with the philosophy of the programme. They request ideas and suggestions, but they  
16 want to explore new approaches by themselves (Ostermeier & Prenzel, 2005).  
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25 We also found important differences between these request-groups concerning the use of  
26 support, the time spent on programme activities, and the perception of local coordination. The  
27 third group of teachers seems to use the support offered to a higher degree and to spend more  
28 time on programme activities. Those teachers also rate the local coordination more positively  
29 (Ostermeier & Prenzel, 2005). In 2002, similar groups could be identified by LCA. The third  
30 group of teachers thereby increased in size (Prenzel & Ostermeier, 2006).  
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36 *Conclusion.* The results indicate that a key feature is the coordination at all levels (school, set,  
37 state). The request types especially show that coordination on the level of the federal states, as  
38 well as the coordination of the small school networks, is crucial. There are different  
39 coordination approaches in the federal states that seem to have an impact on the way teachers  
40 engage in the programme.  
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46 The different teacher groups seem to need different support and treatment in the programme.  
47 So we drew the attention of the coordinators to different styles of engagement and needs and  
48 sensitized the facilitators to carefully take account of these differences.  
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3 (d) What products and understandings did the teachers develop?  
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5 (Analyses of products and processes)  
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7 *Effects of modules.* We refer to effects of the framework supplied by the modules and to  
8 teachers' experiences with the programme. We also report an example with regard to what  
9 products the teachers developed.  
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12 *Experiences in the pilot phase.* Very interesting effects of the modules find expression in  
13 visible products. They can be found on the internet server of the programme – both the  
14 internal and external sites – but also in a large number of publications.  
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18 These products include the outlines, worked-out examples, and materials, which have been  
19 provided by the scientific managers of the programme. In addition, there are a large number  
20 of materials, teaching units, classroom projects, curricula, and collections of tasks that have  
21 been developed by the teacher groups in the schools. For example, a group of teachers  
22 working on Module 2 “Scientific inquiry and experiments“ developed a learning setting  
23 where students approach chemical phenomena by observing experiments in groups of three or  
24 four. Students are asked to describe their observations and think aloud about their ideas. The  
25 purpose of this setting is mainly to stimulate the students' pre-knowledge structures and to  
26 make their basic scientific ideas transparent so that further learning can be linked to them. The  
27 students' classroom interactions were videotaped and published on a CD along with  
28 comments that can be used to stimulate other teachers working on module two (Stamme &  
29 Stäudel, 2000).  
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40 With the support of local and central coordinators, a large portion of these materials is  
41 presented in a systematic module-specific way. A lot of these materials can be downloaded  
42 from the central internet server of the programme, as well as from the regional programme  
43 web pages of the participating federal states. The internet server is frequently used to gather  
44 information and to download module-related materials (Strecker, 1999). Also a huge amount  
45 of module-related approaches have found their way into written publications (Hertrampf,  
46 2003). In the two phases of scaling-up (2003-2007) we used the portfolio-method to support  
47 and evaluate teacher professional development (Barton & Collins, 1993; Craig, 2003; Tucker,  
48 Stronge, Gareis, & Beers, 2003). We designed a tool (subject department portfolio) that  
49 requires teachers of one school to collaboratively document and reflect on efforts to improve  
50 their teaching and to make their thoughts and developments accessible to others (Meentzen,  
51 Ostermeier, & Prenzel, 2006). About half the schools were randomly chosen and asked to  
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3 send in copies of their portfolio. The analyses of those portfolios promise to produce valuable  
4 insights into the products the teachers developed and the learning processes the teachers went  
5 through. Due to the vast amount of qualitative data results will be available after the scaling-  
6 up-project ended in 2007.  
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11 *Conclusions.* The experience in the programme indicates that a necessary condition for a  
12 professional development programme is to bring teachers into a situation where they have to  
13 invent new approaches very early. Therefore, we consider it crucial that they invent these new  
14 approaches in a very carefully-defined framework (modules), so that the chance that they  
15 might fail with new approaches is reduced to a minimum and the chance to experience  
16 success is increased. In this respect, the modules show very concrete ways to improve  
17 instruction step-by-step, and they increase the probability that changes can be integrated in  
18 teachers' routines.  
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27 (e) What did the students learn? (Studies on the effectiveness of the programme)

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29 *Purpose of investigation.* Besides the above-mentioned aspects of formative evaluation, we  
30 asked how we could study the effectiveness of the pilot programme (in the sense of a  
31 summative evaluation). It is an important but rather complicated issue to design the evaluation  
32 of a pilot programme in the field where 180 schools and around 1000 teachers are  
33 participating.  
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39 *Design of the study.* The programme schools were assessed with PISA instruments again in  
40 2003 (N=144 schools). As in 2000, we drew test items from the national extension of PISA  
41 2003. Instruments assess the students' mathematics and science competencies and their  
42 motivation. Thus, the design allows us to evaluate the progress, at the school and programme  
43 level, in the students' mathematics and science performance and interest, as compared to a  
44 national sample of schools not participating in the programme. Additional school and teacher  
45 questionnaires provide information on teacher cooperation, school programme and evaluation  
46 policies.  
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54 *Results.* The results of the 2003 comparison of SINUS and PISA-schools indicate that SINUS  
55 showed positive effects in all areas investigated. The teachers in SINUS schools report more  
56 cooperation activities at the school level. Students in SINUS schools perceived classroom  
57 teaching as being more cognitively activating. Both interest and competencies were higher in  
58 SINUS schools compared to PISA schools. These positive results however must be  
59 differentiated. Positive results were more pronounced in SINUS schools with lower school  
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3 tracks. Also the difference between SINUS-schools and PISA-schools is much higher in  
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5 science as compared to mathematics.  
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7 *Conclusions.* The analysis of the second study 2003 (after the end of the programme) yielded  
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9 valuable information concerning the most important criterion for success of professional  
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11 development programmes: the improvement of student competencies and the increase of  
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13 interest and motivation. The data suggest that especially students from lower track schools  
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15 seem to benefit to a high degree from an effort like SINUS. However, it is not trivial to  
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17 evaluate a professional development programme with hard measures when an implementation  
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19 strategy is applied that purposely offers a considerable number of degrees of freedom in order  
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21 to let teachers adapt their work to their local problem situations.  
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## 23 **Discussion**

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26 In this article, professional development is viewed as a key factor in improving classroom  
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28 instruction, a vehicle for conveying knowledge from research into classrooms, and an object  
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30 of research itself. The quality development programme to improve instruction of science and  
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32 mathematics in Germany presented here serves as an example to illustrate these three  
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34 perspectives of professional development. We refer to this categorization in our discussion.

35 *Professional development as a key factor to improve classroom instruction and to promote*  
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37 *quality development.* In this article, a professional development programme was outlined that  
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39 has certain key characteristics. The SINUS pilot programme employs a problem-oriented  
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41 approach to improve classroom instruction. Teachers are seen as the experts for instruction  
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43 who are capable of cooperatively improving their own teaching. They do this within a frame  
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45 of modules that refer to problem areas in German science and mathematics teaching and give  
46  
47 a structure for support measures. Altogether, the SINUS project is an example of a  
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49 professional development approach taking a perspective of situated learning. Teacher learning  
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51 is located as close as possible to the daily task of the profession, classroom instruction  
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53 (Borko, 2004; Borko et al., 2000; Putnam & Borko, 2000). The reaction from teachers and  
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55 facilitators for the SINUS programme has been very positive. The decision was made to  
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57 undertake the challenge of disseminating the approach to a larger number of schools. In a first  
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59 phase of scaling-up, about 750 schools in 13 German federal states participated in the  
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programme SINUS-Transfer. In a second phase of scaling-up (ending in July 2007), over  
1,700 schools have been involved in the programme. From August 2007 on, it is the federal  
states' responsibility to use the built-up infrastructure and competencies of networks,

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3 facilitators and teachers and to further disseminate the SINUS approach to more schools. The  
4 central question for this enterprise is how to disseminate experiences and processes - not only  
5 products and developed materials - to a larger group of schools and teachers. It is agreed that  
6 the key elements of the programme (cooperative development of classroom teaching, framed  
7 by modules) have to be retained. In a way new schools and teachers have to start their own  
8 development from the beginning. Even so, the dissemination programme as a whole has been  
9 in a headstart position. New schools and teachers could draw on a huge amount of experience  
10 and developments from the pilot period. For instance, SINUS-experienced teachers could take  
11 over facilitator functions, a network of science and mathematics educators used to the SINUS  
12 approach had been established, and a vast amount of materials had been developed to inspire  
13 the teachers' work.

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Another challenge of dissemination relates to the fact that the SINUS pilot-project was aimed at secondary science and mathematics instruction. For this reason, a programme started to transfer the approach to primary education. A special challenge is the fact that primary schools, in contrast to secondary schools in Germany, are not differentiated into performance-dependent school types. Another challenge lies in the fact that German primary teachers cannot rely on a very strong training in mathematical and science-related content knowledge.

*Professional development as a vehicle to convey knowledge from research into classrooms.*  
Transferring knowledge from mathematics, science and general education research into classrooms is considered a very significant problem. There is no direct way to accomplish this transfer. However, the SINUS approach tries to bridge this gap in building a support network where teachers can get help for their cooperative quality development. The problem-oriented way of working, using modules as a frame for development and support, seems to be a possible way to make the transfer of knowledge into practice more likely. Science and mathematics educators are increasingly recognized as holding helpful, scientifically-founded knowledge to foster quality development at the classroom level. However, teachers in general very carefully evaluate what they are offered, and it becomes apparent which educators are considered to give useful assistance for working on the modules.

*Professional development as an object of research itself.* Evaluation plays a crucial role in the programme. There are five questions we tried to answer that may be critical for the evaluation of the programme:

- Are the schools in the programme 'normal' schools? (Control of selection effects);

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- 3 - How did the teachers engage in the programme? (Acceptance studies);
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- 5 - What kind of support do teachers want? (Research on conditions for implementation);
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- 8 - What products and understandings did the teachers develop? (Analyses of products and
- 9 processes);
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- 12 - What did the students learn? (Studies on the effectiveness of the programme).
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14 So far the research in SINUS could be categorized as what Borko (2004) calls Phase 2  
15 research. In Phase 2, research focuses upon a single professional development programme  
16 that is enacted by several facilitators in several sites.  
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19 For research in SINUS, case studies focussing on a single site – for example, a group of  
20 teachers from one school’s subject department or one school network -- could lead to  
21 important additional insights into programme processes. These kinds of studies are  
22 categorized as Phase 1 research (Borko, 2004). Also interesting findings could be achieved in  
23 Phase 3 research, which compares different professional development programmes. In  
24 Germany, for example, there are professional development programmes on a national level  
25 that, in contrast to SINUS, do not primarily focus on classroom instruction in such a  
26 consequent manner. However, the same questionnaires have been used in one of these  
27 programmes making a comparison of teacher acceptance between the programmes possible.  
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30 SINUS seems to be a highly accepted programme that could be implemented in normal  
31 schools. The challenge, however, is to disseminate the approach. An important task in this  
32 respect is to foster the implementation of the specific ideas of the approach into the pre-  
33 existing support structures (institutes that offer conventional professional development).  
34 Institutes offering teacher training should increasingly take on a perspective of professional  
35 development that takes into view central problem areas of teaching and learning in science  
36 and mathematics. Central to all professional development initiatives should be teachers’  
37 learning related to daily pedagogical challenges in the classroom.  
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For Peer Review Only

Table 1: Programme modules:  
The table shows the module name, a short description of the module as well as the number of schools working on the module during the pilot phase – (N=180 schools)

| <i>Module</i>   | <i>Problem area and emphasis of the specific work package the module refers to</i>   |
|---|--|
| (1) Development of the task culture (114 schools)   | Aims at a larger variety of tasks used in mathematics and science instruction (e.g. tasks that allow different ways of solving them) in situations where a new concept or phenomenon is introduced and elaborated, as well as when knowledge or skills are practiced or applied to new cases or situations (Lampert, 1990).  |
| (2) Scientific inquiry and experiments (34 schools)   | Emphasizes more open forms of experiments that allow active student participation; discourse among students about research questions, hypotheses, planning and interpreting an experiment; and understanding of the nature of science (Harlen, 1999; Lunetta, 1998).   |
| (3) Learning from mistakes (33 schools)   | Claims that mistakes are essential in learning, but to be avoided in achievement situations (F. Oser, Hascher, & Spychiger, 1999). Students' conceptions and mistakes are viewed as opportunities for learning, using conceptual change strategies as powerful tools (Duit, & Treagust, 1998).   |
| (4) Securing basic knowledge – meaningful learning at different levels (47 schools)         | Training tools are developed to compensate for student weaknesses. Tasks that allow solutions on different levels are constructed and used. In general it is important to differentiate between levels of understanding that can be reached by students starting with different learning pre-requisites (Prawat, 1989).  |
| (5) Cumulative learning - making students aware of their increasing competency (39 schools) | Aims at higher coherence by linking the actual subject matter to the prior knowledge (principle of vertical linking). This module also stresses the differentiation and integration of conceptual knowledge in order to design cumulative teaching and learning sequences which make progress obvious for students.  |
| (6) Towards integrated features of mathematics and science instruction (37 schools)         | Aims at a better understanding of science phenomena by differentiating and linking the perspectives provided by the scientific disciplines, mathematics and other school subjects (DeCorte, Greer, & Verschaffel, 1996). In this multi-perspective instruction, more complex and meaningful applications of science can be treated and studied.  |
| (7) Promoting girls' and boys' achievement and interest (9 schools)                         | Focuses on gender differences in the development of interest and possibilities for support. For example, by establishing differential courses or by embedding the content to be learned in contexts which are especially interesting for girls, but also for boys (Hoffmann, 2002).  |
| (8) Development of tasks for co-operative learning (12 schools)                             | Students are stimulated to verbalize what they think, to argue and to deal with discrepant views and opinions, so that cooperative work will result in social learning as well as in cognitive gains (Linn, Songer, & Eylon, 1996).  |
| (9) Strengthening students' responsibility for their learning (15 schools)                  | Supports students' readiness and ability for self-regulated learning within the context of the particular subject. Problems and tasks are to be solved independently and various means of repeating previously-learned knowledge are to be explored as well as supporting strategies for the self-structuring and self-monitoring of learning.   |
| (10) Assessment: measuring and feedback on progress towards learning goals (14 schools)     | Takes into account that the kind of assessment is of utmost significance for the success of instruction (Black, 1998; Crooks, 1988). The aim is to develop assessment tasks that allow the evaluation of students' progress beyond routine knowledge, including linking the newly-acquired with the already-known and application of understanding gained in new contexts and situations (Ruiz-Primo, Schultz, Li, & Shavelson, 2001; White & Gunstone, 1992). |
| (11) Quality development within and across schools (22 schools)                             | Functions on a meta-level in attempting to develop the conditions and cultures in the participating schools which are necessary for the success of the programme. The aim is to develop standards for science and mathematics instruction that are also valid beyond the participating schools (National Council of Teachers of Mathematics (NCTM), 1995).   |

Table 2: Teacher acceptance and contentedness with the programme

Scales to assess teachers' acceptance of cooperation, contentedness with the programme and perceived development throughout the programme. Comparison of means (scales with response categories from 'I strongly disagree' = 1 to 'strongly agree' = 4) from two points of measurement: Results of one-sample t-tests (t-values, degrees of freedom, p-values, effect sizes d). For comparing results of two points of measurement, data from the surveys in 2000 (N = 557 teachers) and in 2002 (N = 527) have been aggregated on school level.

| Scale (number of items)   | 2000 |      | 2002 |      | t      | df  | P    | D    |
|---|------|------|------|------|--------|-----|------|------|
|   | M    | SD   | M    | SD   |        |     |      |      |
| <i>Teachers' acceptance of cooperation</i>                        |      |      |      |      |        |     |      |      |
| Effective cooperation (7)   | 3.14 | 0.51 | 3.29 | 0.45 | - 2.81 | 108 | <.01 | 0.27 |
| Gain through cooperation (3)                                      | 3.16 | 0.48 | 3.32 | 0.49 | - 3.11 | 107 | <.01 | 0.30 |
| Unhampered cooperation (3)  | 3.54 | 0.39 | 3.62 | 0.29 | - 2.24 | 106 | <.05 | 0.22 |
| <i>Teachers' contentedness with programme</i>                     |      |      |      |      |        |     |      |      |
| Appreciation of cooperative quality development (4)               | 3.49 | 0.33 | 3.63 | 0.31 | - 4.77 | 110 | <.01 | 0.45 |
| Positive impulses for future classroom instruction (3)            | 2.61 | 0.51 | 2.87 | 0.50 | - 4.68 | 108 | <.01 | 0.45 |
| No additional work load through programme activities (5)          | 2.76 | 0.50 | 3.07 | 0.38 | - 6.51 | 109 | <.01 | 0.62 |
| Support by coordination on different levels (4)                   | 3.02 | 0.51 | 3.09 | 0.45 | - 1.54 | 110 | Ns   | 0.15 |
| <i>Teachers' perceived development throughout the programme</i>   |      |      |      |      |        |     |      |      |
| Perceived development regarding own professional competencies (3) | 3.21 | 0.45 | 3.42 | 0.36 | - 5.05 | 110 | <.01 | 0.48 |
| Perceived improvement with respect to classroom instruction (3)   | 2.61 | 0.46 | 2.93 | 0.39 | - 7.38 | 108 | <.01 | 0.71 |
| Approval of programme activities from colleagues and parents (3)  | 2.01 | 0.42 | 2.28 | 0.39 | - 6.26 | 111 | <.01 | 0.59 |



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12 **Improving Science and Mathematics Instruction -**  
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18 Christian Ostermeier, Manfred Prenzel and Reinders Duit  
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## **Improving Science and Mathematics Instruction - The SINUS-Project as an Example for Reform as Teacher Professional Development**

### **Abstract**

This article presents an example of teacher professional development based on a perspective of situated learning and implemented on a large scale. We consider teacher professional development from three perspectives. First, teacher professional development is a key factor in improving classroom instruction. Second, teacher professional development is a vehicle for conveying knowledge from research into classrooms. Third, teacher professional development is an object of research itself. A German project to improve science and mathematics teaching (SINUS) – comprising 180 schools in a pilot-phase and more than 1,700 schools in a second phase of scaling-up – serves as an example of this framework for teacher professional development. Using these three views we describe the foundations of the programme and provide a brief account of the programme's background and its conception. We show how the central elements of the programme (11 modules) are based on an in-depth analysis of science and mathematics education, as well as how those modules structure the professional development of the teachers. Finally, we provide an overview of the evaluation of the programme. A large-scale comparison between SINUS schools and a representative sample of German schools tested in PISA 2003 showed positive effects of the programme with regard to students' interest and motivation as well as competencies in science and mathematics. In the light of these findings, we argue that teachers' learning related to daily pedagogical challenges in the classroom should be central to professional development initiatives.

## Introduction

Teacher professional development is often discussed as one of the key factors in improving educational systems. Teachers constitute the key group of professionals acting in educational systems. In the following we will consider teacher professional development from three perspectives.

First, teacher professional development plays a crucial role in improving classroom instruction. Teachers are directly involved in designing learning environments for their students. They provide learning opportunities for their students, and thus have a major impact on learning processes and outcomes. Obviously, teachers are the pivotal target group when it comes to improving the quality of schools, instruction, learning and understanding. In this respect the professional development of teachers should be related to professional standards (National Council of Teachers of Mathematics (NCTM), 1991; Oser, 1997; Darling-Hammond & Bransford, 2005, Darling-Hammond, 2006). Besides these more or less normal demands, professional development could also foster teachers' competence to deal with and to solve educational problems in classrooms and schools.

Secondly, professional development can serve as a vehicle to convey research-based educational knowledge into classrooms. It must be emphasized that there is no simple and direct way to transfer findings and insights from research on learning, instruction and science and mathematics education into principles for acting in the classroom. Educational research provides background knowledge and tools for instruction. Educational research helps to identify problem areas of learning, teaching and schooling that could serve as a frame for professional development. Additionally, educational research can offer empirically-founded theories as scaffolds when teachers are tackling typical problems of their profession (Hiebert, Gallimore, & Stigler, 2002; Hewson, 2007).

From a third perspective, teacher professional development itself is an important and interesting object of educational research. More or less obvious are the questions of how professional development programmes for teachers are designed, how they can be implemented, and what impact they have on the participating teachers as well as on their classrooms, schools, and students. Besides the research on aspects of implementation and evaluation studies, the effects of professional development on teacher expertise is of special relevance (Garet, Porter, Desimone, Birman, & Yoon, 2001; van Driel, Beijaard, & Verloop, 2001).

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3 In the following these three views of teacher professional development will be discussed in  
4 more detail. The different perspectives played a decisive role in the design of a professional  
5 development programme in the field of mathematics and science instruction. The aim of the  
6 programme was to improve the quality of mathematics and science education in Germany as a  
7 reaction to the findings of TIMSS and PISA. As this programme – called the SINUS project -  
8 has been enlarged during recent years from a pilot study (including 180 schools) to an  
9 extensive programme involving over 1,700 schools, it may serve as an example of a  
10 comprehensive attempt to improve the quality of education by means of teacher professional  
11 development. To classify the approach, two general directions of professional development  
12 can be discerned.  
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21 On the one hand, we find professional development programmes offered by institutes  
22 responsible for in-service teacher training. These institutionalized programmes comprise more  
23 or less conventional approaches to professional development and normally characterize the  
24 situation in many countries, including the U.S. or Germany (Sykes, 1996). This approach to  
25 professional development often attempts to transmit knowledge and skills by providing  
26 isolated training seminars dedicated to a specific topic. Often this kind of teacher professional  
27 development is regarded as less effective because it does not take into account the daily  
28 problems of classroom instruction.  
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36 On the other hand, there are professional development initiatives that are related to  
37 educational reform (Beeth, Duit, Prenzel, Ostermeier, Tytler, R., & Wickman, 2003; Beeth &  
38 Rissing, 2004; Krainer, 2005; Sykes, 1996; Tytler, 2007). These professional development  
39 programmes are often designed from a perspective of situated learning (Borko, 2004; Borko  
40 *et al.*, 2000; Putnam & Borko, 2000) and aim to relate teacher learning to the daily tasks of  
41 classroom instruction. The programme that will be outlined in the following is best classified  
42 as an example of this second approach as well.  
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### 51 **Improving the Quality of Science and Mathematics Instruction: A Professional** 52 **Development Programme** 53

54 As an example of a programme for professional development that was designed from a  
55 perspective of situated learning and that relates to reform as a problem-oriented change  
56 process to improve science and mathematics teaching, we will describe one approach taken in  
57 Germany in more detail. We discuss the programme using the three perspectives mentioned in  
58 the beginning.  
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### *Professional Development as a key to promote Quality Development*

In this section, we give a structured overview of the programme by employing the four key elements of professional development suggested by Borko (2004): (a) The professional development programme; (b) the teachers, who are the learners in the system; (c) the facilitators, who guide teachers as they construct new knowledge and practices; and (d) the context in which the professional development occurs.

#### (a) The professional development programme: SINUS

Before describing the approach to professional development in the following section, we briefly describe the background of the programme. The responsibility for school teaching in Germany, as, for example, in the United States of America, lies within the administrative authority of each of the federal states ('Länder'). The Third International Mathematics and Science Study (TIMSS) (Beaton *et al.*, 1996a; Beaton *et al.*, 1996b) and German students' mediocre performance strongly aroused public interest. An effort to tackle the problematic findings was considered necessary.

Thus, the German federal government, in cooperation with the federal states, commissioned a group of experts to develop a framework in preparation for the set-up of a programme to increase the efficiency of mathematics and science instruction (Bund-Länder-Kommission für Bildungsplanung und Forschungsförderung, 1997). The conception of the programme was based upon an analysis of problem areas of German mathematics and science teaching (Baumert, Bos, & Lehmann, 1998; Baumert *et al.*, 1997; Bund-Länder-Kommission für Bildungsplanung und Forschungsförderung, 1997). The major goal of the programme is to improve classroom instruction in mathematics and science and, in doing so, to foster student learning and understanding, as well as motivation and interest in those domains. There are four central characteristics of the programme aimed at achieving those goals.

First, the programme refers to central problem areas in German mathematics and science teaching as pointed out, for example, by the TIMSS 1995 Video Study (Stigler & Hiebert, 1997). The problem areas are conceptualized into 11 modules that provide a framework for improving classroom instruction (Table 1). Schools in the programme had to choose at least two modules to work on. Modules are not preformed teaching units or whole science or math programmes. Rather, they outline central aspects of the problem area and provide examples of how to overcome the identified shortcomings. Modules serve as a starting point and frame to improve teaching. They also help to categorize the documentation of processes and products

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3 (developed units, materials, etc.) and provide a shared language to facilitate communication  
4 about science and mathematics teaching. The choice of a system of modules also makes  
5 professional development adjustable to the specific local situation and problems in the  
6 participating schools. In which way these modules provided the framework for the work of  
7 the participating teachers and examples for the role the modules played in the practice of the  
8 work in the school sets is more fully described below.  
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17 INSERT TABLE 1 ABOUT HERE  
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21 Second, the programme introduces processes of quality development at the level of the  
22 participating schools. The teachers are encouraged to set their specific working goals, to  
23 develop new materials or modify existing approaches, and engage in self-evaluation methods  
24 that are easily applied to their classroom teaching. To ensure steady and sustainable  
25 improvement, teachers first are sensitized to typical problems in mathematics and science  
26 teaching. A culture of feedback is considered crucial in order to detect problems and work on  
27 them. The programme seeks to draw upon the collective wisdom inherent in the communities  
28 of colleagues. In the long run, an enduring system to ensure the quality of teaching should  
29 develop at the school level.  
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37 Third, the programme's leading principle is cooperation and collaboration on different levels,  
38 especially between the teachers participating in the programme. In German schools,  
39 cooperation is rather uncommon (Terhart, 1987). Nonetheless, according to school  
40 effectiveness research, collaboration among teachers constitutes a main characteristic of  
41 effective schools (Sammons, 1999; Scheerens & Bosker, 1997). Also professional  
42 development initiatives prove to have the greatest effect if a group of colleagues from one  
43 school is engaged in the activities (Garet et al., 2001). However, although collaboration  
44 certainly is a key feature of effective teacher professional development programmes it is  
45 claimed that teachers usually are not used to cooperative norms (Roth, 2007, 1236).  
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54 Fourth, the teachers' work is supplemented by support from science and mathematics  
55 educators and through research on learning and instruction. Teachers working on modules  
56 have access to scientifically-based materials and worked-out examples referring to the  
57 modules. There are also various possibilities for consultation and in-service training offered  
58 within the programme.  
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3 (b) Teachers as the learners in the system  
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5 Teachers are the group of professionals who have immediate influence to improve learning  
6 environments in classrooms. Therefore, the best chance to increase student competencies and  
7 motivation is to devote a programme to the professional competencies of in-service teachers.  
8

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10 Different forms of teacher involvement exist in the programme. The basic level of  
11 involvement is the cooperative work of science and/or mathematics teachers at a particular  
12 school. That is, the smallest unit of cooperation is the subject department. This can be the  
13 physics, biology, chemistry or the mathematics department (or some combination, if two,  
14 three or four departments take part). In addition to cooperating at the school level, teachers  
15 work together across school boundaries. To foster this level of cooperation, the programme  
16 schools are organized into small school networks (school sets) of six schools each.  
17

18 Teachers in the programme are seen as the experts in teaching and learning who are capable  
19 and responsible for further developing and improving their own classroom teaching. In order  
20 to do so, they have an array of problem areas (modules) with which they can frame their  
21 work, and they share their thoughts and ideas with their colleagues. The teachers, who are the  
22 learners in the programme, are seen as reflective practitioners (Schoen, 1987) who work in a  
23 self-directed and cooperative way. The teachers in the particular school sets decide which of  
24 the deficits of actual science and math instruction described by the 11 module in table 1 they  
25 want to address in their work. As mentioned already the work on developing and evaluating  
26 new teaching and learning methods provides many opportunities to rethink their normal views  
27 of good teaching and learning.  
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43 (c) The facilitators, who guide teachers as they construct new knowledge and practices  
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45 The cooperative work of the teachers is supported on different levels. In each school, there is  
46 one person coordinating the programme activities at the school level. In addition, the schools  
47 are organized in small school networks. Each school network has at least one coordinator who  
48 gives technical support and guides and structures the classroom-related work of the teachers.  
49 Besides the coordination of the school networks, several support structures are located at the  
50 level of the participating federal states. Local district authorities and ministries of education,  
51 as well as the states' in-service training institutes, serve as valuable assets for the  
52 infrastructure of the programme. Additionally, the people in charge of the programme in each  
53 state are encouraged to cooperate closely with faculty and staff of local universities and to  
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3 utilize the knowledge and experience of science and mathematics educators and researchers  
4 studying learning and instruction.  
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8 As a result, staff responsible for teacher training is familiarized with the approach to  
9 professional development suggested by the programme – that is, teachers improving their own  
10 classroom teaching in a collaborative way over a longer period of time within a conceptual  
11 framework related to problem areas (modules) of science and mathematics teaching. Thereby  
12 the existing institutions of teacher training will experience a steady influence in the direction  
13 of a long-term and school-based professional development approach designed from a  
14 perspective of situated learning.  
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21 (d) The context in which the professional development occurs  
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23 The TIMS-study (Baumert et al., 1997; Beaton et al., 1996a; Beaton et al., 1996b) gained a  
24 high level of interest in German public discussion. This has been the most important reason  
25 for developing the programme SINUS. However, the professional development programme  
26 occurs in a special educational context that is characterized by the following aspects. Clearly,  
27 most of these aspects are also well known in the context of other countries:  
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33 - The general appreciation of mathematics and science and corresponding school subjects –  
34 or even school and education in general – is rather low in Germany and elsewhere  
35 (Koballa & Glynn, 2007; Duit, Niedderer, & Schecker, 2007). Often success and failure in  
36 mathematics and science subjects is only attributed to ability. Thus, efforts to improve  
37 one's competencies appear not to be worthwhile from the students' point of view.  
38  
39 - There is a high degree of individualism of teachers in German schools (Terhart, 2000).  
40 Most commonly the teacher is a "lone warrior" who almost never opens her or his  
41 classroom door in order to share teaching experiences with colleagues (c.f. the above  
42 remarks on the necessity to guide teachers to close cooperation).  
43  
44 - There are almost no incentives to engage in professional development. Schools and  
45 districts do not have systematic requirements to participate in in-service-training.  
46 However, some federal states have started to make in-service professional training  
47 compulsory.  
48  
49 - Existing support systems tend to offer in-service-training without taking much account of  
50 teachers' needs. Professional development is seldom oriented towards the actual demands  
51 of teachers. Often "one-shot training" is offered that is not part of a coherent curriculum.  
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3 Additionally, universities do not play a substantial role in teacher professional  
4 development (c.f., Sykes, 1996).  
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8 In conclusion, there is a high level of need for professional development that takes into  
9 account the demands of daily classroom teaching and support systems that are demand-  
10 oriented. Instead of stand-alone training, in-service-training should be embedded into a  
11 classroom-related professional development structure that focuses on continuous  
12 development. The professional development approach outlined above takes those aspects very  
13 seriously and adheres to them in multiple ways as will be outlined more fully below. Briefly  
14 put there are the following key features: (1) Teacher cooperation as a basic principle of the  
15 programme; (2) a long term approach of professional development with a significant focus on  
16 classroom teaching instead of a one shot attempt.  
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27 *Professional Development as a Vehicle to convey Knowledge*  
28 *from Research into Classrooms*  
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31 The starting point for the teachers' work is the set of 11 modules. Findings from research on  
32 learning and instruction, educational psychology, and science and mathematics education are  
33 the foundations of the modules (e.g., Häußler, Bündler, Duit, Gräber, & Mayer, 1998). Science  
34 and mathematics educators are engaged to support the professional development on various  
35 levels. The modules are a frame of reference for support. Within the frame of the modules,  
36 written materials, in-service training or consultation is offered to the teachers developing their  
37 own classroom instruction. In the following we choose module 2 "Scientific inquiry and  
38 experiments" in order to (1) demonstrate how scientifically-based knowledge is introduced  
39 into the modules and to (2) show the ways teachers are introduced to the basic ideas of the  
40 modules.  
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49 (1) The foundation of each of the modules is a thorough analysis of the current state of the art  
50 of research in science and mathematics education and research on learning and instruction in  
51 general (Seidel & Shavelson, 2007). Module 2 "Scientific inquiry and experiments" takes up  
52 the current academic discussion of scientific work and experiments and their effect in science  
53 classrooms (Harlen, 1999; Hofstein & Lunetta, 2004; Tesch & Duit, 2004; Seidel & Prenzel,  
54 2006). The use of scientific inquiry and experiments in classroom learning has been studied  
55 thoroughly in science education. For instance, White and Frederiksen (1998) showed that  
56 students learning with an inquiry approach improved significantly on physics as well as  
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3 inquiry assessments. Furthermore, positive effects on students' attitudes towards science  
4 could be observed (George & Kaplan, 1998). However, studies focussing on the role of  
5 student experiments do not yield such a clear picture. The mere implementation of student  
6 experiments does not seem to have a positive impact. Rather, the way in which experiments  
7 are embedded in classroom instruction and the way in which science is represented by inquiry  
8 and scientific investigations seems to be more crucial to student learning and attitudes  
9 (Harlen, 1999). In order to integrate experiments and scientific investigation and inquiry in  
10 classrooms with the goal of enhancing student thinking and deeper understanding, some  
11 principles can be drawn from research in science education (Harlen, 1999; Hofstein &  
12 Lunetta, 2004; White & Frederiksen, 1998):

- 21 - Experiments should be both challenging and thought-provoking. They also should  
22 stimulate students' interests.
- 23 - The students need to have a clear picture about the intention of the experiment.
- 24 - The main objective for employing student experiments is learning and deeper  
25 understanding. Students have to deal with an idea and not just act upon or handle scientific  
26 equipment.
- 27 - Students need to be given the choice to plan and interpret their own experiments.
- 28 - Experiments should support students to work in a self-directed manner.
- 29 - Scientific inquiry and experiments should bring about experiences of competence for  
30 students.

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42 (2) As mentioned previously, the teachers of each participating school decide upon the focus  
43 of their work. There are several ways in which the teachers are introduced to the basic ideas  
44 of the modules. Typically the group of teachers at a participating school chooses at least two  
45 to three modules to work on. They can also access an array of module-specific support  
46 measures like basic written module descriptions (which also include brief summaries of  
47 research findings), module-related classroom materials and in-service training-workshops.

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A first way to get acquainted with the idea of the module is through the basic written module  
description. These papers include a brief introduction to the problem area and its empirical  
foundation. A description of shortcomings of "traditional" instruction addressed by the  
module is typically followed by specific examples of possibilities to overcome these problems  
in classroom instruction. In module 2, for example, teachers are introduced to the state of

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3 empirical research knowledge concerning the role and use of experiments outlined above and  
4 also how experiments may be used to make students familiar with the particular role of the  
5 experiments within the other science processes and within science inquiry. Exemplary  
6 experiments described in the basic description serve as examples teachers may use as  
7 “models” for designing their own experiments.  
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12 Besides the basic module descriptions, there is of course a considerable amount of module-  
13 related reform-oriented material available to the teachers. There are many “best practice”  
14 examples provided especially by science and mathematics educators from universities and  
15 teacher-training institutes. The internet server of the programme plays a crucial role in  
16 managing and providing this module-related information. However, a critical view is in place  
17 here. The work in the school sets of teachers showed that some of the material was too  
18 complicated and papers were too long for many teachers. Much guidance was necessary to  
19 allow the teachers to make fruitful use of the many materials provided. In other words,  
20 materials provided usually are used by teachers in their own ways. Davis and Krajcik (2005)  
21 point out that “educative” materials need to be provided, i.e., presentation of the materials  
22 should be closely linked with the intentions they were developed.  
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33 Another important way to introduce teachers to the basic content of the modules is through in-  
34 service training sessions. These sessions typically start with a brief introduction to the  
35 module-specific ideas and their research base. A main focus, however, is to offer innovative  
36 module-related examples that can be applied to classroom instruction. The basic idea is that  
37 teachers develop their views about good instruction by trying out new examples and sharing  
38 the experiences with the group of colleagues at the school or school network level.  
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44 In summary, modules serve as a frame of reference for teacher professional development and  
45 support. They are based on current research on learning and instruction, especially in the  
46 domains of science and mathematics education. Science and mathematics educators, as  
47 experts on module-related topics, are engaged to support the teachers’ work. As a result, a  
48 network of support is being built throughout the country. Through the set of modules,  
49 research-based knowledge can find its way into “normal” classrooms. However, the route is  
50 not a direct one. An important characteristic of the kind of professional development in the  
51 SINUS programme is that it is oriented towards key problem areas. The teachers can locate  
52 their own crucial classroom-related problems within the frame of the modules and are then  
53 supplied with examples that help to solve those problems.  
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*Professional Development as an Object of Research:*

*Evaluation of the SINUS-Programme*

In this section, we present an overview of the research accompanying the professional development programme. We used different approaches for evaluation that served different purposes. Means of formative evaluation played a significant role in order to support the work in the individual sets. In the following, we focus on findings of research linked to key features of the professional development programme. We will try to answer some questions that are essential for the evaluation of the programme:

- *Are the schools in the programme 'normal' schools? (Control of selection effects).* This question refers to the control of possible selection or sampling effects.
- *How did the teachers engage in the programme?* The second question deals with the acceptance and appreciation of the programme by the teachers. This is a necessary condition for success. We are interested, for instance, to assess the extent of teachers' agreement with the programme's philosophy and how they put the programme into practice.
- *What kind of support do teachers want? (Research on conditions for implementation).* Most interesting for the management of the programme is information about conditions that foster or hamper the realization of important principles of the programme. For example we looked at the support the teachers wanted.
- *What products and understandings did the teachers develop? (Analyses of products and processes).* The success of the programme finally depends on the output. In this respect we looked at the materials the teachers developed themselves. Finally, an important aspect of investigation is the effects on the students.
- *What did the students learn? (Studies on the effectiveness of the programme).* This question deals with the major goal of the professional development programme: to increase student competencies and motivation in science and mathematics.

In the following we refer to these questions in describing the purpose of the investigation, the design of the study and methods used as well as the results. We end by drawing conclusions about each of the questions.

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3 (a) Are the schools in the programme 'normal' schools? (Control of selection effects)  
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6 *Purpose of the investigation.* Our first aim was to check the sample of schools. Professional  
7 development programmes may attract schools and teachers who are already more engaged in  
8 innovation than others. In order to disseminate the programme conception to a wider range of  
9 schools, it is important to rule out the hypothesis that the approach only worked because of  
10 more favourable conditions at the programme schools. Thus, we wanted to investigate  
11 whether the participating schools were a special sample with regard to classroom- and school-  
12 related preconditions. Relevant conditions refer to mathematics- and science-specific  
13 cognitive and motivational student variables at the school level, as well as more general  
14 student ratings about the school (e.g. school climate).  
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22 *Design of the study.* 171 programme schools were tested in a first study in 2000 to answer  
23 these questions. The instruments were selected from our national extensions of the PISA  
24 study so that a comparison of SINUS-schools to a representative sample of German schools  
25 (PISA/E 2000 - an extended PISA-sample) could be made.  
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32 *Results.* Our data show no meaningful differences between the PISA sample and the  
33 programme schools in the first assessment (year 2000) (Ostermeier, Carstensen, Prenzel, &  
34 Geiser, 2004). The schools did not differ with respect to resources, staff, programmes,  
35 experiences with innovations and school climate. Also we found comparable levels of  
36 interest, motivation and self-concept. Most importantly the programme schools did not  
37 systematically show a higher or a lower performance on the mathematics and science  
38 assessments.  
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54 *Conclusions.* Overall, the programme schools did not differ systematically compared to a  
55 nationally representative school sample. This result is an important prerequisite for the  
56 dissemination of the programme approach. It is more likely to successfully disseminate an  
57 approach tested in “normal” schools, whereas it would seem almost impossible to do this with  
58 an innovation tested only in the most excellent schools. In addition, the data from the first  
59 study will serve as a baseline for the investigation of changes in student competencies and  
60 interests towards the end of the programme.

(b) How did the teachers engage in the programme?

*Purpose of investigation.* The programme has been conceptualized by integrating research findings on school innovation and reform showing that changes of professional actions are

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3 most likely to occur when they are appreciated by the main actors, the teachers, and become  
4 part of their professionals' routines (Anderson & Helms, 1999; Brown, 1997; Knapp, 1997;  
5 Stake, Burke, Flôres, Whiteaker, & Irizarry, 1997). Hence, investigating teachers' views of  
6 the intentions of the programme and their appreciation of the work within the sets also serve  
7 the purpose of formative evaluation, i.e. provide significant information on improving the  
8 actual work.  
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14 *Design of the study.* Questionnaires were designed containing questions about the degree to  
15 which the teachers appreciated the programme and its goals. Specifically, items were  
16 developed to study how engaged the teachers are in the cooperative quality development, how  
17 the teachers accept the cooperation, how content they are with programme activities, and how  
18 they perceive the development of their professional competencies throughout the programme.  
19 The teachers were also asked to assess the quality of the support provided as well as to give  
20 an account of their actual use of this assistance.  
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27 Clearly, questionnaires provide a somewhat limited picture of teachers' appreciation of the  
28 programme. But they are the only means to gain data that allow comparing the views of  
29 teachers in the participating sets all over Germany. Additional data on teacher appreciation  
30 are available on the level of the individual sets provided by various methods of formative  
31 evaluation (like protocols of meetings).  
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37 Two surveys were conducted during the pilot phase of the programme. In 2000, a total of 557  
38 teachers, and in 2002, 527 teachers completed the questionnaire. Because of data protection  
39 regulations, data from the two points of measurement could not be linked on an individual  
40 level. However, data from both times can be compared using data aggregated at the school  
41 level (Table 2). Although the participating teachers were the main target group, we  
42 additionally included other groups in our study, namely the principals of the schools, the  
43 coordinators, as well as small samples of parents and students from the schools.  
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49 *Results.* The results of both surveys suggest that participating teachers engage in programme  
50 activities to a high degree. In general, teachers invest a lot of time in cooperative quality  
51 development. The additional time spent on programme-related activities exceeds the amount  
52 of reduction of teaching load to a significant degree.  
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57 Teachers report exchanging programme-related materials, cooperative clarification of goals,  
58 working together on modules, cooperatively reflecting on teaching, and receiving as well as  
59 providing feedback on cooperatively-developed materials. Naturally, the frequency of those  
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3 activities is higher at the level of the schools. Cooperation at the level of the school networks  
4 takes place less often but is still remarkably high, bearing in mind the considerable effort  
5 needed to get together at this level.  
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9 As a next step, we looked at how the teachers' ratings developed throughout the course of the  
10 pilot programme. Table 2 shows results for those three aspects for the two points of  
11 measurement: the surveys in 2000 (N = 557 teacher responses) and in 2002 (N = 527)  
12 (Ostermeier, 2004). For comparison of the two points of time, data were aggregated at the  
13 school level (scales with response categories from 'I strongly disagree' = 1 to 'strongly agree'  
14 = 4).  
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21 - *Teachers' appreciation of cooperation.* Three aspects regarding cooperation in the  
22 professional development programme were assessed (Table 2). Each aspect was  
23 operationalized by a scale comprising three to seven items, with the first one referring to  
24 what degree teachers experience cooperation as being effective. The second scale includes  
25 items that assess to what extent the participants experience a gain for their professional  
26 work through cooperation. The last aspect deals with issues that could foster or hamper  
27 cooperation and is labelled "Unhampered cooperation". As Table 2 shows, teachers rate  
28 all three aspects rather positively. The ratings even increase in the second survey.  
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36 - *Teachers' contentedness with programme activities.* The next step was to study how  
37 content the teachers are with different features of the programme. For example, items  
38 referred to collaboratively developing and testing new approaches in classroom instruction  
39 (scale labelled "Appreciation of cooperative quality development") or getting new ideas  
40 for future classroom instruction. Two further scales related to the amount of additional  
41 work load through programme activities and the support and consultation provided by  
42 coordination on different levels. As in the ratings referring to the assessment of  
43 cooperation, teachers' answers were positive. Except for one scale ("Support by  
44 coordination on different levels"), the already positive ratings increase significantly in the  
45 second survey.  
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54 - *Teachers' perceived development throughout the programme.* Teachers were asked to rate  
55 how they perceive the development of their own professional competencies, how they  
56 perceive improvement with respect to classroom instruction, and how they perceive the  
57 support and approval of programme activities from parents and colleagues not  
58 participating in the project. Again, ratings are significantly higher at the second  
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3 measurement point. As in the two former areas, ratings are also very positive. However,  
4 there is one exception in this positive appraisal. Participating teachers rate the approval  
5 and appreciation of the programme expressed by non-participating colleagues and parents  
6 rather low. Although those ratings are significantly higher in 2002, they are still below the  
7 theoretical mean (2.5) of the scale.  
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19 *Conclusions.* In general, findings indicate engaged teachers. The appreciation of the  
20 professional development programme seems to be high. Also appreciation does not decrease  
21 over the course of the pilot phase. Two findings seem to be of particular relevance. First,  
22 teachers' appreciation of cooperation increases significantly during the work in the  
23 programme. Second, teachers rated their personal gain of participation significantly higher in  
24 the second survey.  
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31 (c) What kind of support do teachers want? (Research on conditions for implementation)  
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34 *Purpose of investigation.* Information from the above questionnaire on teachers' appreciation  
35 can be interpreted as information on conditions for successful implementation of the  
36 programme. An important question in this respect is, for example, how teachers use and  
37 appreciate the offered support: What kind of support do teachers prefer or request? We also  
38 used the above teacher questionnaires to ask some questions which could help to identify  
39 conditions of a successful implementation of the programme. We were, for instance,  
40 interested to learn which conditions support or hamper the implementation of the central  
41 principles of the programme.  
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49 *Design of the study.* We also used the data of the above studies in 2000 and 2002. Teachers  
50 were, for instance, asked to rate the extent to which they would need more of the following  
51 aspects: autonomy for programme work, supply of written materials, training meetings,  
52 possibilities of mutual exchange, precise instructions, and a precise determination of the goals  
53 for the programme work at the school (Ostermeier & Prenzel, 2005).  
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58 *Results.* The requests for support do not point in a specific direction. Nearly one half of the  
59 teachers want more support concerning each item, whereas the other half long for less. The  
60 data structure seemed suitable for running a Latent Class Analysis, looking for different



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3 patterns or types of requests. With LCA we could identify three groups of teachers. Two  
4 groups had in common that teachers wanted to get more material and wished for more precise  
5 instructions and a precise determination of the goals for the programme. The third group  
6 emphasized the need for mutual exchange, whereas the level of request for materials or  
7 precise instructions and goal determination was rather low. This group of teachers seems to be  
8 in line with the philosophy of the programme. They request ideas and suggestions, but they  
9 want to explore new approaches by themselves (Ostermeier & Prenzel, 2005).

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11 We also found important differences between these request-groups concerning the use of  
12 support, the time spent on programme activities, and the perception of local coordination. The  
13 third group of teachers seems to use the support offered to a higher degree and to spend more  
14 time on programme activities. Those teachers also rate the local coordination more positively  
15 (Ostermeier & Prenzel, 2005). In 2002, similar groups could be identified by LCA. The third  
16 group of teachers thereby increased in size after more experiences with the programme  
17 (Prenzel & Ostermeier, 2006).

18  
19 *Conclusion.* The results indicate that a key feature is the coordination at all levels (school, set,  
20 state). The request types especially show that coordination on the level of the federal states, as  
21 well as the coordination of the small school networks, is crucial. There are different  
22 coordination approaches in the federal states that seem to have an impact on the way teachers  
23 engage in the programme.  
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26 The different groups of teachers seem to need different support and treatment in the  
27 programme. Therefore, we drew the attention of the coordinators to different styles of  
28 engagement and needs and sensitized the facilitators to carefully take account of these  
29 differences.  
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32 (d) What products and understandings did the teachers develop?  
33 (Analyses of products and processes)

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35 *Effects of modules.* We refer to effects of the framework supplied by the modules and to  
36 teachers' experiences with the programme. We also report an example with regard to what  
37 products the teachers developed.  
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3 *Experiences in the pilot phase.* Very interesting effects of the modules find expression in  
4 visible products. They can be found on the internet server of the programme – both the  
5 internal and external sites – but also in a large number of publications.  
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9 These products include the outlines, worked-out examples, and materials, which have been  
10 provided by the scientific managers of the programme. In addition, there are a large number  
11 of materials, teaching units, classroom projects, curricula, and collections of tasks that have  
12 been developed by the groups in the schools. For example, a group of teachers working on  
13 Module 2 “Scientific inquiry and experiments“ developed a learning setting where students  
14 approach chemical phenomena by observing experiments in groups of three or four. Students  
15 are asked to describe their observations and think aloud about their ideas. The purpose of this  
16 setting is mainly to stimulate the students’ pre-instructional knowledge structures and to make  
17 their basic scientific ideas transparent so that further learning can be linked to them. The  
18 students’ classroom interactions were videotaped and published on a CD along with  
19 comments that can be used to stimulate other teachers working on module two (Stamme &  
20 Stäudel, 2000).  
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31 With the support of local and central coordinators, a large portion of these materials is  
32 presented in a systematic module-specific way. A lot of these materials can be downloaded  
33 from the central internet server of the programme, as well as from the regional programme  
34 web pages of the participating federal states. The internet server is frequently used to gather  
35 information and to download module-related materials (Strecker, 1999). Also a huge amount  
36 of module-related approaches have found their way into written publications (Hertrampf,  
37 2003). In the two phases of scaling-up (2003-2007) we used the portfolio-method to support  
38 and evaluate teacher professional development (Barton & Collins, 1993; Craig, 2003; Tucker,  
39 Stronge, Gareis, & Beers, 2003). We designed a tool (subject department portfolio) that  
40 requires teachers of one school to collaboratively document and reflect on efforts to improve  
41 their teaching and to make their thoughts and developments accessible to others (Meentzen,  
42 Ostermeier, & Prenzel, 2006). About half the schools were randomly chosen and asked to  
43 send in copies of their portfolio. The analyses of those portfolios promise to produce valuable  
44 insights into the products the teachers developed and the learning processes the teachers went  
45 through. Due to the large amount of qualitative data results will be available after the scaling-  
46 up-project ended in 2007.  
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59 *Conclusions.* The experience in the programme indicates that a necessary condition for a  
60 professional development programme is to bring teachers into a situation where they have to

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3 deal with new approaches very early. Therefore, we consider it crucial that they experience  
4 these new approaches in a carefully-designed framework (modules), so that the chance that  
5 they might fail with new approaches is reduced to a minimum and the chance to experience  
6 success is increased. In this respect, the modules show concrete ways to improve instruction  
7 step-by-step, and they increase the probability that changes can be integrated in teachers'  
8 routines.  
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15 (e) What did the students learn? (Studies on the effectiveness of the programme)

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18 *Purpose of investigation.* As a significant feature of the summative evaluation we asked how  
19 we could study the “effectiveness” of the pilot programme. As the about 1000 participating  
20 teachers from the 180 schools developed rather different new instructional approaches and  
21 materials such a study is rather difficult to design. We decided to use the framework of school  
22 effectiveness employed in the PISA studies. In particular, a sample of 144 SINUS schools  
23 became part of a national extension of the German PISA sample in 2000 and 2003 (Prenzel,  
24 Carstensen, Senkbeil, Ostermeier, & Seidel, 2005).  
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31 *Design of the study.* The programme schools were assessed with PISA instruments in 2000  
32 and again in 2003 (N=144 schools). Instruments assess the students' mathematics and science  
33 competencies and their motivation. In addition a set of items provides information on  
34 students' perceptions of their science and math instruction (e.g., on the role of everyday  
35 examples, the extend stimulating questions were asked, and how often challenging  
36 applications of science and math knowledge were provided). Thus, the design allows us to  
37 evaluate the progress, at the school and programme level, in the students' mathematics and  
38 science performance, interest, and perception of instruction experienced, as compared to a  
39 national sample of schools not participating in the programme. Additional school and teacher  
40 questionnaires provide information on teacher cooperation, school programme and evaluation  
41 policies.  
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51 *Results.* The results of the 2003 comparison of SINUS and PISA-schools indicate that SINUS  
52 showed positive effects in all areas investigated. The teachers in SINUS schools report more  
53 cooperation activities at the school level. Both student interest and competencies were higher  
54 in SINUS schools compared to PISA schools. Students in SINUS schools also perceived  
55 classroom teaching as being more cognitively activating. Hence, there is empirical evidence  
56 in our study that instruction actually changed in the desired direction in SINUS schools as  
57 compared to other schools.  
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3 These positive results however must be differentiated. Positive results were more pronounced  
4 in SINUS schools with lower school tracks. Also the difference between SINUS-schools and  
5 PISA-schools is much higher in science as compared to mathematics.  
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9 *Conclusions.* The analysis of the second study 2003 (after the end of the programme) yielded  
10 valuable information concerning the most important criterion for success of professional  
11 development programmes: the improvement of student competencies and the increase of  
12 interest and motivation. The data suggest that especially students from lower track schools  
13 seem to benefit from an effort like SINUS.  
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### 18 19 20 **Discussion** 21

22 In this article, professional development is viewed as a key factor in improving classroom  
23 instruction, a vehicle for conveying knowledge from research into classrooms, and an object  
24 of research itself. The quality development programme to improve instruction of science and  
25 mathematics in Germany presented here serves as an example to illustrate these three  
26 perspectives of professional development.  
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32 *Professional development as a key factor to improve classroom instruction and to promote*  
33 *quality development.* The SINUS programme presented here employs a problem-oriented  
34 approach to improve classroom instruction. Teachers are seen as the experts for instruction  
35 who are capable of cooperatively improving their own teaching. They do this within a frame  
36 of modules that refer to key problem areas in German science and mathematics teaching. The  
37 SINUS project is an example of a professional development approach taking a perspective of  
38 situated learning. Teacher learning is located as close as possible to the daily task of the  
39 profession, classroom instruction (Borko, 2004; Borko et al., 2000; Putnam & Borko, 2000).  
40 The reaction from teachers and facilitators for the SINUS programme has been very positive.  
41 The decision was made to undertake the challenge of disseminating the approach to a larger  
42 number of schools. In a first phase of scaling-up, about 750 schools in 13 German federal  
43 states participated in the programme SINUS-Transfer. In a second phase of scaling-up  
44 (ending in July 2007), over 1,700 schools were involved in the programme. From August  
45 2007, it is the federal states' responsibility to use the built-up infrastructure and competencies  
46 of networks, facilitators and teachers and to further disseminate the SINUS approach to more  
47 schools. The central question for this enterprise is how to disseminate experiences and  
48 processes - not only products and developed materials - to a larger group of schools and  
49 teachers. It is agreed that the key elements of the programme (cooperative development of  
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3 classroom teaching, framed by modules) have to be retained. In a way new schools and  
4 teachers have to start their own development from the beginning. Even so, the dissemination  
5 programme as a whole has been in a headstart position. New schools and teachers could draw  
6 on a huge amount of experiences and documents from the pilot period. For instance, SINUS-  
7 experienced teachers could take over facilitator functions, a network of science and  
8 mathematics educators used to the SINUS approach was established, and a large amount of  
9 materials was developed to inspire the teachers' work.

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11 A particular challenge of dissemination relates to the fact that the SINUS project aimed at  
12 secondary science and mathematics instruction. For this reason, a programme started to  
13 transfer the approach to primary education. A special challenge is the fact that primary  
14 schools, in contrast to secondary schools in Germany, are not differentiated into performance-  
15 dependent school types. Another challenge is the fact that German primary teachers cannot  
16 rely on a very strong training in mathematical and science-related content knowledge.

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18 *Professional development as a vehicle to convey knowledge from research into classrooms*  
19 Transferring knowledge from mathematics, science and general education research into  
20 classrooms is considered a very significant problem. There is no direct way to accomplish this  
21 transfer. However, the SINUS approach attempts to bridge this gap in building a support  
22 network where teachers can get help for their cooperative quality development. The problem-  
23 oriented way of working, using modules as a frame for development and support, seems to be  
24 a possible way to make the transfer of knowledge into practice more likely. Science and  
25 mathematics educators are increasingly recognized by teachers as holding helpful,  
26 scientifically-founded knowledge to foster quality development at the classroom level.  
27 However, teachers in general very carefully evaluate what they are offered, and it becomes  
28 apparent which educators are considered to give useful assistance for working on the  
29 modules.

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31 *Professional development as an object of research itself.* Formative and summative evaluation  
32 play a crucial role in the programme – first, to gain information on the “effects” of the  
33 programme but also to contribute to research on professional development in general. As is  
34 more fully outlined above, the findings of the various studies carried out provide reliable and  
35 valid research knowledge on professional development.

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37 In a nutshell, the SINUS programme seems to be a highly accepted programme that can be  
38 implemented in normal schools. The challenge, however, is to disseminate the approach. An  
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3 important task in this respect is to foster the implementation of the specific ideas of the  
4 approach into the pre-existing support structures (institutes that offer conventional  
5 professional development). Institutes offering teacher training should increasingly take on a  
6 perspective of professional development that takes into consideration key problem areas of  
7 teaching and learning in science and mathematics. Central to all professional development  
8 initiatives should be that teachers' learning is related to daily pedagogical challenges in the  
9 classroom.  
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16 The results of the evaluation presented paint a generally positive picture indicating  
17 considerable "success" of the programme. However, we are aware of a number of limitations  
18 – of the programme and the evaluation. The role of the parents in improving instruction needs  
19 more attention than we gave that issue so far. It has also to be taken into account in which  
20 way the teachers in a school who did not participate may be integrated. There are several  
21 cases of such teachers who kept to be sceptical and did not like to be part of the programme.  
22 Also the support materials used (especially the description of the modules) need to be  
23 considerably revised as they often were too long and too complicated for many teachers.  
24 Finally, we would like to briefly comment on a concern of the two reviewers of the present  
25 paper. They argued that our evaluation does not provide much information on changes of  
26 teachers' subjective theories about efficient teaching and learning science and math as well as  
27 about changes of their instructional behaviour. Clearly, these are essential features when  
28 evaluating programmes on teacher professional development. We admit that more data on  
29 these features would be most desirable. However, our studies on the effectiveness of the  
30 programme also include student data on their perception of instruction as outlined above.  
31 Further, teacher questionnaires used provide information in which way they perceived the  
32 way they changed views during participation.  
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47 We would like to add a few additional remarks. First, the approach of the SINUS programme  
48 was recently recommended as a model for improving science education in Europe (European  
49 Commission, 2007). Second, also in Germany the SINUS approach has become a "model"  
50 standing for renewed science and math education – on the levels of ministries of education,  
51 school administration, teacher education, the teachers, and research on teaching and learning.  
52 Third, the SINUS programme is a central part of various activities on various levels in  
53 Germany to improve science instruction. It provided, for instance, significant features adopted  
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3 by the programmes “Chemistry in Context”<sup>1</sup>, “Physics in Context”<sup>2</sup>, and “Biology in  
4 Context”<sup>3</sup> that deal with improving, chemistry, physics and biology instruction and have a  
5 strong focus on teacher professional development as well.  
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58 <sup>1</sup> [http://www.ipn.uni-kiel.de/abt\\_chemie/chik.html](http://www.ipn.uni-kiel.de/abt_chemie/chik.html) (29/07/2008)

59 <sup>2</sup> <http://www.uni-kiel.de/piko/> (29/07/2008)

60 <sup>3</sup> <http://bik.ipn.uni-kiel.de/> (29/07/2008)

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Table 1: Programme modules

The table shows the module name, a short description of the module as well as the number of schools working on the module during the pilot phase – (N=180 schools)

| <i>Module</i>   | <i>Problem area and emphasis of the specific work package the module refers to</i>   |
|---|--|
| (1) Development of the task culture (114 schools)   | Aims at a larger variety of tasks used in mathematics and science instruction (e.g. tasks that allow different ways of solving them) in situations where a new concept or phenomenon is introduced and elaborated, as well as when knowledge or skills are practiced or applied to new cases or situations (Lampert, 1990).  |
| (2) Scientific inquiry and experiments (34 schools)   | Emphasizes more open forms of experiments that allow active student participation; discourse among students about research questions, hypotheses, planning and interpreting an experiment; and understanding of the nature of science (Harlen, 1999; Lunetta, 1998).   |
| (3) Learning from mistakes (33 schools)   | Claims that mistakes are essential in learning, but to be avoided in achievement situations (Oser, Hascher, & Spychiger, 1999). Students' conceptions and mistakes are viewed as opportunities for learning, using conceptual change strategies as powerful tools (Duit, & Treagust, 1998).  |
| (4) Securing basic knowledge – meaningful learning at different levels (47 schools)         | Training tools are developed to compensate for student weaknesses. Tasks that allow solutions on different levels are constructed and used. In general it is important to differentiate between levels of understanding that can be reached by students starting with different learning pre-requisites (Prawat, 1989).  |
| (5) Cumulative learning - making students aware of their increasing competency (39 schools) | Aims at higher coherence by linking the actual subject matter to the prior knowledge (principle of vertical linking). This module also stresses the differentiation and integration of conceptual knowledge in order to design cumulative teaching and learning sequences which make progress obvious for students.  |
| (6) Towards integrated features of mathematics and science instruction (37 schools)         | Aims at a better understanding of science phenomena by differentiating and linking the perspectives provided by the scientific disciplines, mathematics and other school subjects (DeCorte, Greer, & Verschaffel, 1996). In this multi-perspective instruction, more complex and meaningful applications of science can be treated and studied.  |
| (7) Promoting girls' and boys' achievement and interest (9 schools)                         | Focuses on gender differences in the development of interest and possibilities for support. For example, by establishing differential courses or by embedding the content to be learned in contexts which are especially interesting for girls, but also for boys (Hoffmann, 2002).  |
| (8) Development of tasks for co-operative learning (12 schools)                             | Students are stimulated to verbalize what they think, to argue and to deal with discrepant views and opinions, so that cooperative work will result in social learning as well as in cognitive gains (Linn, Songer, & Eylon, 1996).  |
| (9) Strengthening students' responsibility for their learning (15 schools)                  | Supports students' readiness and ability for self-regulated learning within the context of the particular subject. Problems and tasks are to be solved independently and various means of repeating previously-learned knowledge are to be explored as well as supporting strategies for the self-structuring and self-monitoring of learning.   |
| (10) Assessment: measuring and feedback on progress towards learning goals (14 schools)     | Takes into account that the kind of assessment is of utmost significance for the success of instruction (Black, 1998; Crooks, 1988). The aim is to develop assessment tasks that allow the evaluation of students' progress beyond routine knowledge, including linking the newly-acquired with the already-known and application of understanding gained in new contexts and situations (Ruiz-Primo, Schultz, Li, & Shavelson, 2001; White & Gunstone, 1992). |
| (11) Quality development within and across schools (22 schools)                             | Functions on a meta-level in attempting to develop the conditions and cultures in the participating schools which are necessary for the success of the programme. The aim is to develop standards for science and mathematics instruction that are also valid beyond the participating schools (National Council of Teachers of Mathematics (NCTM), 1995).   |

Table 2: Teacher appreciation and contentedness with the programme

Scales to assess teachers' appreciation of cooperation, contentedness with the programme and perceived personal development throughout the programme. Comparison of means (scales with response categories from 'I strongly disagree' = 1 to 'strongly agree' = 4) from two points of measurement: Results of one-sample t-tests (t-values, degrees of freedom, p-values, effect sizes d). For comparing results of two points of measurement, data from the surveys in 2000 (N = 557 teachers) and in 2002 (N = 527) have been aggregated on school level.

| Scale (number of items)   | 2000 |      | 2002 |      | t      | df  | P    | D    |
|---|------|------|------|------|--------|-----|------|------|
|   | M    | SD   | M    | SD   |        |     |      |      |
| <i>Teachers' appreciation of cooperation</i>                      |      |      |      |      |        |     |      |      |
| Effective cooperation (7)   | 3.14 | 0.51 | 3.29 | 0.45 | - 2.81 | 108 | <.01 | 0.27 |
| Gain through cooperation (3)                                      | 3.16 | 0.48 | 3.32 | 0.49 | - 3.11 | 107 | <.01 | 0.30 |
| Unhampered cooperation (3)  | 3.54 | 0.39 | 3.62 | 0.29 | - 2.24 | 106 | <.05 | 0.22 |
| <i>Teachers' contentedness with programme</i>                     |      |      |      |      |        |     |      |      |
| Appreciation of cooperative quality development (4)               | 3.49 | 0.33 | 3.63 | 0.31 | - 4.77 | 110 | <.01 | 0.45 |
| Positive impulses for future classroom instruction (3)            | 2.61 | 0.51 | 2.87 | 0.50 | - 4.68 | 108 | <.01 | 0.45 |
| No additional work load through programme activities (5)          | 2.76 | 0.50 | 3.07 | 0.38 | - 6.51 | 109 | <.01 | 0.62 |
| Support by coordination on different levels (4)                   | 3.02 | 0.51 | 3.09 | 0.45 | - 1.54 | 110 | Ns   | 0.15 |
| <i>Teachers' perceived development throughout the programme</i>   |      |      |      |      |        |     |      |      |
| Perceived development regarding own professional competencies (3) | 3.21 | 0.45 | 3.42 | 0.36 | - 5.05 | 110 | <.01 | 0.48 |
| Perceived improvement with respect to classroom instruction (3)   | 2.61 | 0.46 | 2.93 | 0.39 | - 7.38 | 108 | <.01 | 0.71 |
| Approval of programme activities from colleagues and parents (3)  | 2.01 | 0.42 | 2.28 | 0.39 | - 6.26 | 111 | <.01 | 0.59 |