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articoli

How do German primary school teachers prepare students for science standards? Findings from a video study of the Professional Development Program *SINUS for Primary Schools*

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Abstract

Il programma di sviluppo professionale per le scuole primarie SINUS (2009-2013) ha l'obiettivo di migliorare la qualità dell'insegnamento di scienze e matematica nella scuola primaria. La ricerca qui presentata è stata coordinata e valutata dal Leibniz Institute for Science and Mathematics Education (IPN) di Kiel, in Germania. Hanno partecipato circa 870 scuole e 5440 insegnanti. In questo articolo si pone l'accento sui metodi scientifici utilizzati per l'istruzione primaria e si analizzano le strategie di attuazione in continuità con gli standard d'istruzione delle scienze nella scuola secondaria. I risultati presentati si riferiscono ai dati descrittivi estrapolati dai video di otto lezioni di docenti del SINUS e tre lezioni del gruppo di controllo. I risultati mostrano che i metodi scientifici orientati verso gli standard di scienze per la scuola secondaria si possono osservare anche nella scuola primaria. I risultati sono discussi in termini di apprendimento cumulativo e si soffermano sull'importanza di coordinare i contenuti educativi tra i diversi ordini di scuola.

Parole chiave: SINUS; standard; scienze; metodi; video.

Abstract

The German professional development program *SINUS for Primary Schools* (2009-2013) aimed to enhance the quality of science and mathematics instruction in primary schools. The implementation was coordinated and evaluated by the Leibniz Institute for Science and Mathematics Education (IPN) in Kiel, Germany. About 870 schools and 5440 teachers participated. In this article we take a closer look at the scientific methods in science instruction and analyse how these are implemented in instruction to address upcoming science standards in secondary school. The results presented refer to the descriptive video data from eight lessons of SINUS teachers and three lessons of teachers from a control group. The findings from the video study show that the scientific methods geared towards the standards in science for secondary school can also be observed in primary school. The results are discussed in terms of cumulative learning and the importance of coordinating educational content between different types of schools.

Keywords: SINUS; science standards; methods; video study.

1. Introduction

Educational standards are currently a “hot topic” in many countries, such as in Germany. Important issues in implementing standards are to inform and convince teachers about these standards, as well as to support them in considering standards in instruction and convert criteria into practice (BMBF, 2003). One aim of the program *SINUS for Primary Schools* is to inform teachers about educational standards and to enable them in using these in their every day school teaching. In the following, we describe how teacher professionalization was conducted in *SINUS for Primary Schools* and our reasons for analyzing scientific methods in science instruction. We then present the scientific methods required in secondary school science standards before we introduce the research questions and the methods. Finally, we report results and give a summary.

2. Enhancing the quality of mathematics and science instruction with SINUS

The results in the international large-scale assessment study “Third International Mathematics and Science Study” (TIMSS) marked the starting point of SINUS in 1998. Students’ mediocre findings (Beaton et al., 1996a; 1996b) indicated that there was a need for innovation according to science and mathematics instruction in Germany (Prenzel, 2000). An expert group developed a framework (BLK, 1997) for a German project named SINUS to improve science and mathematics teaching based on identified problem areas of German mathematics and science instruction. Thus, SINUS has a long tradition compared to other professional development programs. It was initially intended for secondary schools (1998-2007) but was also adapted for primary schools (2004-2013). *SINUS for Primary Schools* was the fourth and last SINUS program, which aimed to enhance the quality of science and mathematics instruction in German primary schools. It was conducted from 2009 to 2013 and implementation was coordinated and evaluated by the Leibniz Institute for Science and Mathematics Education (IPN) in Kiel, Germany. In total about 870 schools and 5440 teachers from 10 federal states in Germany participated in the program (Fischer & Rieck, 2014).

All SINUS programs are characterized by cooperation among teachers and between schools. Of course, research and new developments (i.e. educational standards) have been adapted to the professional development idea in SINUS over time. Nevertheless, the framework of the expert group, referred to as “modules” is still the basic concept of the program. Schools and teachers choose the modules most relevant to their needs or development areas. Modules are no detailed recipes for teaching, but are meant to provide impulses and a framework to improve teaching and instruction (Ostermeier, Prenzel & Duit, 2010). Schools and teachers are free to choose modules, content, and intensity of program work themselves to a large extend. The modules 1 to 3 contain important basic knowledge, thus beginners are encouraged to start with them. Meanwhile, the modules were modified for primary schools and five key objectives were added to meet with current trends in education, e.g. “implement educational standards”, “make science accessible” and “create transitions between primary and secondary school” (Figure 1). In the following section, we will emphasize these areas more closely.

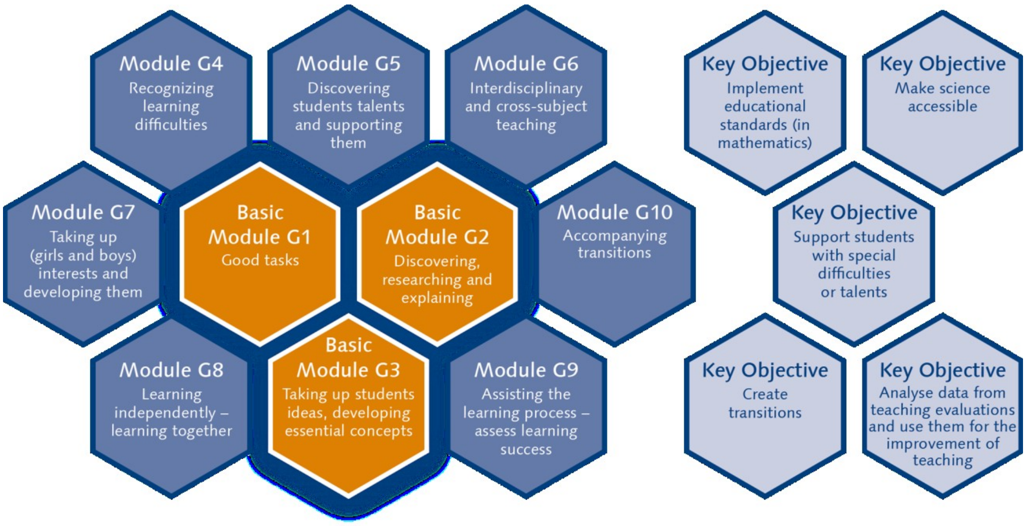

Figure 1. Ten modules and five key objectives in *SINUS for Primary School*.

3. Educational standards are important for cumulative learning

Implementing educational standards is currently a very important issue in the German education system. It is a far-reaching intervention and the success of the implementation depends to a high degree on how they are accepted and used among school principals and teachers (BMBF, 2003). Thus, it is a core challenge to inform and qualify those in charge in order to guarantee a transfer of educational standards into practice. For this reason implementing educational standards became a key objective in *SINUS for Primary Schools*. The SINUS program arranged teacher trainings and offered online materials (http://www.sinus-an-grundschulen.de) to familiarize teachers with educational standards and to support their work on making science accessible. Implementing educational standards is also relevant for students' transitions from primary to secondary school, because they define the competencies students are supposed to achieve on a certain level (BMBF, 2003). This offers transparency among teachers in both primary and secondary schools. This transparency is an important tool for teachers in order to enable students' cumulative learning. However, in science no educational standards for primary school exist in Germany. Hence, *SINUS for Primary Schools* alternatively provided science teachers with information about the Perspectives Framework offering concepts and contents in science for primary school (GDSU, 2013). This framework is an important contribution to the curricula debate in Germany.

Although findings in TIMSS 2011 show that German primary school students' competencies of science are on average of the OECD (Organisation for Economic Cooperation and Development) countries and above average of countries in the European Union (EU) (Bos, Wendt, Köller & Selter, 2012), there are some difficulties connected to the support of students' cumulative learning related to the transition from primary to secondary school. In most federal states in Germany, secondary school starts with 5th class. Regarding the creation of good transitions from primary to secondary school and enabling students' cumulative learning, the situation for science teachers is not as transparent as those for mathematics teachers. In primary school, "science" is only a part of a school subject called "Sachunterricht," which also concerns geographical, historical, technological, regional, social and cultural contents. This influences the science education and also the teachers' priority of science instruction within the subject Sachunterricht (Möller, Kleickmann & Lange, 2013). In addition, studies on transition problems from primary to secondary school report a downward trend in students' interest, as well as in physics achievement (Ohle, Fischer & Kauertz, 2011). Also, secondary school teachers report that they are uncertain of what they can expect from students coming from primary school (Hempel, 2010).Thus, it seems to be a lack of exchange about science content and scientific methods between the different school forms.

In science, there are no educational standards for primary school. However, in the Perspectives Framework (GDSU, 2013) scientific methods are mentioned as one important aim of primary school instruction. In regards to the educational standards for secondary school scientific methods are required in all three standards for biology (KMK, 2005a), chemistry (KMK, 2005b), and physics (KMK, 2005c). As an example (Figure 2) shows the scientific methods and competencies students should have acquired at the end of grade 10, listed in physics standards for secondary school (KMK, 2005c).

Scientific methods

- Observing and describing
- Comparing and systematization
- Explanation, modeling and hypotheses creating
- Experimentation, analysis and hypotheses testing
- Use models, describing relations and making generalizations

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Scientific activities

The students …

- describe phenomena and link them with known physical facts.
- select data and information from various sources in order to solve tasks and problems. The data is analyzed and classified
- use analogies and model concepts to obtain knowledge
- apply simple forms of mathematization
- make simple idealizations
- create hypotheses using simple examples
- carry out simple experiments according to instructions and draw conclusions from them
- plan and conduct simple experiments and document the results
- evaluating data obtained, where appropriate, through simple mathematical operations
- assess the validity of empirical results and their generalizations

Figure 2. Scientific methods and activities at the end of grade 10 in physics (KMK, 2005c).

These scientific methods are not identical in biology, chemistry or physics, yet all three subjects have in common that they refer to the categories "observing and describing", "finding and developing scientific questions", "systematizing, comparing and categorizing", "generalizing, using analogies and models", "exploring and experimenting", and "summarizing and evaluating" as important competencies students ought to reach in secondary school.

Due to the lack of primary school standards in science there remains an open question how well primary school prepares students to achieve competencies that are in line with educational standards in secondary school science. If primary school teachers use secondary school standards in their teaching, it is relevant for secondary school teacher to know. If they do know about the incorporated standards in primary school, they can avoid repeating content students already know and thereby optimize students' cumulative learning. Knowledge about how scientific methods are conducted and implemented in German primary school is needed because it is crucial for creating students' learning opportunities, and important information for teachers continuing science work in secondary school.

4. Research Questions

International and national video studies have shown that observing teaching practices and instruction in school gives us important information about instructional scripts and students' learning opportunities (Roth et al., 2006; Seidel et al., 2007). For professional development programs, classroom observation is a valuable research tool to obtain an impression of how program features are implemented in instruction. This was also a main focus in *SINUS for Primary Schools*. In general, very little is known about how science is actually taught according to educational standards and if certain activities in science instruction are in line with those standards. In this article, we take a closer look at the scientific methods in science instruction (grade 1-4) and analyse how these are used to address upcoming science standards in secondary school. It is also important to identify at what age level scientific methods are introduced to students. This indicates when teachers have confidence in their students' abilities and introduce them to certain scientific methods.

Within a lesson, different time frames are provided for certain interactions and working methods (Seidel et al., 2007). In primary school, lessons are organized differently from secondary school according to science (Möller et al., 2013). For instance, the "circle" (students and teacher sit in a circle and have open discussions more or less guided by the teacher) often used in primary school (Lotz, Lipowsky & Faust, 2013) hardly appears in secondary school physics classes (Seidel et al., 2007). Some classroom activities are more teacher-centred (like teacher talk, dictation, class discussion and circle), and some are more student-centred (individual work, partner and group work). These different settings might influence how students will be physically and cognitively activated in the instruction. Thus, classroom activities can determine students' possibilities to work on scientific methods and it is of great interest to investigate to which degree scientific methods go along with certain classroom activities. The research questions are: i) to what degree do teachers consider scientific methods that are in line with the secondary school standards in science and which scientific methods are most frequent?; ii) in which grade do scientific methods occur in German primary school science instruction?; iii) how are scientific methods implemented in the classroom activities?

5. Methods

In total about 870 schools and 5440 teachers participated in *SINUS for Primary Schools*. One research goal of the program was to evaluate if the mathematics and science instruction was in line with educational standards. As part of the scientific research within the study, 13 SINUS and 12 control group teachers participated voluntarily in a video study. The total sample consists of 39 videos of mathematics and science instruction recorded in German primary schools. The videos were collected from 2010 to 2013. During the program, SINUS-teachers were videotaped one to three times in their mathematics and/or science classes in order to determine their individual development and to collect video material for teacher workshops. The teachers decided for themselves whether they wanted to teach mathematics or science in the recordings. Some SINUS-teachers alternated between the two subjects and different grade levels from time to time. Thus, differences between the measurement points can be difficult to trace back to a professionalization development. Throughout the program SINUS-teachers were given two workshops with general suggestions on how they could work with their videos. The teachers in the control group were videotaped only once at the end of the program. They received their video with written information about "learning from observation" (Dalehefte & Kobarg, 2013) by mail.

The video study referred to in this article aims at analysing the science instruction (grade 1-4) and consists of eight videotaped lessons of four teachers in primary school within SINUS schools and three lessons of different teachers from a control group. Detailed information about the distribution of lessons, grade levels, teachers, recording per teacher and contents within the sample are summarized in Figure 3.

Lesson No.	Grade Level	Teacher No.	Rec. No.	Content of the lesson
1	3	1	1	Cherry blossom - anatomy of flowers
2	2	2	1	Water displacement
3	3	2	2	Soil samples, soil and water
4	4	3	1	Making and using magnifiers
5	3	3	2	Convection pinwheel
6	3	3	3	Surface tension of the water
7	1	4	3	Categorizing food according to specific criteria
8	4	1	3	Pond - adaption to the environment - local food chain
9	3	14	1	Aggregation states of water
10	4	15	1	Salt water as a living space - triops
11	1	16	1	Ants' olfaction - create a lavender perfume

Figure 3. Description of the video study sample (science).

The teaching units were videotaped according to standardized guidelines adapted from the IPN Video Study (Seidel, Prenzel & Kobarg, 2005) and adjusted to primary school instruction. We chose a two camera setting, with a lateral "zone of interaction camera perspective" and a frontal "whole class perspective" with an additional option to use a third camera when the class was divided to work in two rooms or outside. Because we were interested in how the SINUS concept influenced the instruction within the program, the teachers were free to set goals and topics themselves. Thus, the lessons were of different length and dealt with different subjects.

Video analyses

The video analyses on i) organizational activities and ii) scientific methods were conducted separately. For our purpose, we used the software Videograph (Rimmele,

2004) for transcribing and coding the videos in time-intervals (time sampling) of 10 (organizational activities) respectively 30 (scientific methods) seconds. We used a low inference category system, that is, we made fine-grained analyzes of teaching with strict coding rules that limit the scope for subjective influence (inference) of the persons coding. For the subsequent calculations, we matched the two data sets of the category systems by relating the 30 seconds intervals to the 10 seconds intervals. The intervals with missing values were replaced with the value of the foregoing interval. Thus, the findings reported refer to the level of 10 seconds intervals. This means that one interval represents 10 seconds of the video. In the following, we give an overview of the category systems (if more detailed information is desired, this can be requested from the authors).

Video analyses – organizational activities

The manual for coding the organization of classroom activities was substantially inspired by two well-known German projects: i) The IPN-Video Study concerning science teaching and learning in German physics classrooms (secondary school) (Seidel et al., 2005); ii) the video study in PERLE on personality and learning development of primary school children (Lotz et al., 2013). The disjunctive low inference category system (10 sec. intervals) in the study presented consisted of the 12 categories:

- 0= no activity
- 1= lecture by the teacher
- 2= dictation
- 3= class discussion
- 4= circle
- 5= play
- 6= silent/individual work
- 7= partner work (work in pairs)
- 8= group work
- 9= several methods at the same time
- 10= transition
- 11= other

The inter-rater reliability (Cohen's Kappa) for this category system was .99 (N=1261 observation intervals) (Kobarg, Dalehefte & Menk, 2012).

Video analyses – scientific methods

The low inference category system (30 sec. intervals) for coding scientific methods required in secondary school considered seven categories:

- 0= no method
- 1= observing and describing
- 2= finding and developing scientific questions
- 3= systematizing, comparing and categorizing
- 4= generalizing, using analogies and models
- 5= exploring and experimenting
- 6= summarizing and evaluating

These categories were not coded in a disjunctive manner because they were not supposed to appear independently. The observation systems used were both developed and tested on a pilot sample. The inter-rater reliability (Cohen's Kappa) ranged from .81 to 1. (N=584 observation intervals).

6. Findings from the video study in *SINUS for Primary Schools*

The results presented refer to descriptive data from the study and are limited to the small sample size and the lack of design and content standardization. Nevertheless, the study takes advantage of using an observational system to achieve a deeper understanding of how scientific methods are embedded in primary school science instruction. Most lessons in the sample are double lessons. On average, the lessons analyzed lasted 71 minutes (SD=21 minutes). The lessons conducted within the SINUS program are generally of a longer duration (M_{SINUS}=76 min., SD_{SINUS}=21 min.) than the lessons in the control group (M_{CG}=57 min., SD_{CG}=17 min.). In total, the control group constituted 22% of the time considered in this sample. We are only focusing on intervals during lessons when teaching took place and do not refer to activities before lesson began or after the lesson was ended. First, we refer to the first research question concerning to what degree teachers consider scientific methods in line with the secondary school standards in science. Second, we take a closer look at the scientific methods from grade 1 to 4. Third, we report how these are implemented in the classroom.

Use of scientific methods in primary schools

To get a first impression of how often scientific methods are used in science instruction in primary school, we analysed the frequencies of the 10 seconds intervals coded. How the intervals are distributed, according to the scientific methods, is presented in Figure 4.

	Observing and describing	Finding and developing scientific questions	Systemati-zing comparing and categorizing	Generalizing using analogies and models	Exploring and experi-menting	Summa-rizing and evaluating
Total number	639 (100%)	851 (100%)	389 (100%)	495 (100%)	2279 (100%)	908 (100%)
SINUS	522 (82%)	615 (72%)	389 (100%)	492 (99%)	1721 (76%)	771 (85%)
Control group	117 (18%)	236 (28%)	0 (0%)	3 (1%)	558 (24%)	137 (15%)

The categories are not disjunctive and can appear at the same time in instruction

Figure 4. Distribution of scientific methods (N=5560, 10 sec. intervals) in the sample.

Figure 4 shows that all categories of scientific methods appeared in the SINUS sample. In the control group we found scientific methods as well, except for the two categories "systematizing, comparing and categorizing" (0%), and "generalizing, using analogies and models" (1%). It is also obvious that the category "exploring and experimenting" seems to have an outstanding role in both groups. At a first glance, more methods occur in SINUS. But we have to keep in mind the limitation of the small sample and the explorative character of the study when we are interpreting the results. We conclude that the primary school students in both groups learn scientific methods that are in line with secondary school standards in science. Thus, we will from now on take a look at both groups together.

Scientific methods in primary school from grade 1 to 4

Second, we assumed that the scientific methods teachers choose probably depend on the age of their students and what they would expect them to understand cognitively. We were interested in the point of time when primary school students begin to learn scientific methods and therefore we took a closer look at what school level certain scientific methods occur.

Scientific methods	Grade 1	Grade 2	Grade 3	Grade 4
Observing and describing	0 %	22,4%	61,7%	15,9%
Finding and developing scientific questions	14%	8,4%	44,2%	33,3%
Systematizing, comparing and categorizing	52,3%	0%	43,8%	3,8%
Generalizing, using analogies and models	0,6%	2,4%	82,4%	14,5%
Exploring and experimenting	3%	12,3%	57,8%	26,9%
Summarize and evaluate	8,2%	3,9%	56,9%	30,9%

Figure 5. Scientific methods in primary school grade 1 to 4.

Figure 5 shows that scientific methods are incorporated from the very beginning in science classes. Beginners at grade 1 in science are above all mainly presented with “systematizing, comparing and categorizing” and “finding and developing scientific questions”. But we also find that older students from grade 3 and onward meet with scientific methods more often and that the scientific methods get more sophisticated. As a result, our sample indicates, that scientific methods in science are introduced at an early stage in primary school and continued and expanded to grade 4.

Implementation of scientific methods in the classroom

In order to understand more accurately how scientific methods are implemented in the classroom, we wanted to know more about the classroom activities, which were used to realize the scientific methods. Figure 6 shows in which kind of classroom activities scientific methods were applied. The categories “dictation”, “play” and “several methods at the same time” were excluded from the figure, because these activities didn’t occur at all within our science sample.

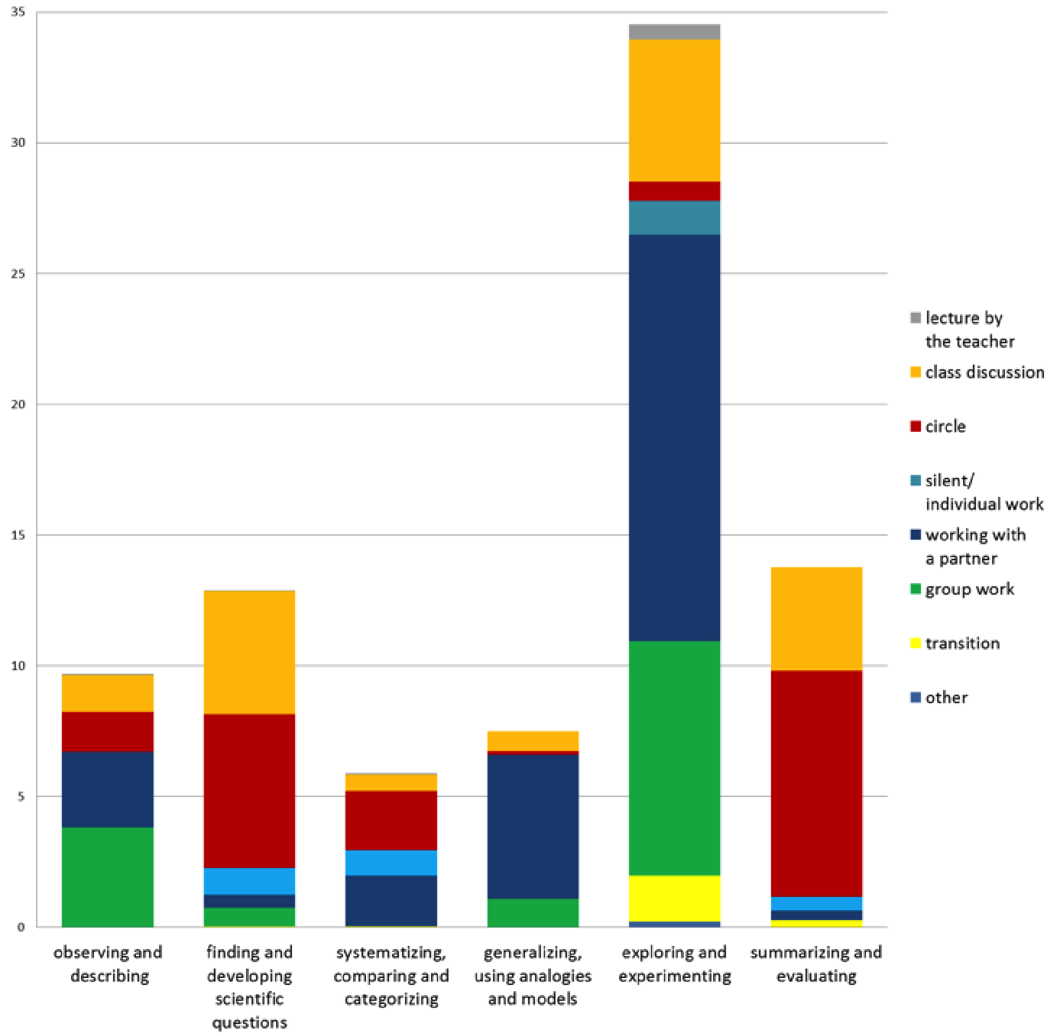

Figure 6. Scientific methods in different settings (on average, in minutes).

Figure 6 shows the distribution of scientific methods (in minutes), but additionally demonstrates that in principle, all scientific methods can occur in many different settings. On average, we found students "observing and describing" primarily in group work (39%) and partner work (30%), but also in circle (15%) and class discussion (15%). For "finding and developing scientific questions", circle (45%) and class discussion (37%) seem to have an outstanding role. "Systematizing, comparing and categorizing" mainly takes place in circle (38%) and partner work (32%). For "implementing, generalizing and use of analogies and models," partner work (73%) was the most frequent choice. "Exploring and experimenting" is primarily conducted in partner (45%) and group work (26%) but also in class discussion (16%). Finally, "summarizing and evaluating" is done to a large degree in circle (63%) and class discussion (28%). In our data, we state that in primary school the circle is a preferred activity to teach various scientific methods.

7. Discussion and conclusion

With this video study we gathered impressions from a wide repertoire of topics. We got information about teacher's procedures in using scientific methods on different age levels and the embedding of scientific methods in organizational activities. In general, we saw a huge variation in duration, activities and scientific methods within the sample consisting mainly of SINUS lessons.

SINUS for Primary Schools has encouraged teachers to think about school transition, educational standards and students' cumulative learning. Thus, we are happy to state that the SINUS teachers are informed about different scientific methods and have specific know-how for realizing instructional conditions that build up students' basic knowledge in science for secondary school. But we also saw in our data that our control group teachers aimed at teaching scientific methods as well. In our sample, the range of instruction from 1st to 4th grade indicates, that scientific methods are considered from the very beginning in primary school but that they get more important from 3rd grade on. We also found that teachers use scientific methods in different settings. "Exploring and experimenting" is the most frequent category and is often conducted in student centred settings, like partner and group work. "Finding and developing scientific questions" and "summarizing and evaluating" are primarily picked up in circle and class discussion, which are more teacher directed settings (Kobarg et al., 2012). Of course, these findings are explorative and not representative. Unfortunately, because of the constitution of the sample, we can neither generalize that SINUS instruction differs from regular instruction nor establish a connection between SINUS instruction and the better student competencies, which were stated in SINUS-schools participating in TIMSS 2011 (Rieck, Dalehefte & Köller, 2014). However, the findings are valuable, because they indicate that it is possible to consider scientific methods in science at an early stage in school. Secondary school teachers are often insecure of what they can expect from their new students attending from primary school (Hempel, 2010). Our findings indicate that students in primary school have learned scientific methods and bring certain basics with them when they enter secondary school.

The transition from primary to secondary school is a very sensitive phase in students' life with emotional and institutional changeovers that need to be addressed (KMK, 2010). With this data we corroborate that students' transition from primary to secondary school is connected to a change in organizational activities (Möller et al., 2013). In our primary school sample "circle" was a preferred setting, but we also know that "circle" is an activity of very little relevance in secondary school science instruction (Seidel et al., 2007). This shows that students experience not only a change in content complexity when they leave primary school, but also in instructional settings. More transparency about science content, organizational activities and scientific methods used in primary school might help secondary school teachers to take over students from primary school.

Our findings lead to further research ideas and new questions. Are younger children confronted with scientific methods on a less ambitious level? What kind of tasks go along with the scientific methods and in what quality? These are further questions and research, which could be connected to our video data. More in depth qualitative studies could help us understand more about what the use of scientific methods in primary school really means for students' learning. Although design and number of participants decide how representative the findings are, we maintain that a small sample can offer valuable information for explorative evaluation purposes of professional development programs. Moreover, we know that videos of instruction can offer nice examples for teachers to learn from and deliver new and important scenarios that contribute to knowledge for teachers' professional development (i.e. Borko, 2004; Roth, 2009; Sherin & van Es, 2009). In *SINUS for Primary Schools* the teachers participating in the video study also met to watch videos together for this purpose. In this way, both the evaluation team and the participating teachers profited from the video study in *SINUS for Primary Schools*.

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