IPN

Increasing the efficiency of mathematics and science instruction (SINUS)

– a large scale teacher professional development programme in Germany

by Manfred Prenzel, Matthias Stadler, Anja Friedrich, Katrin Knickmeier, Christian Ostermeier

Leibniz-Institute for Science Education (IPN) | Kiel 2009

PROGRAMM

SINUS - Transfer

Steigerung der Effizienz des mathematisch-naturwissenschaftlichen Unterrichts

Contents

Background

Background

The publication of the results of the TIMS study (Third International Mathematics and Science Study) in 1997 prompted the BLK (Commission of the Federal Government and Federal States, Department for Educational Planning and Research Promotion) to initiate a programme for the improvement of mathematics and science instruction in Germany. The mediocre performance of German students in the international comparison of TIMSS destroyed the long cultivated conviction about the high quality of German schools. However, even more alarming than the unexpected position in the ranking of the participating countries were the results which were obtained from more in-depth investigations carried out within the TIMSS context.

Many students in Germany had difficulties in mathematics and science. In the application of simple routines, their performance was relatively good in the international comparison. However, in more complex tasks which required the flexible use of knowledge, their performance showed significant weaknesses. Similarly, their ability to reason mathematically or scientifically was only weakly developed. One quarter of the students did not even possess the most basic skills and was in danger of being left behind. Furthermore, several findings indicated that students' interest in mathematics and science was low and constantly declining and that this was reflected in their choice of subjects, further studies and careers.

A quick reaction to these results was necessary. Therefore, one year after the publication of these results, the SINUS programme was set up as a direct measure. On a scientific basis, the aim of SINUS was to improve instruction quality and to then systematically disseminate it in the school system. For this purpose, the BLK thus created an experts' report for the preparation of the programme.

_The SINUS concept

A group of experts from schools, teacher training institutes, educational administration, educational science, psychology and relevant subject areas formed the conceptual framework for SINUS (BLK 1997). The basis of the conception was the analysis of problem areas in mathematics and science teaching in Germany. Alongside instruction approaches, these include the low value given to mathematics and science in society, the syllabi which are seldom cumulative and coherent, and teacher training courses and further training programmes which no longer meet current educational and didactic requirements. As out-of-school causes did not provide many possibilities for measures which would have a fast effect, instruction became the centre of attention. Admittedly, substantial changes can only be expected when those people who are responsible for instruction, i.e. the teachers, want and support these changes. Therefore, SINUS recognises the professionalism of teachers, addresses their problems in instruction and supports them in finding solutions.

Specifically, the experts' report describes a content framework ranging across eleven modules. Each of these modules describes one problem area and provides possible examples for how to work on these problems. The modules enable the teachers to concentrate on problems which are particularly urgent for them and to thus achieve noticeable improvements within a manageable time frame. Therefore, the teachers do not have to drastically question their instruction conception. However, by working on the individual modules, they experience that they can successfully further develop their instruction approaches. The modules can be combined in a variety of ways and thus make it possible to change instruction bit by bit.

An important principle of the work with SINUS is the cooperation between the teachers of a school. The teachers of one subject or subject area are thus the smallest working units within the programme. Cooperation between the teachers is a prerequisite if quality development and assurance is to be firmly established in the participating schools. The exchange of ideas, the existence of feedback from colleagues on instruction approaches, and the orientation towards common goals are necessary elements in developmental processes. Working together on common problems reduces the workload of the group's individual members and, at the same time, strengthens their position in the teaching staff. In addition to cooperation within a school, the SINUS conception calls for systematic cooperation with the teachers of neighbouring schools. Hence, work is organised and coordinated in school groups, so-called school sets. By exchanging information and experience with further schools, the teachers profit from the experiences of others and can thus reach their goals more quickly.

Work on the SINUS programme is coordinated and supported at a local and regional level. Thus, on the one hand, the schools are integrated into a larger context while, on the other hand, receiving custom-made suggestions for their own specific problems situations. The school supervisory board, state institutes and teacher training institutes are involved in the local and regional coordination. In the long-term, this leads to the emergence of an institutionally secured support structure which can continue to work on instruction development after a temporally limited model programme has been completed.

_Dates and facts about the SINUS and SINUS-Transfer programmes

The original model trial programme SINUS started in April 1998 and ended in March 2003. 180 schools from 15 federal states participated in this programme. These schools were organised into 30 sets of 6 schools each. A total of 1000 teachers participated in SINUS.

Following SINUS, the SINUS-Transfer programme disseminated the approach to further schools. This took place in two two-year phases between August 2003 and July 2007. 800 schools in 13 federal states participated in the first dissemination phase. They were organised into 84 sets of approximately ten schools each. Approximately 4500 teachers participated in this first phase. In the second dissemination phase, the number of schools rose to about 1800, organised into 176 school sets. The number of participating teachers rose to over 10,000. SINUS-Transfer is thus the largest instruction development programme to ever have been implemented in Germany.

With its 1800 schools, SINUS-Transfer had surveyed approximately fifteen percent of all general secondary level 1 schools (comprising grades 5 to 10) by the end of the nationwide programme. Although this is a very large amount, it is nowhere near a nationwide dissemination. Further dissemination is the responsibility of the federal states.

_The impact of SINUS

"We're finally talking about our lessons!" This statement from one teacher seems to characterise most clearly what SINUS triggered. Teachers enter a professional dialogue, analyse problems and look for solutions together. SINUS caused a new spirit of optimism: young teachers feel addressed just as experienced teachers do. SINUS provides the chance to finally make a difference. And, because the whole teaching body of a school notices the changed atmosphere, teachers of other subjects often ask whether there could also be a SINUS programme for their subject.

SINUS also has an impact on students. Once the new requirements of the lessons have become familiar, they start to enjoy learning more. It sometimes then happens that a teacher who is not participating in SINUS is asked if he/she could not also teach a SINUS lesson.

Furthermore, parents are also affected. Although, at the beginning of the SINUS programme, there were very sceptical reactions to the unusual working methods of their children, the children's positive attitude towards SINUS lessons soon convinced their parents. Thus, it is not surprising when parents who are registering their children at a school ask whether they will be placed in a SINUS class.

Finally, SINUS makes itself noticeable outside of school. SINUS ideas come up in new syllabi, teacher training courses adopt the SINUS topics, and measures are decided on in the federal states which aim to examine the quality of school and instruction.

_Literature

BLK (1997): Expertise „Steigerung der Effizienz des mathematisch-naturwissenschaftlichen Unterrichts“ (Expertise „Increasing the efficiency of mathematics and science instruction“). Bonn: Bund-Länder-Kommission für Bildungsplanung und Forschungsförderung.

Modules

Increasing the efficiency of mathematics and science instruction (SINUS)

What are the SINUS modules?

Eleven modules (see box) are at the core of the SINUS conception. The starting point for their development was provided by problem areas in mathematics and science instruction which were identified in the middle of the 1990s by international school comparison studies and, in particular, by video studies. By distinguishing the problem areas from each other and concretely describing them with regard to subject-specific instruction, the modules make these problem areas accessible so that teachers can work on them. At the same time, the modules are connected by having the common aims of improving learning and promoting students' motivation. Furthermore, they can be combined flexibly. The choice and combination of modules make it possible for the schools to start their work on instruction at various points and to tailor it to the specific problem situation of their school. The modules thereby structure the further development of instruction in the schools.

The eleven SINUS modules	
1	Further development of the task culture
2	Scientific inquiry and experiments
3	Learning from mistakes
4	Securing basic knowledge – intelligent learning at different levels
5	Cumulative learning – making students aware of their increasing competency
6	Making subject boundaries visible – working in an interdisciplinary way and a way that connects subjects
7	Promoting girls and boys
8	Developing tasks for student cooperation
9	Strengthening students' responsibility for their learning
10	Assessment – surveying and providing feedback on competency increases
11	Quality assurance within and across schools

_How do the modules work?

The SINUS programme takes empirical findings from educational and psychological teaching and learning research and from subject didactics into account when designing its modular approach towards quality development in instruction. In order to facilitate intelligent learning, instruction must, for example, pick up on the prerequisites of the students. For this reason, standard instruction cannot do justice to the normal heterogeneity of a class. This is why the SINUS programme consciously chose not to provide the teachers with elaborate lesson drafts for trial lessons. This is also connected to a second insight, namely, that lessons largely take place according to specific patterns which are shared culturally. Within these well-practised 'scripts', both teachers and students have a routine at their disposal which gives them the security of being able to fulfil the specific requirements in accordance with expectations.

The modules encourage the teachers to develop their own approaches and to adjust them to suit the specific class situation. These approaches broaden their teaching possibilities without completely destroying the routines which are necessary to provide the teachers with confidence in their everyday teaching.

Successful procedures should be used repeatedly in order to gradually make these broader teaching possibilities routine and to facilitate decisions which are adapted to the situation. The module approach makes it possible to concentrate on manageable individually selected sub-areas of instruction. Furthermore, it leads to new impulses for the further development of work within a module or to the addition of a new 'script' which can, in the long-term, lead to a change in lesson scripts.

This procedure addresses the core of teachers' professional tasks: these tasks are to provide learning opportunities, support students' learning, diagnose learning progress and provide appropriate feedback on this progress. However, in doing so, the programme is fundamentally open and provides teachers with the freedom to determine both the start of the work as well as the following steps according to the situation in their own classrooms. Thereby, the cooperation between teachers within a school and the exchange of information and experience with further schools in the area are important aspects because they, on the one hand, open up new learning possibilities and, on the other hand, reduce the teachers' work load.

Module 1

Module 1: Further development of the task culture

Tasks are the core of instruction. They are employed at different stages in the course of a lesson, and they have a fixed position and a specific function which can be expressed in the form of homework, practice exercises or examination questions. They provide the lesson with a structure and they keep the learning process going. A sequence of coordinated tasks forms, in short, the central point and the foundation of successful mathematics and science teaching. However, studies on teaching have shown that a task monoculture prevails in German classrooms. Too frequently, the tasks used require routine skills more than anything else, restrict learning and exclude other learning opportunities.

It is this central area that SINUS module 1 addresses – “Further development of the task culture”. It causes teachers to open up to the diversity of tasks and task types available for the different stages of learning. By working on the module, they learn to consciously select tasks which have the characteristics desired, to create tasks themselves if required, and to implement them in lessons in a targeted way.

_Task types and their importance for learning

When starting work on module 1, teachers make themselves familiar with the different task types and the different purposes which they are to fulfil over the course of learning processes for the following reasons:

- Tasks for *working on* new material confront the students with problems which they have not come across up until then. These tasks should motivate them to develop a solution themselves.
- Then, tasks for *working throu*gh recently worked-on material are necessary. They help to immerse the students in the material, help them to understand the thoughts and processes presented within the material and to come to a solution.
- *Practice tasks* take up a lot of space within lessons. They are implemented in order to promote the confident application of newly learnt actions and operations and to work against this new knowledge being forgotten.
- With the more complex demands of *application tasks,* teachers aim to develop students' capability to independently select which steps need to be taken to reach a solution and to transfer their knowledge to unknown situations.
- *Repeat tasks* serve to recall subject matter which was dealt with in the far past and to thereby make it available in finding the solution to a problem. Tasks which systematically gather previous knowledge on a new topic also fulfil this purpose.
- Finally, *test tasks* should show what a student is capable of and where gaps still need to be filled.

_The presentation and features of tasks

In SINUS, teachers not only examine the diversity of tasks in a targeted way; they also concern themselves with the appropriate presentation of these tasks in lessons. Alongside the task type, other factors such as the intended learning step, the degree of difficulty, and individual student characteristics also determine the modes in which the tasks are to be purposefully administered. If the level of previous knowledge in the classroom is low, the teacher guides the work and uses questions and summaries and points things out to the students in order to help them to understand the problem exactly, to penetrate to its core, and to come to a solution. If the students have knowledge and experience at their disposal which can contribute towards the solution to the problem, they mostly work on the task independently. If they come across difficulties which they cannot deal with by themselves, the teacher supports them with helpful material, for example. Finally, a task culture which has been developed in SINUS must make individual and cooperative learning (in the group and within the whole class) possible. Module 1 thereby defines a framework in which different task types in different arrangements contribute towards a diversified learning design and a support of learning that is adapted to the individual prerequisites of the students.

In order for tasks to fulfil their function and to ensure that students learn more from them than simply to apply a routine confidently, SINUS directs attention to their characteristics: a task should formulate a problem which cannot be solved by the application of a simple algorithm. It allows for several approaches to and ways of finding a solution and also maybe has several solutions. It potentially leads to new questions and problems or makes surprising findings possible. Finally, these tasks make sense to students and they find them motivating. The so-called "open" tasks display several of these characteristics. Therefore, many SINUS schools have intensively worked with these tasks within the framework of an improved task culture.

_Open tasks become accessible for teachers and students

It was relatively easy for the teachers in the programme to form open tasks out of closed ones: they omitted information or instructions or questions aimed towards a specific solution, for example. However, what happens when teachers, together with their students, work on such tasks and what do they experience? The following example answers this question.

At the beginning of a teaching unit on fractions, the teachers wanted to teach the concrete idea of a fraction being a part of a whole. For this purpose, the teachers gave their students circles, squares and rectangles and asked them to halve and quarter them. The students initially developed their suggestions individually and then introduced them to the whole class. They thereby frequently needed to be encouraged as they were, after all, often not familiar with this procedure. The overall results show that the children possess sustainable ideas from everyday life which they were able to use in obtaining the correct solutions. A new question arose from one variation of the division of a rectangle: are the two types of triangle which occur when a rectangle is divided in the same way as a square equally large or not?

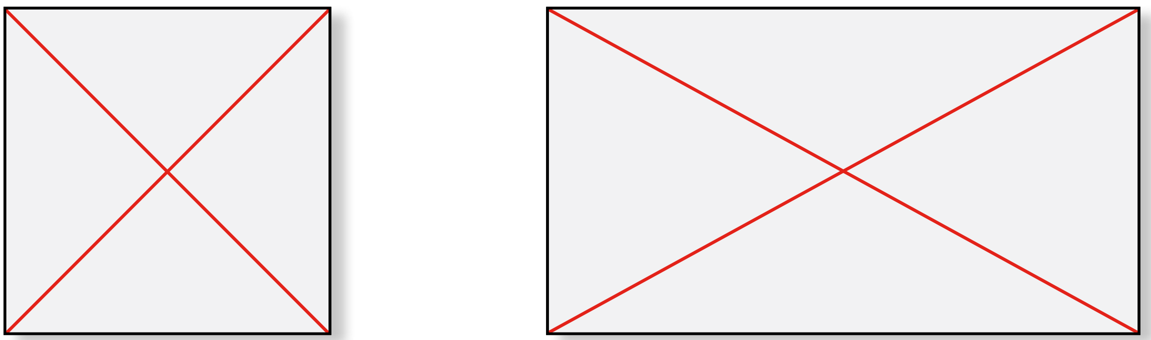


Figure 1: Dividing rectangles

Working on this question led to new solution strategies. The method of counting the squares on squared paper which was used when calculating the area of rectangles or quarters of squares no longer worked as the squares in the squared paper were cut "diagonally". However, when taking a closer look at this problem, the idea of dividing the triangles and placing them together in such a way that squares were formed came up. After the successful solution of the problem, some children suggested then applying the dividing problem to triangles. They produced various approaches which were immediately recognised to be suitable or not or had to be tested in the same way as in the case of the rectangle.

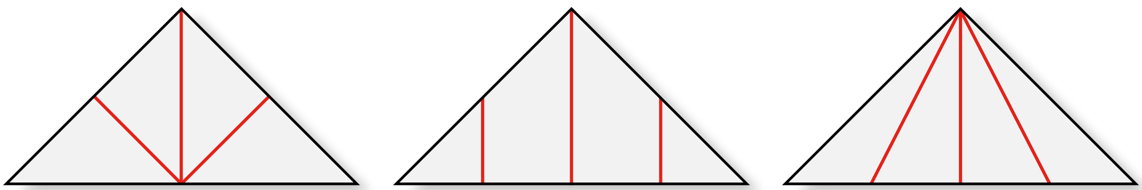


Figure 2: Dividing triangles

_Experience with the use of open tasks

The teachers in the programme found that they had to initially invest time and effort when working on open tasks. In the preparation phase, they needed time to develop an appropriate task. Working on an open task generally required more lesson time than working on a closed task. The increase in the quality of the results depended on the extent to which the students adapted to the expectations and lesson procedures which were new to them. At the beginning, they had to repeatedly be animated and encouraged to document their ideas and to present them in front of the whole class. In these situations, the teachers were presented in particular with the task of establishing a class climate that allows mistakes and, furthermore, sees mistakes as learning opportunities. Moreover, they learnt to be open for unexpected changes in the course of a lesson and to recognise and use the potential of such situations. They thereby succeeded in reconciling the content-related course of a lesson with the requirements of the syllabus.

What was established on the part of the students was that their motivation, experience of competency and self-confidence were strengthened. If they were interested in a task, they did not let the interval signal distract them from their work. They became ever more capable of finding versatile solutions, from which the whole class profited. Moreover, further questions repeatedly came up which provided an active role for students in the design of the lesson. Finally, noticeable progress could be seen in the availability of knowledge and abilities and their flexible use. The students also applied solution strategies sensibly and tested whether their application to new problems led to the correct results.

Open tasks were a success story in SINUS. They made a considerable contribution towards a change of the task culture. However, this success was not so easily come by in all cases.

_ “Open tasks for lower secondary schools (Hauptschulen)? Our students can’t cope with that!”

Open tasks were used in varied ways in higher and intermediate secondary schools (Gymnasien and Realschulen). Teachers from lower secondary schools, however, were cautious when brought into contact with open tasks. They argued that already existent open tasks were often too difficult for their students and required too much of them. Further hurdles that they mentioned were the large amount of text, the reading burden connected to this and the longer amount of time required for working on such tasks. They claimed that students with low reading ability would not understand the tasks and that their concentration span would not be sufficient to complete the task.

In order to deal with these problems, two procedures were chosen which enabled low-performing students to learn successfully with open tasks. First, the tasks used within this procedure mostly used pictures as information providers. In one version, they were arranged into a short story in which a problem was presented. The situations were chosen from contexts with which the students were familiar, e.g., shopping, traffic or locomotion. Different questions were formulated for the stories which indicated possible ways of working on the problem. In addition, by adding or subtracting information or questions, as well as by having a class discussion about the story presented beforehand, the tasks could be varied in their openness and be adapted to the different prerequisites of a class. In this manner, it became possible to solve the tasks in a relatively short time. The second approach used pictures from newspapers, in which unusual objects such as a large pile of newspapers on a bicycle or a huge cake at a party animated the students to ask questions, for example, about the height of the newspaper pile, its mass, the number of newspapers in the pile, or, the amounts of the various ingredients required for the cake, its mass, the number of pieces of cake which could be obtained from the cake or the proceeds of selling the cake.

Just as in the mathematics instruction of lower secondary schools, open tasks also found their niche in science instruction.

_Tasks in science instruction

Tasks play a less central role in traditional science teaching than in mathematics teaching. There are several reasons for this. For example, the concept of the task is not as clearly defined in science. Furthermore, studies on instruction patterns have shown that science lessons largely take place in a question-developing way and that they present content in a systematic way. The knowledge mediated by the teacher is – due to the lower amount of time, amongst other things – not stabilised as intensively as in mathematics instruction by practice, repeat and test tasks. Inspired by the experience of the mathematics teachers in SINUS, science teachers started to focus more on so-called “learning tasks” in their lessons. These tasks mostly serve the purpose of working on and through a problem and then applying it. With questions such as ‘why is water used to put out fire?’, or ‘why is it important to chew food properly?’ the students were asked to find out something that led to scientific explanations or concepts. At the same time, they were given a more active role as the questions were mostly worked on in groups. Instead of listening to and understanding what had been presented, they constructed the new knowledge themselves.

_Task culture as the quintessence of instruction development

The module ‘Further development of the task culture’ was worked on by far the most in SINUS. In nearly all of the federal states, it was the focal point of instruction development. What makes it so attractive is the fact that tasks are implemented in lessons on a daily basis. SINUS thereby succeeded in picking up on teachers’ experience and successfully mediating impulses for further development. The suggestions on how to change tasks were concrete and could be directly tested in the classroom. By using changed tasks, the teachers experienced positive effects on their instruction. Module 1 thus encouraged them to start with instruction development and to apply the variety of tasks, adapted according to the function required and the relevant classroom setting, to support their students’ learning.

Work on module 1 made an impression on all of the school sets. The view taken on tasks was broadened. The teachers gathered experience with task types which they had not used or had only seldom used until then. They worked intensively on the constitutive criteria of tasks which support learning and on embedding the tasks in their lessons. These changes also met with a positive reaction on the part of the students. Furthermore, even beyond the boundaries of the programme, the further development of the task culture – which can be recognised by the abundance of corresponding publications – has become an important topic.

Module 2

Increasing the efficiency of mathematics and science instruction (SINUS)

Module 2: Scientific inquiry and experiments

Interest in science decreases over the course of schooling in Germany, as several studies have shown. This development is reflected in the decisions which students make with regard to higher level courses (or profiles) and in their choices of training courses or subjects for further study. Many scientists are surprised by this development because, as far as they are concerned, there is not much that is more interesting than scientific research. In particular, scientific ways of working are considered to have a highly motivating potential: experimenting, observing, comparing and systematising, but also modelling, arguing and reflecting are important and diversely applicable ways of thinking and working which are also part of instruction. SINUS sees an even stronger orientation of school instruction towards scientific research and scientific approaches as a chance to use process-oriented work to better support the development of scientific competencies and interests. For example, experiments should be conducted intelligently, i.e. in a theory-driven and problem-related manner, and should be documented and interpreted. Accordingly, teachers can guide and support their students in planning, conducting, analysing and presenting experiments in a targeted way.
One central aspect of the module “Scientific inquiry and experiments” addresses teachers’ abilities to design demonstration and students’ experiments in a way that accustoms students to thought-

fully prepared, targeted and systematic experimenting and observing. Formulating questions and assumptions, and preparing and interpreting results are just as much part of this as is reflecting on the procedure used. The SINUS schools developed and tested imaginative suggestions for experiments and trials for nearly all of the topics. An essential characteristic of all of these approaches was that student experiments were not carried out following a detailed manual without having to think. Rather, the working steps were embedded in a general context and the students were significantly involved in the planning of the experiment.

The contributions towards scientific inquiry and experiments made in the SINUS programme are oriented towards a basic process model:

- The *planning and conception phase* is of central importance. At this stage, preliminary considerations are made. An experiment is thoroughly prepared. This involves working on the problem, formulating hypotheses, predicting results and, finally, drawing up a concrete experiment plan.
- The *implementation phase* describes the practical working phase, i.e. the elements of scientific inquiry and experiments which the students are going to deal with in the lesson. An experiment is either carried out according to the "cooking recipe" aspect or independently. The students thereby observe or evaluate the procedure and survey data.
- The *analysis and interpretation phase* involves student activities which serve to evaluate the data which has been gained. The data must thereby be prepared and further processed (e.g. in a graph or a table). Error estimations and control experiments are also part of this. The interpretation of the data, i.e. the evaluation and analysis, leads to the development of generalisations and, in many cases, to the formulation of new questions.
- In the *application phase* the students are involved in transfer activities. Based on the problem posed at the beginning of the experiment, they formulate new hypotheses or apply the findings gained to new situations. Here, the students also observe the social relevance of the research findings.
- In the *presentation phase* students have the opportunity to present their work to the whole group, class or school. This can take place, for example, in the form of a PowerPoint presentation, posters or talks, i.e. in a manner comparable to that used by a scientist at a symposium. This business-like presentation of their own work and its integration into a larger scientific context (verbal or written) is an important activity which leads to a reflection on and an understanding of the context.

_Feeling like a researcher – wanting to understand instead of just cramming facts

Understanding scientific ways of thinking and working is relevant in all science subjects (physics, biology, chemistry, interdisciplinary science instruction) and can thus be learnt and practised in all disciplines. Scientific ways of working can also be adapted to other subjects.

Of course, there is not always enough time in lessons to work through all the phases of scientific inquiry and experiments. But then, that is not always necessary. Once the students have learnt and understood the targeted and systematic way of experimenting in its entirety, the respective phases can be worked on in more depth individually. For example, the learners can be given a complete data set from a research laboratory or a measurement protocol and, subsequently, "only" practise the graphical representation, analysis and presentation.

Students often reported being very motivated and enjoying the independent work and the experiments in such lessons (… "how a real researcher feels"). This supports the development of interest. When students work on experiments in groups, the different phases of scientific experiments offer all of them the opportunity to use their respective strengths because different questions are asked: students can adopt different roles in each of the different phases. Thus, a student who is weak in the evaluation of the experiment can be brilliant in presenting the overall experimental procedure and is thus motivated to follow the science lesson despite his/her weakness.

_How did the schools implement module 2?

SINUS provided numerous impulses for science instruction. For example, the schools that chose module 2 demonstrated a broad spectrum of scientific ways of working. In particular, the planning and conception phase, as well as the application phase, were taken into consideration to a large degree. Students were to think like a researcher. They were thereby requested to present hypotheses about the outcome of an experiment and to refer to these hypotheses in their analyses. In partner or group work, the students activated their previous knowledge and worked intensively on a problem. Working instructions such as "What result do you expect to achieve from the experiment?" or "Compare your hypotheses with the observed outcome of the experiment" or "How can the experiment be developed further?" facilitated this aspect.

Many scientific learning cycles were developed together by teachers of one subject at a school, and sometimes by teachers of several subjects, or by teachers from different schools. For example, "Learning box ear", "Little ones' world" and "Everyday matters".

Schools frequently combined module 2 and module 6 (making subject boundaries visible). Phenomena or problems from the students' everyday world which went beyond the traditional boundaries of school subjects then formed the starting point in instruction.

_Taken from students' everyday context

Examples from the students' everyday world or from their current interests are easy to find. For example, one school oriented chemistry lessons towards Harry Potter where the students were animated to draft an experiment themselves by a letter: "Hello you muggles, I desperately need your help. Professor Snape, our horrible teacher for magical potions, has given us a very tricky task. Unfortunately, we are not allowed to use any magic. [….] Professor Snape made us sweep up all the debris that had gathered under the tables in the laboratory over the last 200 years. Worst of all, he now wants us to analyse its properties. […] This is how I need your help! I've sent you a sample. [….] If you can manage to separate the matter, then you could write some simple instructions with pictures which are easy for an outside person to read and understand."

Another example from chemistry and biology is the effervescent tablet experiment. Here, students work on the everyday phenomenon of dissolving an effervescent tablet in water. In this case, though, they have to measure the gas volume that emerges. If they dissolve a further tablet in the same glass cylinder, then more than double the amount of gas is generated. On the basis of this surprising and discrepant observation, the solution to the mystery can be found by using solution hypotheses and interpretations.

_Conclusion

The module 'Scientific inquiry and experiments' provides numerous possibilities to further develop instruction – in small and in large steps. When learning and practising the individual phases of working in a scientific way, important fundamentals can be laid for a scientific way of thinking and working. Students learn how to experiment in a questioning and hypotheses-led manner and achieve a new and deeper understanding of science while being intrinsically motivated. This is crucially important for existence in a world which is continually becoming more and more complex.

Module 3

Increasing the efficiency of mathematics and science instruction (SINUS)

Module 3: Learning from mistakes

We learn from our mistakes. This phrase shows that mistakes are common and are part of everyday learning. Learning from mistakes is especially targeted in careers in which mistakes can have very serious consequences. Even doctors, the proverbial white gods, have broken the taboo which ruled for a long time and now admit to their mistakes. They presume that, by openly working on treatment errors and by searching for their causes, they will be able to at least reduce – if not completely wipe out – avoidable harm to patients.

Learning from mistakes: What is the situation in school; the institution in which learning is the central activity? In examinations and class tests, mistakes result in a bad grade. In question-developing instruction mode students are afraid of saying something wrong because this could have an effect on their oral grade or because it's unpleasant to give a wrong answer in front of the whole class. If such open and hidden performance situations prevail in lessons, a lesson climate which leaves no room for learning from mistakes results. To make it possible to learn from mistakes, students must be able to express themselves freely in lessons without immediately feeling assessed or even humiliated. Then, mistakes do not represent personal failure in a task, but rather a challenge for the individual or the whole class.

_The framework of the "Learning from mistakes" module

The "learning from mistakes" module focuses on the clear separation of learning and performance situations in lessons:

In school learning situations, mistakes are inevitable when knowledge and experience from everyday life meet scientific concepts. If these mistakes are to be used as learning opportunities, the mistakes themselves must become the subject of discussion. If students think about the origin of, and logic behind, a mistake together with their teacher, this makes it possible to change the idea that is connected to the mistake. SINUS actively targeted this way of dealing with mistakes in order to initiate deeper understanding.

Mistakes should be avoided in performance situations. In order for this to be successful, the first requirement of the students is an understanding of the content being tested. In addition, knowledge about how systematic or coincidental mistakes (for example, the incorrect application of an algorithm or oversights), which are not dependent on knowledge, can be discovered and avoided has a positive effect.

How can teachers approach the topic of learning from mistakes?
Video studies have shown that mistakes are often not visible in mathematics and science instruction in Germany. Especially in the widespread question-developing discussions, students show patterns of behaviour which are well-coordinated in order to avoid mistakes. So, how can teachers successfully make mistakes a topic in lessons in order to then gradually form a way of dealing with them that supports learning?
In SINUS, the teachers basically used two approaches:

- Working on typical mistakes which emerged, for example, in situations of performance appraisal, and
- Making mistakes in lessons visible by writing them down, preparing a drawing or recording them on video.

The first approach enables the teachers to consciously make mistakes the subject of discussion in the lesson without having to fundamentally re-design their instruction. For example, they change the discussion of the results of class tests – which is generally perceived to be unsatisfying – in such a way that students have to work more intensively on their mistakes. The manner in which one group of mathematics teachers proceeded will be presented briefly in the following section.

_Learning from typical mistakes

In written performance examinations, much to the regret of all those involved, far too many mistakes occur. Hereby, two different types of mistakes can basically be differentiated between, from which the students can learn different things:

1. Oversights which are due to a lack of attention or time pressure,
2. Comprehension mistakes which are systematic when they are due to an incorrect concept or an incorrect idea, or are coincidental when guessing strategies are applied.

In one mistake in a mathematics task, it is not possible to determine which type of mistake it is. Thus, the mistake in transforming the equation

$A = -4(x^2-2x-8)\ cm^2$
$A = -4(x^2-2x-1^2+1^2-8)\ cm^2$
$A = -4((x-1)^2-7)\ cm^2$

can either be due to carelessness or an incorrectly applied algorithm. Both of these types of mistakes can be reduced if students are presented with incorrectly solved tasks in lessons, then find the mistakes and continue the arithmetic correctly. Alongside the increased attentiveness to such mistakes, a further positive effect can be achieved if the teachers additionally teach strategies (rough calculations, checking the individual units, checking the results) for discovering and avoiding such mistakes in the future.

In order to also deal with comprehension mistakes in lessons, the teachers made their students study incorrect task solutions and write down their speculations about the reasons for the mistakes and justifications for suggested solution steps. In this way, they wanted to learn more about the students' understanding. The teachers thereby noticed that this procedure did not lead to the desired results with tasks which could generally be worked on with routine procedures. They needed other tasks in order to achieve this.

A suitable example from mathematics is the question of whether there is a fraction between ½ and ⅓. Many children answer no to this question (in a test of sixth grade classes of all school forms, the proportion was 78 percent). Their explanations show that their concept of fractions is incorrect and that they often infer their incorrect answer from the knowledge that there is no natural number between 2 and 3. This insufficient concept must be worked on with appropriate task material, for example, making fractions out of objects or presenting fractions on the number line.

In this way, the teachers started work on the second approach mentioned above: they worked with mistakes which were based on incorrect concepts. The following section deals with this approach.

_Incorrect concepts as learning opportunities

Students' scientifically inadequate conceptions about the phenomena of animate or inanimate nature are often referred to in the research literature as incorrect concepts which must be replaced by scientific concepts. Hereby, the fact that students' concepts are based in their everyday experience and are functional and plausible is often overlooked. In mathematics, one speaks in a neutral manner of basic concepts which influence work on mathematical problems.

One example for a conflict between everyday experience and scientific concepts which often occurs in physics instruction is the concept of uniform linear motion. While the physics law of motion states that objects move with constant speed when no force is applied, the students generally presume that, for such movement to take place, continual or constant force must be exerted on the object. They argue in this manner based on their experience that vehicles become slower and finally stop if they are no longer powered. If this discrepancy between the two views is not discussed in detail, and the individual arguments are not tested and considered at length, then the physics viewpoint is still ultimately not understood and has to be learnt by heart. It is then, on the one hand, quickly forgotten and, on the other hand, cannot be flexibly transferred to other situations.

_Making concepts visible means learning from mistakes

As the two examples from mathematics and physics show, mistakes can only be learnt from in lessons if, firstly, mistakes are recognised and, secondly, the concepts behind the mistakes are focused upon. In the mistake diagnosis, the central question is how a mistake occurred and on which concepts it is based. This leads to the question of how these concepts can be changed. Making the thinking processes and the chains of reason used when solving a task visible is

thus a necessary requirement when learning from mistakes. In SINUS, the following elements have proved worthwhile, for example: students write down their own thoughts when working on the task, the method of thinking aloud is used, and appropriate instructions are provided for group work.
One school set used the method of thinking aloud in order to survey concepts about chemical processes in introductory chemistry classes. In this manner, groups of students observed Petri dishes filled with water to which some cooking salt was added on one side and some silver nitrate on the opposite side. The groups had to comment on their observations and were recorded on video as they did so. In the evaluation, the teachers recognised numerous concepts which were not consistent with scientific views. For example, the dissolving of the white substance in the water was equated with its disappearance, the slow formation of a white line in the middle of the dish with its renewed appearance. In describing their observations and perception, the students used metaphors such as “the cooking salt moves to the middle” or “it forms a wall” in which they attributed the status of actors to the substances. It became obvious from the videos that hardly any adequate concepts about the chemical interpretation of the procedures existed. Teachers then looked for ideas for further experiments which seemed to be suitable for further developing the students’ concepts, e.g., by observing coloured substances or the reaction of two white substances forming a coloured one.

_A new way of looking at mistakes

The described examples from work on SINUS module 3 show how the teachers implemented the learning from mistakes module in their lessons and thereby developed a different perspective on mistakes: mistakes no longer represent proof of failure and, therefore, no longer have to be avoided if at all possible. Rather, teachers find hints in mistakes about students’ non-existent or inappropriate concepts which explain the occurrence of these mistakes. Furthermore, they have learnt to develop these concepts, to differentiate between them and to secure them so that they can form the foundation which makes it possible for the students to approach complex problems from the real world in a rational way.

Module 4

Increasing the efficiency of mathematics and science instruction (SINUS)

Module 4: Securing basic knowledge – intelligent learning at different levels

_Intelligent learning in heterogenous groups

Module 4 “Securing basic knowledge – intelligent learning at different levels” directs attention to the topic of how students with different levels of previous knowledge can acquire a common level of basic knowledge in individual domains. Basic knowledge in this sense includes knowledge and certain abilities that are necessary in order to be successful in further learning and to participate in society. In recent years, this perspective has led to the formulation of educational standards: they define basic competencies which should be achieved by all students at different time points of their school careers.

SINUS module 4 emphasises that basic knowledge must be available and applicable at all times and must therefore be consolidated and secured after being learnt. In this sense, practising not only means acquiring certain abilities by mechanically and frequently repeating the same procedures. Rather, in the securing of basic knowledge, it means practising in a varied and intelligent way so that the knowledge can be applied flexibly in different requirement situations. Furthermore, due to the heterogeneous learning requirements of the classes, the practise tasks must be designed in such a way that they can be worked on at different levels of difficulty.

_What does basic knowledge encompass?

Teachers participating in SINUS module 4 first discussed with their subject colleagues what they really consider basic knowledge to be. Together, they worked on a summary of the basic skills, concepts and principles which, from their point of view, students need in order to be able to participate in society and further learning. They thereby oriented themselves towards the curricula, on the one hand, and the SINUS experts' report on the other. For example, in mathematics, alongside elementary calculation skills which have already been worked on in primary school, this includes ideas about the concept of numbers and sizes, and an understanding of functional dependencies and geometrical forms with regard to area and space. Furthermore, students should be capable of reading and interpreting representations of data in graphs and tables, and they should be able to use heuristic skills in problem-solving strategies. The teachers then used this basic knowledge as the object of regular practice.

_Practice, practice, practice

Before SINUS, this practice often involved working through task packages which frequently required the same routines. This regular repetition of this procedure increases confidence in the application of the calculation tasks practised and leads to better performance; however, it has some disadvantages:

1. As the focus is on the repeated automatic application of procedures, contextual understanding seldom emerges. If the students already have clear concepts, they are in danger of being destroyed.
2. Through the schematic and largely identical practice tasks, dull knowledge which is susceptible to mistakes and to being forgotten is secured. Moreover, it can hardly be used in other contexts or for solving problems.
3. Weak students with comprehension problems profit the least from the regular practice of routines. Even if it is they who demand such practice tasks – from their insecurity, the construction of a stable knowledge base becomes more and more difficult for them in this way.
4. Stubborn practice does not motivate as much as varied or diversified practice.

SINUS teachers concluded that basic knowledge can only be successfully constructed and secured in their students if practice is varied, commented and reflected on, and thus simultaneously serves to establish understanding. The promotion of intelligent learning by intelligent practice thus became the focus of instruction.

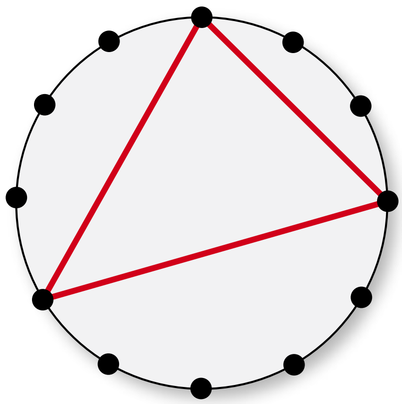
_Promoting intelligent learning in mathematics

Intelligent learning is characterised by the fact that the tasks used are not simply oriented towards the application and automation of abilities. Rather, they aim at different requirements and applications and highlight weaknesses. Furthermore, the practice of basic competencies is, in connection with the acquisition of new knowledge, often simply interspersed throughout instruction. In this way, the students feel that basic knowledge is secured incidentally.

In order to create learning situations in which understanding can be achieved even with different levels of previous knowledge or different learning speeds, the teachers developed and used different task types and practice forms. These forms have clearly found their way into school books over the last years and are described as consolidating or linking tasks. What is characteristic for these types of practice forms is that the students can influence the difficulty of the tasks themselves by the explicit or implicit choices they make when working on the tasks. As this practice form is thereby better adapted to the particular student level, these forms have a motivating affect.

Explanatory tasks, for example, are one type. With these, the students have to explain and prove with arguments or sketches why the solution to a task is correct. They are often given the solution in order to relieve them of complex calculation procedures or to avoid the case where it is not ultimately possible to work on the actual task due to an incorrect solution. In their explanation, the students show the extent to which they have understood the solution to the problem and, at the same time, they use the abilities required for this.

Exploratory or discovery tasks are a second type. They ask the students to investigate the properties of and connections between a group of objects, e.g. numbers or geometrical figures.



1. Form different triangles with the rubber band.
2. Collect them on a piece of paper and form groups.
3. What can you find out about the angles and the relationships between them?

Figure 3: Exploring triangles

Such tasks are also suitable for practice in heterogeneous learning groups. Depending on how quickly the students work, different numbers of triangles are formed; some work more systematically than others and thereby make more discoveries. Weaker students obtain more confidence from this intensive form of working. When the individual results are gathered in the class, further learning opportunities arise: individual students explain and justify their results or the whole class discusses which solution is the best.

Task variations also offer multitude possibilities for productive practice. By making small changes to a task, a larger number of tasks with different levels of difficulty and a multitude of learning possibilities emerge. Experienced classes are able to conduct these variations themselves and this leads the students to take their learning processes into their own hands to a larger degree.

Tasks from real contexts are popular and effective. These tasks often present mathematical problems via pictures (e.g. estimation of the size of objects, statues or buildings). Such material can also be used for practice tasks in science, for example, a satellite photo of a tornado from a newspaper article.

_ … and in science

In principle, intelligent practice forms can also be used in the science subjects. However, the smaller number of lessons available for individual science subjects, together with the considerable amount of time required for experimenting compared to mathematics lessons, leaves little time for practising tasks. Therefore, it is especially important to interlock practice and learning in order to use learning time efficiently. Scientific ways of thinking and working are central here (for example, observing, measuring, experimenting, using models). These aspects are the basic tools that are used in all science subjects for understanding and investigating phenomena. Furthermore, their importance can be seen in the fact that they are the object of a further SINUS module.
Similar to the exploratory or discovery tasks mentioned above, tasks of observing, measuring, comparing and arranging can be practised when the floatability of different objects is tested. Students' assumptions about the characteristics which cause this are manifold (for example, size, form or mass) and can be easily tested in experiments.

The "science learning boxes" provide clear concrete introductions to implementing scientific ways of thinking and working (Stäudel/Werber/Freiman 2002 and Stäudel/Werber/Wodzinski 2006). For example, thinking in models, which is so characteristic for science, is initially introduced with toys in order to establish that they are not a direct representation of reality but that their specific characteristics are formed by the purpose they serve. For instance, a wooden toy locomotive has similarities to a real locomotive; it can drive on its wheels – sometimes even on tracks – and can pull carriages. In contrast, the locomotive of a model railway is as true to the reality as possible in a miniature version. It can drive on tracks – similar to a real locomotive but without being exactly the same.

Such basic knowledge about models enables students to, for example, develop atom models used in chemistry according to targeted aims (such as the representation of structure or function) or to consciously choose an appropriate model from several different ones. A secure understanding of models hereby provides them with criteria according to which they can make their decision. In order to understand and interpret changes of state, solution procedures and separation processes, which are frequently dealt with in elementary instruction, they use a simple solid sphere model, for example. In contrast, in the interpretation of chemical processes, they need a model which enables them to make further assumptions based on observable connections, for example, the assumption that two elements always occur in certain fixed proportions in a compound.

_How successful basic knowledge is developed and secured

In their work on the module "Securing basic knowledge – intelligent learning at different levels", teachers in the SINUS programme rediscovered the meaning of practice. Instead of the previously common mechanical use of routines, practice forms which cleverly link repetition with further learning now dominate their instruction. Due to the alternative choices available in the tasks, the teachers strengthen the self-monitoring ability of their students and take their different levels of previous knowledge into consideration. As a consequence of this, they discover that their students can remember the lesson content dealt with more easily and are more confident in its application.

_Literature

Stäudel, L., Werber, B. & Freiman, T. (2002): Naturwissenschaften verstehen und anwenden (Understanding and applying science). Seelze/Velber.

Stäudel, L., Werber, B. & Wodzinski, R. (2006): Forschen wie ein Naturwissenschaftler. Das Arbeits- und Methodenbuch (Researching like a scientist. The working and methods book). Seelze/Velber.

Module 5

Increasing the efficiency of mathematics and science instruction (SINUS)

Module 5: Cumulative learning – making students aware of their increasing competency

"Last week we worked on alcohols. Today we're starting a new topic: carbonic acids." For many students, this sequence of lesson topics seems arbitrary. They cannot see any connection between things that they have already learnt and the material that they are now about to start. Thus, the acquired knowledge is fragmented, unsuitable for the solution of new problems and, at the latest, after the performance test at the conclusion of the topic, they forget the material in order to make room for new things.

SINUS module 5 "Cumulative learning – making students aware of their increasing competency" combats this type of learning. It aims at the conscious linkage of subject content whereby new material draws on material which has already been dealt with. For example, the work on alcohols or carbonic acids should not be limited to work on the respective characteristics and application possibilities. The two topics can be connected to each other by the question of what the differences between an alcohol and a carbonic acid are based on. From a chemical viewpoint, this concerns the type and structure of their constitutive particles. If students work on this question, they can expand their existent competencies. They then see the effort they put into learning as being worthwhile as they recognise that the previously learnt content is useful and they see which further effort is necessary. Experiences such as these support motivation more than external incentives such as rewards and grades or the reference to later use in professional life which is still far in the future for students.

Which possibilities do teachers have to construct students' knowledge step by step and with which approaches have SINUS teachers had positive experiences? First of all, the challenges of cumulative learning will be addressed.

_Cumulative learning requires coherency

Curricula more or less determine the aims and content of a subject in a detailed way. At least at the class level, they also prescribe a chronological sequence. However, links between the content dealt with in one school year or in further school years can only be found to a small degree. The teachers may clearly see the aims and links due to their extensive subject knowledge and their familiarity with the curriculum. However, this is not the case for the students as they only gain an insight into – or even an overview of – the subject after a lot of learning effort. Therefore, teachers must first of all clarify how they can sequence the content in a way that makes sense and how they can clarify the links between the various content with suitable material. In science, basic concepts are suitable for this purpose. They represent content-related thinking concepts which provide interpretation and explanation possibilities for phenomena and, step by step, become more elaborate and increase the students' explanatory capabilities. Moreover, tasks which show students what they are already capable of and how this ability is connected to current and future learning content are necessary.

_Achieving content coherency with basic concepts

In several school sets in the SINUS programme, teachers first of all thought about how they could allocate the content of a subject to structuring principles in order to form a central theme throughout their instruction. For example, in chemistry, one group of teachers chose four basic concepts (later formulated in a similar way in the national educational standards) around which the content of secondary level 1 was arranged. The four basic concepts are suitable for answering the essential questions about the composition and transformation of substances.

1. Substance-particle concept: Phenomena at the macroscopic level can be traced back to submicroscopic particles.
2. Structure-properties relationship: The type of linkage between the submicroscopic particles is reflected in the physical and chemical characteristics of the substances.
3. Donator-acceptor concept: The connection between the particles is based on the (partial) exchange of electrons.
4. Energy concept: Chemical processes occur with an absorption or release of energy.

Using an extract from a 9th grade lesson plan as an example, the following section shows which content the teachers chose to elaborate on the substance-particle concept and to make a deeper understanding possible for their students. In this case, the focus is on repeatedly using a suitable conception of particles (discontiuum) to interpret phenomena which can be observed at the substance level (continuum).

_Elaborating on particle conceptions in chemistry

The observation of substance mixtures provides the starting point. Mixtures of sand, salt and water introduce the students to different types of mixtures: in one type it's possible to recognise the individual components (salt and sand, and sand and water), in another type the mixture appears to be consistent (salt and water). The question about the separation of the mixtures ties in with previous experience from kindergarten, primary school or everyday life. For example, a puddle which occurs after a shower of rain disappears again because the water evaporates. Accordingly, the salt can be gained after the water has evaporated, or the sand by pouring the water off and drying the mixture. The characteristics of the homogenous salt solution in which the salt is no longer visible can be explained if one presumes that salt and water consist of small particles which – up to maximum solubility – can move freely amongst each other. Further characteristics of the particles such as size, appearance or constitution cannot be deduced.

This changes once chemical reactions come into play. The teacher burns different material, such as alcohol, wood or candle wax and then asks the students what happens to the substances when they are burnt. The idea that they simply disappear contradicts the experience that evaporated water becomes fluid again on a cold object, as well as the result of an experiment in which the mass of the residue increased when iron is burnt. Thus, the substances change when burnt. The presumption is that the particles re-group and re-assemble in a new way. What remains unknown is what the linkage of the particles to each other is based on and what happens in the reactions. In these experiments, students experience aspects which can also be used to develop the concept of energy.

In continuance with the line of this lesson, a further lesson could deal with what happens when substances are decomposed (analysed) or synthesised. In water electrolysis, for example, two gasses which have completely new characteristics are formed. Their volume is thereby always in a ratio of two to one. Thus, the water particles consist of at least two types of particle which exist in a fixed relationship. Further experiments and considerations lead to the conclusion that the two new substances obtained from the water cannot be decomposed any further. One thus comes to see the elements as the building blocks of all substances. The constant mass and volume ratios of the substances involved in the reaction provide information about the ratios of the types of individual element within a compound and the existence of the smallest particles (atoms).

The question of how the particles are held together finally leads to the conclusion that they themselves consist of even smaller particles (electrons, nuclear particles). The examination of the spatial composition of the atoms in a compound leads on to work on the structure-characteristic relationship with atomic and bonding models. These topics are then dealt with in following grades.

_Cumulative learning in mathematics

Like the basic concepts in chemistry, basic ideas serve a similar function for cumulative learning in mathematics. They include the mathematical interpretation of things with which we are confronted in the everyday world. For example, we can count objects, can have an idea of distances and sizes or can recognise forms and patterns. In order for learning to be cumulative, such basic ideas must be constructed and further developed in an appropriate way. The educational standards for mathematics provide another starting point with their central ideas and the general mathematical competencies which they describe, such as the use of mathematical representations. Teachers in the SINUS programme worked with both of these possibilities.

For example, one group of teachers worked on students' basic conceptions of fractions. As an introduction, they asked their students to present fractions as fragments of areas (circles and rectangles). The students thereby activated their school knowledge on the calculation of area from previous school years and their everyday experience with portions of area. By linking this knowledge, they formed the conception of a fraction as a part of a whole which, in turn, made this section of the new learning area – the addition and subtraction of fractions – more accessible to them. By falling back on the surface ratio, the new topic is linked to existing conceptions and its use in a new area makes the concept more flexible and transfers it to another field. At later points in time, fraction calculation is expanded upon: fractions as operators which are applied to a number, and the fraction as a number which, according to its size, is allocated to the number line.

_Conclusion

Module 5 "cumulative learning" encouraged the groups of teachers in the SINUS programmes to work on a coherent assembly of lesson units. Basic ideas and concepts proved helpful in this structuring process. The detailed example from chemistry makes clear that the step-by-step differentiation of a basic concept in the sense of cumulative learning relies on the method of first observing phenomena so that they can then be interpreted in a plausible manner. The complete transformation hereby from a macro level which we can perceive and observe to a micro level whose constitution and dynamics we can only indirectly understand, is characteristic for science. The fact that the diversity of appearances can be traced back to so few principles means that the contribution of basic concepts leads to a deeper understanding of the world.

Furthermore – especially in mathematics – productive practice also plays a role in cumulative learning. In such practice, topics which have already been dealt with are not only repeated but are also connected to new problems via open tasks. The students thereby directly experience what they are already capable of and what they can use these capabilities for.

Module 6

Increasing the efficiency of mathematics and science instruction (SINUS)

Module 6: Making subject boundaries visible: working in an interdisciplinary way and a way that connects subjects

Science looks at living creatures, objects and phenomena from the world around us from a specific perspective and, with its findings, makes a contribution towards a better understanding of these things. However, the complexity of problems often only becomes clear when they are viewed from different – not least subject-related – viewpoints. In contrast, students often experience science instruction as a sequence of different content which does not feature connections either within a subject or between the various subjects. For example, dealing with the structure and function of the eye in biology is separate from the lenses laws in physics. The newly acquired knowledge remains closely linked to the context of the corresponding subject.

Module 6 “Making subject boundaries visible: working in an interdisciplinary way and a way that connects subjects” thus aims to complement systematic learning in a subject with learning that goes beyond subject boundaries. The students should look at phenomena from the perspectives of different disciplines, should see how useful these different perspectives can be but also which boundaries the individual disciplines come up against. If questions can not be answered by one subject, students should consult the perspective of another in order to achieve a deeper understanding. By this access to multi perspectives, they should also be able to describe complex problems in an appropriate way and learn how to develop solution suggestions.

Teachers who work with module 6 “Making subject boundaries visible” are confronted with the task of, on the one hand, working on and making students aware of the scientific procedures and principles common to the different science subjects and, on the other hand, making the limitations of the individual subjects clear as part of an explanation of the world around us. For this purpose, they need tasks whose solutions must implement knowledge taken from different disciplines.

_School projects

The SINUS framework refers to interdisciplinary projects as an important possibility for making the limitations of a subject visible from an external perspective. Their implementation seems to be a task which is familiar to, and gladly performed by, the SINUS schools and, in particular, by the science teachers. The method of looking at things from the perspective of different subjects is not limited to the other science subjects; rather it is also directed at mathematics, art, geography and history. For example, teachers developed a project called “rainforest and climate change”. Questions about the location and size of the rainforests came from geography. Biology discussed the plants and animals and their living conditions, the threat to this habitat and the consequences of this threat for the earth’s climate. Art lessons suggested working on the beauty of the rainforest and using pictures of this for its protection.

The time span required for these projects is as wide as the range of questions which can be worked on within a project. The typical amount of time required ranges from one day to one week. Preparation time is extra. The participating teachers gather and discuss tasks and assignments, draw up the necessary task and lesson material and organise the schedule and the allocation of activities to rooms. Finally, they supervise and support the working groups who are largely responsible for the processes themselves. Teachers find that both the preparation and the implementation require a lot of time and work. Nevertheless, they often rate the quality of the results as higher than average. In turn, the students report being more challenged than in traditional instruction but they also report having higher motivation and more fun due to the freedom which they have to design their work. Thus, project days and weeks have also proven to be productive in SINUS and to be measures which can easily be realised by most teachers in order to bring interdisciplinary aspects to the fore and thus achieve more complex learning results. Nevertheless, the teachers also recognised the possible limitations of the approaches.

_Removing the exception characteristic

Projects typically take place once in a school year – often at the end of a longer learning section, before the holidays or the end-of-school report. If they also follow a self-contained topic, they represent doubly exceptional circumstances. Because they are clearly separated from the usual lessons, they can only be integrated into them afterwards with difficulty. In contrast, if a project consists of many tasks which are closely oriented towards the instruction procedure in the individual subjects, they are in danger of getting bogged down in the traditional instruction framework. Teachers tried to avoid this by developing an overall task within which the students could also work on their own questions. Furthermore, they formulated open assignments which also made it easier for subject boundaries to be crossed. In order for this to succeed, the teachers, in turn, had to pay attention to appropriately supporting the working and learning processes. If students are to establish connections between different aspects, the number of aspects cannot be too high. Otherwise, the breadth of knowledge being aimed at competes with the depth of the work being done. Deeper understanding requires long-term work with a topic, leaving enough time to penetrate new material sufficiently and to secure this new knowledge.

Several schools attempted to integrate these experiences into the development of interdisciplinary lesson units.

_Interdisciplinary lesson units

In order to realise the advantages of project-style work in normal lessons, one school, for example, developed a lesson unit, oriented towards a new framework guideline, on the topic of "senses and perception" for the 7th grade. The group which consisted of all the science teachers of the 7th grade worked together with a subject expert from the local university on a row of experiment stations on the sensory organs and procedures of perception. The central question behind these experiments was how perception works. The topic contains diverse connections – especially between biological (e.g., structure and function of the ear) and physical aspects (e.g., the origin and dispersal of sound) – and was supposed to be closely oriented towards the students' realm of experience. The teachers developed the tasks and instructions themselves as textbooks seemed to be unsuitable due to the strict guidelines and detailed instructions. In a complex agreement process, they constructed the individual stations, replaced hem after the first trial if necessary or improved them. After two further trials and revisions – in a final step, together with several university students as external experts – they concluded the development. The lesson unit was documented in detail and passed on to the schools from the school set. In the following years, it was regularly implemented in the 7th grade in the school that had developed the unit due to the very positive experience that had been had with it.

_Learning in a scientific institution

Over the last years, many research institutes have opened their doors to schools. One SINUS school from the federal state of Lower Saxony wanted to clarify the interlocking of different subjects and disciplines through its cooperation with a marine research institute. For this purpose, the topic of 'the carbon cycle and the climate' was used which is one of the topics researched at the institute. Students from three ninth grade classes participated in two project days at the institute during which they were supposed to assume the role of researchers in an authentic environment.

Together with the accompanying experts, the teachers planned experimental tasks on the carbon cycle which were to be carried out at the institute. For example, experiments on currents in the sea, the solubility of carbon dioxide in water, the growth of algae, and on fossilisation picked up on different aspects of the superordinate topic. The instructions contained open questions which prompted the students to propose hypotheses about the expected connections and to develop further experiments. The students formed small groups in which they then intensively worked on one of the experiments. As experts for their topic, they were given the task of summarising their results and presenting them to the other groups. From all the contributions gathered, the classes then formed a model of the carbon cycle which contained the complex dependencies.

Back at school, the three classes then each worked on one presentation of their results. One presentation took place for the parents of the class and one for the advanced biology course (12th grade). The third class developed an exhibition for the school.

_Diversity possible, supportive framework necessary

The experience that was had with the module "making subject boundaries visible" shows that teachers have enough ideas and tools at their disposal to incorporate interdisciplinary aspects into their instruction. At the same time, it becomes clear that projects and even more project-oriented lessons place high demands on teachers. Both the preparation and the implementation require more effort than traditional instruction. On the other hand, this type of instruction leads to a stronger activation of the students, higher motivation and, not infrequently, excellent learning results.

The teachers emphasise that the work with module 6 could only be successfully carried out in collaboration with other teachers. This can be traced back to the fact that existent material cannot usually be directly used, but has to be thoroughly revised. In this case, further suggestions from external sources – for example, from scientists – have proven to be particularly helpful. These experts may, for instance, introduce working methods oriented towards their research activity which differ from school procedure or they may use their subject or specialist knowledge to provide support, for example, on students' ideas about the topic being dealt with.

Furthermore, the cooperation made it easier for the teachers facilitated to meet the challenge of entering new territory and, for example, dealing with the problem of sometimes not feeling competent enough themselves to cope with the mathematical or ethical side of problems. The intense exchange of information between the teachers created the trust necessary for this.

Module 7

Increasing the efficiency of mathematics and science instruction (SINUS)

Module 7: Promoting girls and boys

The changes that can be seen in the educational participation of girls in Germany since the 1960s present a success story: girls have overtaken boys in all areas – in taking higher education courses, in the school leaving certificate quota (Abitur), in the university first-year students. Is it really the case in all areas? No! Science and, in particular, mathematics, remains an exception. Here, worse results can repeatedly be seen for girls in Germany – right up to the current international comparative studies. They achieve lower performance scores than boys; above all, they have lower self-confidence in their own performance ability and their interest is also lower than that of boys.

Numerous studies have proved that the lower performance levels of girls in mathematics and science is not a natural law. At an international level, the competency differences between girls and boys in mathematics and science are mostly smaller than those in Germany. At this stage, girls are even performing at a higher level than boys in some countries. As regards interest, various studies show that the differences between girls and boys depend on the contexts and topics: several contexts are equally interesting for boys and girls. However, these contexts do not yet dominate everyday instruction.

The SINUS module 7 “Promoting girls and boys” inspires teachers to use changes in instruction to remove the disadvantages which girls have in mathematics and science and, at the same time, to contribute to a general increase in interest and, as a consequence, in the performance of girls and boys in these subjects. In the promotion of boys, the module aims to improve their arguing and cooperating ability and to support scientific work which is shared and equal between girls and boys.

_Noticing differences and strengthening strengths

Coeducational instruction is the normal case in Germany. Teachers are aware, both from their own teaching experience (subject choice in advanced courses, career choice) and from public discussion, of the problem that girls’ participation in mathematics and science subjects is lower. Some subject groups in the SINUS programme started to introduce changes in a targeted way.

Depending on the local particularities and possibilities, they chose different starting points such as, for example, girls’ interest in comparison to boys’, the organisation of the lesson, or the curricular composition of science instruction.

_Physics instruction: Ideals and reality

In one school set, teachers began by asking their classes about their physics lessons. The aim was to contrast the lesson reality perceived by the students with their ideal picture of a lesson. This survey revealed that both boys and girls wanted a positive atmosphere in lessons, wanted to have fun in physics lessons, and wanted to understand physics properly. In the lessons they experienced, their critique was that physical laws, formulae and calculations were too often the focus of the lesson. In contrast, they wanted more topics on the environment and topics with a reference to their own everyday life and to society. The girls’ ideal of physics lessons was further apart from their perception of the lesson reality than that of the boys. The number of girls actually interested in physics lessons was thus also lower.

_Improvements through separate instruction of girls and boys

Teachers in three schools studied the influence of the composition of learning groups on motivation and performance. Two of them conducted mono-educational physics instruction for one school year. The accompanying experts from the local university found a positive influence on the attitudes and performance of the girls who received instruction without boys.

One school had previously been an all-girls school and, although no longer an all-girls school, the number of boys enrolled in the school was regularly lower than the number of girls enrolled. This situation was used as a starting point to examine students’ subject selection preferences in classes with and without a large majority of girls. By partially removing the co-education element by having working phases with small one-sex groups, the teacher expected to find a positive development in the girls’ interests. This procedure led to visibly better working processes and results in the girls’ groups.

Although the removal of the co-education element in science proved to be suitable to improve both the motivation and the performance of girls in this subject, this positive experience did not initially lead to this approach being spread to other schools. There seem to have been two reasons for this: First, organisational aspects which are rarely possible to achieve have to be fulfilled (doubling the number of teachers or providing parallel instruction in two classes). Second, some of the teachers seemed to be sceptical about whether the approach described would really lead to positive results once dispersed more broadly. Teachers thus accept the challenge of providing equal opportunities for girls and boys in mixed-sex instruction. They try to stop boys dominating experiments or class discussions.

_Using the school's scientific profile to support interest

A school which implemented a whole batch of measures in the context of school profile development also reported experiencing positive effects on subject performance and interest in science. The focus of the changes in secondary level 1 was on a block scheduling of the science subjects: From grade 7 onwards, physics, biology and chemistry each had a time frame of ten weeks within the school year, with six hours of lessons per week. The curricula developed for this purpose contained a small number of central topics which were worked on in depth and in which the students were strongly involved.

The students enjoyed the intensive work on a topic and stated that they learnt more in this way than in one or two hours per week. Comparisons between classes who were taught according to this concept over four years and classes who were taught with the traditional model showed noticeable differences. For example, the average grade continuously increased and the number of students who chose science subjects in advanced courses was tripled. In the new model, girls still showed the well-known preferences for topics that are related to the human body and health, but across all the topics there was no longer any difference from boys. The frequently observed decline in interest from grade to grade also no longer occurred. Moreover, the increase in both the girls' grades and the number of courses they chose was higher than the boys' increase. Thus, the gap between girls and boys which existed before the new curricula were implemented noticeably declined.

Although the activities introduced within the SINUS programme led to positive results and to promising approaches, they were limited to just a few schools. Why was the module only implemented to this limited extent within the SINUS programme? Why could it not be strongly established? Why did it not lead to clearly visible results?

_Problem situation was recognised but not consistently tackled

In the SINUS-Transfer survey of teachers from 2005 to 2007, approximately one percent of the teachers reported working on module 7. Furthermore, many groups stated that the aim of their work with other SINUS modules was to increase their students' interest in their subjects. Thus, the aims linked to module 7 are generally supported by the teachers and are even taken for granted. This could be the reason why the concrete activities of the module, as they were carried out by some groups in the SINUS programme, were not often continued in the subsequent transfer phase.

The attempt to dedicate themselves more strongly to girls' interests in instruction may also be seen by teachers as positive discrimination or as a disadvantage for the boys. On the other hand, they want to treat both girls and boys equally in their lessons – and approach them with the same tasks and requirements. They want to behave in a neutral way themselves and do not want to discriminate against anybody or put anybody at a disadvantage.

_A module with a future

Against the background of the problem areas which are currently being attributed to boys in the area of education, the disadvantages which girls have in mathematics and science which are still existent are in danger of being pushed aside. Thus, it is all the more important for schools to work on the aims of module 7 "promoting girls *and* boys" in the future. A sufficiently high and stable level of student interest in mathematics and science is an important result of instruction at secondary level 1. It is not just the performance achieved in a subject that depends on this; the tendency of young people to aim at a career with a scientific or technical background is also influenced by it. Women are still largely underrepresented in this area. If this problem could be solved, the ever re-emerging danger of there not being enough new blood in these professions would be averted. The increase in school numbers and activities in this area reported by some states in the second phase of SINUS-Transfer indicates that the correct path is being taken.

Module 8

Increasing the efficiency of mathematics and science instruction (SINUS)

Module 8: Developing tasks for student cooperation

Cooperation between students in lessons has a positive effect on learning. It enriches the range of instruction forms, contributes to a supportive learning atmosphere by developing social competencies and thereby also supports subject learning. In contrast to the widespread question-developing instruction style, in cooperative work, students have lots of possibilities to actively work with the content. For example, if they are asked to interpret experiments on the behaviour of matter (gasses, liquids and solids) when warmed up and cooled down, they first individually think about their observations and try to form their own explanation. They then exchange their ideas with a partner. Thereby, they have to explain their own ideas in a comprehensible way, listen attentively to their discussion partner, ask questions when things are unclear, suggest supplements, argue and justify their opinion. Together with another student pair, they examine the speculations and weigh contradictory positions up against each other in order to finally come to a shared explanation. The results are then presented in front of the whole class and are explained and checked for mistakes.

The following text describes the conditions under which cooperative work can be successfully carried out in the classroom and how the experience initially gathered by a smaller group of SINUS schools was dispersed in the participating federal states.

_What are the features of cooperative work?

The concept of cooperative work and learning does not simply refer to group work. Rather, it is characterised by structured lesson situations in which social and subject learning is intertwined. One pre-condition for successful cooperative learning is that a mutual sense of responsibility exists between the students, i.e. they must work together in order to reach the goal. They should recognise the fact that the better the other group members learn, the higher their own learning success is. A further pre-condition is that an individual sense of responsibility also exists. Thus, the group result has to depend on how much each individual has contributed towards it. This prevents individual students from withdrawing or wanting to simply profit from others' performance or only concentrate on their own learning. The third pre-condition is that the groups must be given the freedom to make decisions. This develops their problem-solving ability and makes it possible to adapt the presented tasks to the conditions in the group.

The SINUS teachers were also faced with new challenges in their work on module 8 "developing tasks for student cooperation". First, they developed suitable tasks to which all of the students could make a contribution and from which they could all also learn something. From the diversity of methods of cooperative learning and working described in literature, they chose those which were best suited to the common learning aims (for example, expanding groups as in the example above or group puzzles). In the implementation, the teachers supported the working processes, ensured that all of the students were working towards a shared goal and intervened in group conflicts. They thus helped the students to develop the social skills necessary for successful cooperation.

How the experience that these groups of teachers had in the first years of their work with SINUS encouraged numerous schools in the whole country to also work with the module will be described in the following sections.

_Small beginnings go far

At the beginning of the programme, the schools of one federal state focused on this task. By the end of the first five years, a second federal state had joined the module. In the subsequent transfer phases, the dispersion rapidly increased so that, finally, schools from two thirds of the participating federal states were working on this approach.

How did this happen? – How did the activities used for supporting student cooperation, which were initially limited to specific regions, find their way into the majority of the federal states within only a few years? Which paths did this dispersal of the approaches take?

_The focal point of a region

At the beginning of the SINUS programme, all of the schools of one federal state agreed to work on the module "developing tasks for student cooperation". After about two years, several lesson units had been drawn up and a lot of experience had been gained from the trials of these units. Due to the positive results, the teachers of one school were very interested in further work with the topic. As a consequence, they expanded their work on the module. When developing lesson material for mathematics and science, they took into consideration the effects of the different basic conditions in the subjects. In the "main subject" of mathematics, which regularly has more hours per week and sometimes has double lessons, the introduction of cooperative work was much easier than in science with its limited time budget and differentiation between subjects.

In order to introduce a 5th grade class to cooperative work in mathematics lessons, the following task was used: the students had to transform a sketched drawing of an elephant to an enlarged chalk drawing in the school yard. For this purpose, they had to measure the lengths in the original and determine the angle between the lengths. The groups then constructed different parts of the elephant in the school yard whereby they had to be careful not to produce too many discrepancies. The teacher thereby observed the individual groups and established how well the cooperation had worked. If motivation sank because the students lost sight of the goals or if the success of the operation seemed to be in danger because one of the task elements was too difficult for one of the groups, the teacher had to intervene, offer help and organise support between the groups. Once the task was completed, everybody then had the opportunity to view the result from the top storey of the school building. From there, the individual contributions toward the overall result could be seen, as could small mistakes.

_Reaching a wider audience

One teacher, who was also involved in the coordination of a school group, gathered all the experiences which the school had with this module and, as co-editor, fed them into a journal issue focusing on"cooperative learning in physics". At roughly the same time, practice handbooks were also published by other authors. This teacher used these in his own school's development and also used them as a prompt to network with other players. At a further training seminar for school set coordinators in the SINUS-Transfer programme whose focal point was "cooperative learning", this coordinator presented basic procedures and also his own experience in a workshop. Here, he addressed a large audience of potential facilitators in the dissemination of this knowledge. As a consequence, he was repeatedly invited to seminars in different federal states in order to present the possibilities of cooperative learning forms to the teachers of the schools participating in the programme. The suggestions met with a huge response and were adopted by several subject groups in their work on further developing instruction.

_How the dispersal of cooperative learning worked

The successful dispersal of cooperative learning forms for students can be related to the following conditions:

- Lesson examples which had been tested and were methodologically convincing and easy to realise were available. The authenticity of the presenter, material and experience supported the open acceptance of the initiative by other teachers.
- Suitable documentation in relevant media presented the application of the methods of cooperative learning in a comprehensible way.
- Existent networks communicated with each other about the material and its effects and this further increased awareness of the approach. For this purpose, informal contacts were suitable, such as those which occurred within the framework of the main SINUS training programmes, at which a large number of interested teachers were present. Formal opportunities offered at seminars were, however, also suitable.
- Those interested were able to receive information about the theoretical background and the methodological aspects of cooperative learning and were also able to carry out parts of the approaches themselves and thus learn by doing.

Alongside the active steps taken in the dispersal of methods for achieving student cooperation described, the expectations which many teachers had of the effects of cooperative learning forms on lessons probably also played a role in the dispersal. Suggestions meet with particularly positive reactions if the possibility of achieving the desired improvements with the changes presented is recognised. Many teachers expected an increase in their students' self-monitoring and a stronger assumption of responsibility on the part of the students with regard to the results of the lesson. Both are constituent aspects of different forms of cooperative work. This assumption is supported by the fact that module 9 "Strengthening students' responsibility for their learning" was increasingly chosen by schools – alongside module 8 "Developing tasks for student cooperation". Module 9 explicitly refers to this shift of responsibility. The strong dispersal of cooperative learning forms which can be seen in SINUS-Transfer should, however, not be taken for granted. Rather, it should be linked to the fact that the general conditions in the programme were conducive and favourable.

_Challenges were met

Up until a few years ago, cooperative learning forms were not very widespread in German classroom instruction. A not insignificant number of teachers consider them to be time-consuming and risky. They fear that they may lead to a loss of control over processes or to disturbances or interruptions which make learning impossible. The SINUS teachers, however, managed to bring diverse approaches to cooperative learning into lessons. They tested how tasks and group constellations can be designed in such a way that each member of the group can learn something and contribute to everybody's learning success. The students also registered that learning in a group was more productive than working on a problem alone or than receiving frontal lessons for the whole class.

What presented the teachers with a challenge was the step-by-step creation of a shared group responsibility for the learning process. In the introduction of cooperative work, it is especially necessary to minimise the requirements of the problem posed so that cognitive and social learning processes do not have to compete with each other as this would lead to an excessive demand being placed on the students. Only once sufficient responsibility has been developed within the learning groups, along with students' growing trust of each other and confidence in themselves, are the groups capable of successfully solving the problems posed. Furthermore, well-rehearsed working routines and self-monitoring and organisation abilities must be constructed. Finally, the teachers learnt to acknowledge the cooperation through the forms which they used to evaluate the performance of the group and the individuals without letting an atmosphere of competition arise as this would impede the cooperation.

The activities within the module "developing tasks for student cooperation" which continually increased over the course of the programme period show that the teachers recognised the potential of cooperation for their students and will also use it in their future instruction.

Module 9

Module 9: Strengthening students' responsibility for their learning

A not insignificant number of teachers notice that their students have negative attitudes towards instruction and learning. Some students show little interest in the lesson content. They make a passive, dependent impression. They are loathe to make an effort and quickly give up when faced with requirements which they cannot fulfil. Teachers quite rightly feel that it is of central importance to change such behaviour. The SINUS module 9 "strengthening students' responsibility for their learning" provides them with assistance.

In line with the current state of research, SINUS presumes that learning is a constructive process. The development of knowledge and abilities does not therefore occur in the sense of passing on solidified knowledge or following an argument in small steps. Rather, learning processes lead to the new construction of meaning in each learner: new knowledge is connected to existing knowledge. Successful learning thus requires the learner to actively participate, to think about the content themselves and to attempt to comprehend the new material, to classify it and to mentally apply it. In the so-called elaboration of the learning process, the learners need suggestions which prompt them to make sufficiently complex considerations. They must try out certain pathways and be able to adapt the tempo according to their capabilities. They need support in becoming aware of learning progress and of existing knowledge gaps and in reaching a realistic self-estimation.

_Supporting motivation and providing freedom of movement

Teachers want their students to work in a motivated and independent way with the tasks posed. They want them to check the procedures they have chosen, find mistakes themselves and correct them. This only happens if students can become active themselves and this means more than, in a lesson which is conducted strictly and conservatively, just delivering the correct key words for the questions which are part of the teacher's lesson plan. The students must have sufficient time to work on complex and challenging problems and must thereby learn that they can bring the posed problems at least partially to a solution. Within this context, two approaches from the variety of approaches used in SINUS will be presented: the use of self and partner evaluation questionnaires according to a Swedish example, and the dialogical learning of the Swiss experts Urs Ruf and Peter Gallin.

_Learning from Sweden

In some federal states, school groups work with diagnosis material from other European countries. They searched for material which would facilitate better individual student support. Results were found in Sweden where individual evaluation material is available in the form of an interview for mathematics instruction in the 6th to 9th grades (PRIM material from http://www.prim.su.se/english/; downloaded on 10.11.2008). This material is comprised of specific tasks in which the tested children are confronted with a problem and are asked to give their opinion on it. They have to assess the solution to a task and explain and justify their opinion. From this, the teacher can, on the one hand, see which mathematical problem-solving ability the student has at his/her disposal and, on the other hand, see which goals have not yet been reached and ways in which to reach these goals. The evaluation forms used in order to record the results of the interviews inspired one SINUS teacher to develop an instrument for self-evaluation. In this, the students were to state on a four-point scale whether they can confidently achieve the aims of a lesson unit or not, for example "I can calculate the circumference of an area". Initially field-trialled as practice before an upcoming test, the test class showed high interest in combating the numerous weaknesses which were revealed. The teacher provided practice material on the relevant topic which could be worked on alone or with a partner and was supposed to fill the knowledge gaps. The students embraced this new practice possibility enthusiastically as they were able to choose tasks from the material which were most suited to their own abilities. They found this procedure to be helpful and wanted to have the opportunity to have these practice phases in the future as well.

Despite the students' positive response to the evaluation form, the teacher searched for a further improvement. She had noticed that, in practice, the form only asked about requirements at a routine level. Thus, comprehension problems would hardly be visible. They would only become visible once suitable practice material was worked on. As a consequence, the teacher developed partner evaluation forms which contained a whole row of mathematical arguments which could not be tested with routine procedures. The students' homework was then to state whether the arguments were correct or false and justify their statements. In the next lesson, each student compared his/her results with one other student and, in the case of dissent, argued about the correct solution. In the following lesson, the teacher marked the correct solution and wrote the name of a student who had the correct solution on the homework of students who had the wrong solution. This in turn formed new pairs who, with the knowledge of the correct solution, could then discuss pathways to this solution.

In using this variation, the teacher succeeded in eliminating the weakness of the initial evaluation form: in applying it as preparation for a performance test, the focus was on practising familiar material. The mathematical arguments of the following version revealed more comprehension problems which could then be worked on in the partner discussions.

_Learning from Switzerland

Many SINUS teachers hoped to strengthen their students' independent learning with the method of dialogical learning. They had learnt about the concept of a connection between language and mathematics at one of the SINUS further training seminars. This concept comes from Urs Ruf and Peter Gallin – Swiss experts from the field of language and mathematics education. A dialogue between teacher and learner is initiated by so-called assignments which encourage students to work on a mathematical idea. At first, the learners search for the aspects of the topic which concern them personally before they attempt to deal with subject-specific challenges. In this manner, access and choice possibilities are created which open up individual solution paths for the problem posed. Starting with their everyday understanding, the learners proceed – step by step and accompanied by their teacher – onto new territory. To facilitate this procedure in a school class, a written version is kept in a so-called travel diary. In this, the learners document their thoughts and the procedures they choose in detail. By writing, they further develop and clarify their thoughts. In addition, the flippancy of spoken language is removed.

_Small steps at the beginning

The experience which teachers in the programme had with this approach – frequently in mathematics, but also in science – was often surprising as the measure of independence seen in the students up until then was clearly increased. With regard to content, the quality of the results was at a level which was not reached in normal lessons. The teachers generally viewed the assignments, which cannot be easily compared with traditional tasks, as challenges. It should not be possible to solve them with routine operations. Rather, they must be so open that they can be successfully solved at several levels and in several ways. The teachers found it helpful to work intensively with the module on task culture and to get to know the diversity of tasks and their respective effects on the different instruction situations. The necessity to organise instruction in a different way also presented a hurdle for the teachers. They largely handed their control of the lessons over to the students. However, at the same time, they had to maintain contact with their students. The writing procedures also progressed slowly at the beginning and tested the teachers' patience.

Yet those who dared to make a start, and then saw the positive effects, could not then resist expanding the newly designed lesson time. The students used the freedom which the teachers gave them to work individually or together, even though not all of them gladly accepted the new responsibility for their own learning and some had difficulties with it. However, in the end, the experience of self-determination, the progress which they achieved by themselves, and the experiences of success in understanding which they had also convinced these students.

_Responsibility grows slowly

Teachers who intensively dedicated themselves to strengthening the responsibility which their students took for learning noticed considerable effects in their classes and a perceivable reduction in their own work load. However, the effects were neither achieved quickly nor without difficulties. The teachers needed to have confidence in their students' abilities, the students needed to assume responsibility, and both teachers and students needed to accept the new instruction patterns in order for these positive effects to emerge.

Module 10

Increasing the efficiency of mathematics and science instruction (SINUS)

Module 10: Assessment – surveying and providing feedback on competency increases

The effectiveness of instruction which is problem and comprehension-oriented, as in SINUS, depends not least on the type of performance assessment used. As school reports are connected to further training and career chances, parents and students often place a higher value on success in formal examinations than on well-grounded and flexibly applicable knowledge. Module 10 "assessment – surveying and providing feedback on competency increases" encourages teachers to develop a new test culture at the same time as developing a new learning culture. This involves examining the quality of the test tasks used and establishing whether they really test the students on what they should be learning.

Numerous studies show that performance tests in Germany up until now have mostly used tasks which require the reproduction of subject matter which has just been dealt with and the application of simple formal procedures. This is seen as one reason why students in Germany perform higher than average in the international comparison of routine applications but perform considerably lower when it comes to tasks which require flexible knowledge and contain complex problems. Therefore, the tests used must be supplemented with further task types. Alongside tasks which test routines, tasks which link newly acquired knowledge with previously learnt subject matter and which test subject understanding and the transfer and application to new contexts must be used more frequently. Furthermore, students should be given feedback about their learning progress and this feedback should not simply be based on a class comparison.

In their work on module 10 "assessment", teachers asked themselves the following questions: how can a more open performance assessment and evaluation process be designed which is oriented towards complex problem-solving skills and the individual progress of the students? When does this fulfil the demands of transparency, objectivity and fairness while being, at the same time, motivating for the students?

_Changed class tests

The testing and evaluation of performance takes up a lot of space in instruction: teachers not only evaluate written performance tests such as class tests or short tests; they also review oral statements made in class, homework and their students' attitude towards class work. At the beginning of SINUS, several school sets devoted themselves to changing class tests. As recommended in module 10, they integrated tasks that repeated subject matter which had been dealt with a long time ago and open tasks into their tests. They had previously already begun to use such tasks in their lessons when working with the other modules.

Task 'decimal fractions':
Convert the following fractions into decimal fractions. In each case, describe how you did this.

$\frac{3}{4}$ $\frac{6}{30}$ $\frac{17}{50}$ $\frac{7}{13}$

Here, the students can show that they can master the conversion of fractions into decimal fractions, which was previously dealt with, by expanding or simplifying them. However, the last fraction cannot be converted according to this pattern. In this case, the students must understand the concept of a fraction as a symbol for the division of two numbers.

Task 'admission tickets':
Ralf likes going to the cinema. The tickets for his favourite cinema cost €4.50.
A multiple entrance ticket with 10 tickets costs €40.

There is no question in this task so the students have to first consider reasonable questions themselves. Simple solutions without any further assumptions are that going to the cinema with the multiple entrance ticket is 50 cent cheaper or that Ralf has to go to the cinema at least nine times for the multiple entrance ticket to be worthwhile.

Task 'animal characteristics':
For several groups of animals, the students have to state the attributes or criteria according to which the animals are classified into the different groups. This task shows an easy way of opening up a task and keeping the workload low. This happens by turning the usual working direction around. The students are presented with a result and then explain how it came about. In this case, there are several solutions.

In the trial of the changed class tests, the teachers established that the students were generally capable of dealing with the new requirements. In order for the work on the open tasks and the repeat tasks to be successful in performance appraisals and evaluations, these tasks had to also first be used in lessons. At the beginning of the changeover, it is important to keep the requirements of the new test tasks low. Furthermore, open tasks should not be too complex as working on them should not take up too much time. Repeat tasks should be limited to basic skills and knowledge which are important for further learning. In this way, it was shown that changing written tests at the same time as developing the task culture was successful.

Nevertheless, the teachers still had questions to which there were no simple answers: how can the different solution paths possible in open tasks be suitably evaluated? What percentage of time and space should the different tasks be given within a class test? Which weighting is reasonable for the evaluation? The teachers have to search for the answers to these questions depending on the individual class situation. The more familiar both teachers and students are with the changed requirements, the easier the changeover is.

_Confirmation from central examinations

The fact that the adapted examination culture in SINUS supports processes of instruction development can be seen in the recently introduced central final exams. On average, the SINUS schools in one federal state demonstrate a higher performance level than the other schools in the state. The SINUS schools have obviously succeeded in increasing the applicability of their students' knowledge. For example, in the presentation examinations, the skills on presenting facts and circumstances and the problem-solving competency, both developed by instruction which is designed in a more communicative way, stand out in a positive way. When the results of work on SINUS become visible in this way, it supports the motivation of those involved and encourages others to follow this example.

_Feedback on learning processes and results

Feedback on competencies and competency gains cannot be limited simply to formal examination situations. If so, many possibilities for motivating the students to learn would remain unused. In the SINUS programme, teachers thus tried an abundance of further approaches, in addition to the changed examination instruments already mentioned, which provided students with feedback on their learning processes and the corresponding results. This included the travel diaries and the self and partner evaluation forms already mentioned in other modules, as well as learning diaries, student portfolios and evaluation procedures in cooperative working forms. Many of these evaluation forms were not introduced explicitly in connection with module 10 "assessment", but with other modules, which again shows that modules are interconnected with each other. These activities were supported by high-quality conceptual contributions from research which had already been tested in school practice (Ruf/Gallin 1998a, b, Winter 2004, Vollstädt 2005). All of these instruments take the learning processes into account in addition to the learning products which were, up until now, often evaluated in isolation. They thus make a contribution towards changing the concept of performance: alongside the comparison with uniform specified standards, or the comparison with the members of a group, a more individualised viewpoint emerges which is oriented towards the best possible support for each learner.

The way in which such motivating feedback was implemented in the programme will be demonstrated by means of the so-called travel diaries. In travel diaries, students document their individual dealings with (mathematical) problems. The results are looked at and commented on by the teacher from time to time. Important thoughts and findings are acknowledged in the comments. Furthermore, questions are formulated at critical stages which do not necessarily indicate the solution but do contain tips about how to continue work – for example, reminders of helpful problems which have already been worked on. The evaluation of a topic which has been worked on is oriented to the known performance level of the learner and is symbolised with a transparent system of ticks:

No tick: performance is not yet sufficient
One tick: requirement is fulfilled
Two ticks: a personal contribution is clearly visible
Three ticks: surprising, unusual or original performance.

This type of evaluation focuses on the path which the learner has taken, avoids the direct comparison of performance within the class and thus supports motivation. The developers of the travel diary concept also developed a practical procedure which makes it possible to combine the evaluation of the travel diary with that of the performance level, i.e. the product of the learning process, in a grade. Differences between both parts of the evaluation have less impact in this way than when a mean is constructed, as the respective better evaluation is weighted more strongly (Ruf & Gallin, 1998a, p. 81 ff.).

Although the integration of both evaluation dimensions connects the learning process to a performance evaluation – whereby the criteria are the individual's skills and developments, not the class average – and introduces a moment of external motivation into the picture, this process signalises, at the same time, that intensive independent learning makes a hugely significant contribution to a positive overall evaluation and is clearly acknowledged as important.

_How supportive feedback pays off

The many positive reactions of the teachers as well as the students to the feedback on competency gains tested in SINUS indicate the path to be taken in the future. It is profitable for all those involved, students and teachers alike, if methods which make learning processes visible are increasingly used in instruction. In the next step, suitable feedback procedures must be initiated which provide feedback on learning processes and results and maintain the motivation of the learners or even increase it. In a last step, it is worth incorporating the learning processes which have been identified, together with the evaluation of the performance level carried out according to the curriculum's criteria, into a grade in a favourable and supportive manner.

_Literature

Ruf, U. & Gallin, P. (1998a): Dialogisches Lernen in Sprache und Mathematik. Bd. 1: Austausch unter Ungleichen. Grundzüge einer interaktiven und fächerübergreifenden Didaktik (Dialogical learning in language and mathematics. Exchanges between unequals. The main features of interactive and interdisciplinary didactics). Seelze.

Ruf, U., & Gallin, P. (1998b): Dialogisches Lernen in Sprache und Mathematik. Bd. 2: Spuren legen – Spuren lesen. Unterricht mit Kernideen und Reisetagebüchern (Dialogical learning in language and mathematics. Leaving tracks – reading tracks. Instruction with core ideas and travel diaries). Seelze.

Vollstädt, W. (2005): Leistungen ermitteln, bewerten und rückmelden (Determining, assessing and providing feedback on performance). Frankfurt: Amt für Lehrerbildung Qualitätsinitiative SINUS.

Winter, F. (2004): Leistungsbewertung – Eine neue Lernkultur braucht einen anderen Umgang mit den Schülerleistungen (Performance assessment – a new learning culture requires different ways of dealing with students' performance). Baltmannsweiler.

Module 11

Module 11: Quality assurance within and across schools

The development and assurance of quality in mathematics and science instruction is the focal point of SINUS. Module 11 “quality assurance within and across schools” contributes to this on a meta-level: in order to be able to further develop instruction together, an assessment of the current situation in a school and the goals which the school wants to achieve step by step is necessary. Module 11 suggests three steps which help teachers to evaluate the situation in the field of mathematics and science. First of all, they have to discuss and agree on the criteria which seem suitable for surveying the performance situation in a class. Following this, they construct tasks with which the performance goals can be tested. Each teacher thus has the possibility to ascertain the performance level and the progress of their students. In order to initiate the development of teaching quality, the teachers discuss the possible reasons for and conditions behind the obtained results in order to indentify promising ways of improving them. The criteria and tasks which were developed within the school then form the basis for the agreement on the standards shared across schools.

Over the last years, the concept of standards has gained in importance in connection with educational topics. Since 2003, national educational standards exist for the subjects German, English, mathematics and, since 2004, for science. Comparative tests are taken in the relevant grades in all of the federal states in order to examine the results of the schools and the conditions under which these results are achieved. Against this background, the following questions should be answered: How did the SINUS schools react to the suggestions of module 11? What is the relationship between this and the national educational standards or comparative tests?

_Long-term methods

Right at the beginning of the SINUS programme, schools in four of the participating federal states addressed the module on "quality assurance". The long-term goal was to support work on the other SINUS modules through the discussion and development of common standards – first within a school and then also beyond it. The targeted improvements, such as the further development of the task culture, which should have a direct effect on instruction, were thus to obtain a more comprehensive framework and be secured long-term.

_Establishing standards and using them in instruction

In order to first of all determine standards within schools, the subject groups of one school participating in SINUS took the following path: the groups looked at the present syllabus and grouped important topics from the individual grade levels together. The teachers then agreed on overall learning goals for these topics which were to be achieved by the students. From these, they in turn formulated more general competencies such as "the students are familiar with subject-specific ways of working" or "the students are familiar with the basic geometric forms and can describe them". The teachers then further elaborated on these general competencies. In the resulting compilations, both basic skills and routine applications, as well as the competencies which were later formulated in the national educational standards, are mentioned: "recognising proportionality or anti-proportionality in problems and working on the tasks with suitable solution procedures" (modelling); "presenting information in tables, in coordinate systems and as arrow diagrams" (using mathematical forms of representation).

The standards assembled form the basis for further activities. Based on them, the teachers developed tasks and lesson units which enabled the students to establish competencies. In addition, they worked on practice forms for securing competencies. Furthermore, they implemented the standards in examination tasks. With the grade tests which were developed from this, the teachers received information about the standards which had been achieved in their classes and how their performance compared with that of other classes.

_Standards = uniform requirements?

In the discussion about educational standards, voices which warn about the negative consequences of the introduction of standards can also be heard. They fear that instruction could be restricted by the necessity to test whether the agreed standards have been implemented. They thereby think that learning which responds to the different performance levels of the students in a differentiated way – as it is encouraged in SINUS – could be endangered. However, the described examples of standards and comparative tests in the SINUS programme show that SINUS teachers do not interpret standards simply as objective criteria or uniform requirements for performance assessment. Although the comparative and final tests implemented to test the learning results were graded and the diagnostic function was linked to a performance assessment (possibly an indication of the necessity to deal with lesson time economically), through the shared discussion and establishing of standards, the teachers' attention was focussed on looking at how the learning goals determined by the standards can be achieved in lessons. The tasks and lesson drafts worked on demonstrate this. The standards thus had a direct influence on the development of instruction quality. The concept of standards and their conversion into instruction of high quality – as designed in SINUS module 11 – was thus confirmed in practice even before the national educational standards were introduced.

_Educational standards and SINUS

At the end of the year 2003, the KMK (Kultusministerkonferenz: Standing Conference of the Ministers of Education and Cultural Affairs of the Federal States) decided on binding educational standards for the subjects German, English, mathematics and science in Germany. These, along with centralised examinations and comparative tests which have, in the meantime, also been introduced in the federal states, serve the purpose of examining the levels achieved in those school grades which are particularly important for the students' educational career (at the end of primary school, secondary level 1 and the higher education entrance qualification). They thus make the measures described in module 11 "quality assurance" binding for all schools. For this reason, the SINUS-Transfer programme began early on to focus on dealing with the "new" educational standards. This revealed that working with the SINUS modules provided excellent opportunities to develop the competencies formulated in the standards. These suggestions were widely adopted in the work of SINUS schools in all of the federal states.

Nevertheless, in several points, it will still be necessary for schools and school groups to work on quality standards – whether due to the fact that there are no external standards for certain subjects or grades, or whether in order to better understand what should be achieved with the standards and how this should be achieved. The establishment and testing of standards are only two steps in quality assurance which must be completed in lessons through the targeted development of the desired student competencies. The SINUS programmes have already done some preparatory work for the introduction and implementation of educational standards and, in addition, provide a model for how they can be effectively introduced to schools.

Teacher Cooperation

Encouraging and supporting instruction-related cooperation between teachers in SINUS and SINUS-Transfer

Cooperation between teachers is frequently and highly recommended in the improvement of instruction quality in a school. The reasons for this can be found, for example, in school effectiveness research. Numerous findings show that cooperation between teachers is one of the characteristics of effective schools. Research on the development of professional competency also places high importance on career-related cooperation.

Although cooperation is an important element in the further development of instruction, up to now, many teachers still work alongside – as opposed to with – each other in their everyday professional life. The hesitant willingness to cooperate could be due to the fact that cooperation is not an aim in itself and does not always make sense. Real cooperative tasks require each participating person to make an individual contribution which cannot be made by the other participants. The requirements can be so complex that, for example, different perspectives must be taken. Or, they are designed in such a way that each individual person participating has only a certain part of the competencies and/or resources required (for example, information, material) at his/her disposal.

Thus, in this respect, the further development of mathematics and science instruction certainly presents a real cooperation task. Whether the cooperation will actually work and lead to success depends on further factors. Not least, a content-related and organisational framework which supports the cooperation is necessary.

The SINUS and SINUS-Transfer programmes succeeded in providing an organisational and content-related framework in which the teachers can cooperate on instruction and thereby experience that the cooperation is worthwhile for them. The present chapter shows how the structures provided by SINUS can encourage, support and sustain teacher cooperation over a long period of time.

_How SINUS encourages and supports teacher cooperation

The aim of SINUS and SINUS-Transfer was to work together with teachers to improve and assure the quality of instruction. In order to achieve this aim, it was assumed that the participating teachers were in principle prepared to work together in a professional sense. On this basis, SINUS provided a content-related and organisational framework which prompted teachers to cooperate and supported them in so doing.

_Modules as reference points for teacher cooperation

Cooperation in SINUS always has the aim of improving instruction together. A framework of eleven so-called modules helps the teachers in working on this. These modules create concrete reference points for the collective further development of instruction. Each of these eleven modules refers to one central problem area of mathematics or science instruction (for example, further development of the task culture, learning from mistakes). The teachers of a school choose two to three modules and work on these together. The modules facilitate cooperation by providing ideas for the collaborative further development of instruction. They define clear concrete problem areas and provide the teachers with a common instruction concept and language about teaching problems. This helps the teachers to agree on the problem areas of instruction and to work together on further developing instruction. Supplementary to this framework which the eleven modules span, extensive support is also placed at the teachers' disposal. They can fall back on numerous module-related handouts, lesson examples, further training seminars and workshops.

_Organisational starting points for instruction-related cooperation

The eleven modules form the content framework for cooperative instruction development. Alongside this, the programme creates organisational structures which facilitate cooperation – at the level of individual schools as well as at the level of cooperation across schools.

Cooperation at the school level. As the programme aims at further developing subject-specific instruction, it makes sense to place the focus on groups of teachers instructing the same subject. The *subject group* thus comprises the most important entity in cooperation at the school level in SINUS and SINUS-Transfer. It presents the starting point for the work with the modules. An average of five to six teachers per school participated in the SINUS and SINUS-Transfer programmes. In quite a number of schools, the number of participating teachers was considerably higher, in others, considerably lower. In the latter case, the challenge was to win further teachers over to work on cooperative instruction development over the course of time. The coordination by a contact person at the school level, who made sure that the working groups regularly met, set themselves goals and followed them consistently, provided support in this aspect. Furthermore, it was helpful if the school head supported the activities of the teachers working on SINUS. Alongside their "moral" support, they could create organisational freedom for the teachers in the everyday life of the school which facilitated cooperation. For example, certain lesson-free time slots helped in setting up regular weekly work meetings. In-school teacher training also obviously concerns this group of teachers of one subject, e.g. with regard to the modules worked on.

Cooperation beyond the school boundaries. Subject groups were and are present in many schools and thus present an appropriate starting point for cooperative instruction development at the school level. This case is different when it comes to cooperation between teachers beyond schools' boundaries. In this case, the cooperation was supported by the network structure which was set up in SINUS and SINUS-Transfer, in particular, by the construction of *school sets*. A school set is a small network of six to ten schools. The schools should preferably be located near to each other in order to keep travel time low. The composition of the school sets differed. The networks were frequently comprised of the same types of schools, sometimes of different types of schools (Hauptschule, Realschule, Gymnasium). The school sets were composed according to the subject to be worked on (for example, school sets working only on the subject of mathematics). At the same time, however, cross-curricular school sets existed. The schools in one school set normally worked on the same modules. The school set served as a forum for the development, presentation and exchange of solution approaches and lesson examples. It provided the possibility to visit the lessons of teachers from other schools. It was important for the teachers to be given the possibility to regularly meet each other in the school set.

In order to support cooperation in the school set, the so-called set coordination was set up in the programme. This task is mostly assigned to experienced teachers and teachers on secondment who are interested in school and instruction development processes. They take care of the regular organisation and the design of the content of the meetings within the school set, amongst other things. They were also given the important task of encouraging and supporting the teachers at a school.

The information exchange and communication about the modules is made easier if the work is documented in a precise way and thus made accessible to other colleagues (for example, from other school sets or other federal states). The set coordinators also make sure that the processes and products are regularly and clearly documented.

There are further cooperation levels alongside the levels of school and school sets in the SINUS and SINUS-Transfer programmes. These include cooperation at the federal state level as well as cooperation between federal states. National cooperation, however, no longer applies primarily to teachers at the participating schools. At this level, the primary focus was on the school set or federal state coordinators (see Figure 1). Thus, regular training seminars were offered at a national level for the school set coordinators. These seminars served the purpose of developing the competency of this central group of people and led to numerous content-oriented cooperations across federal states.

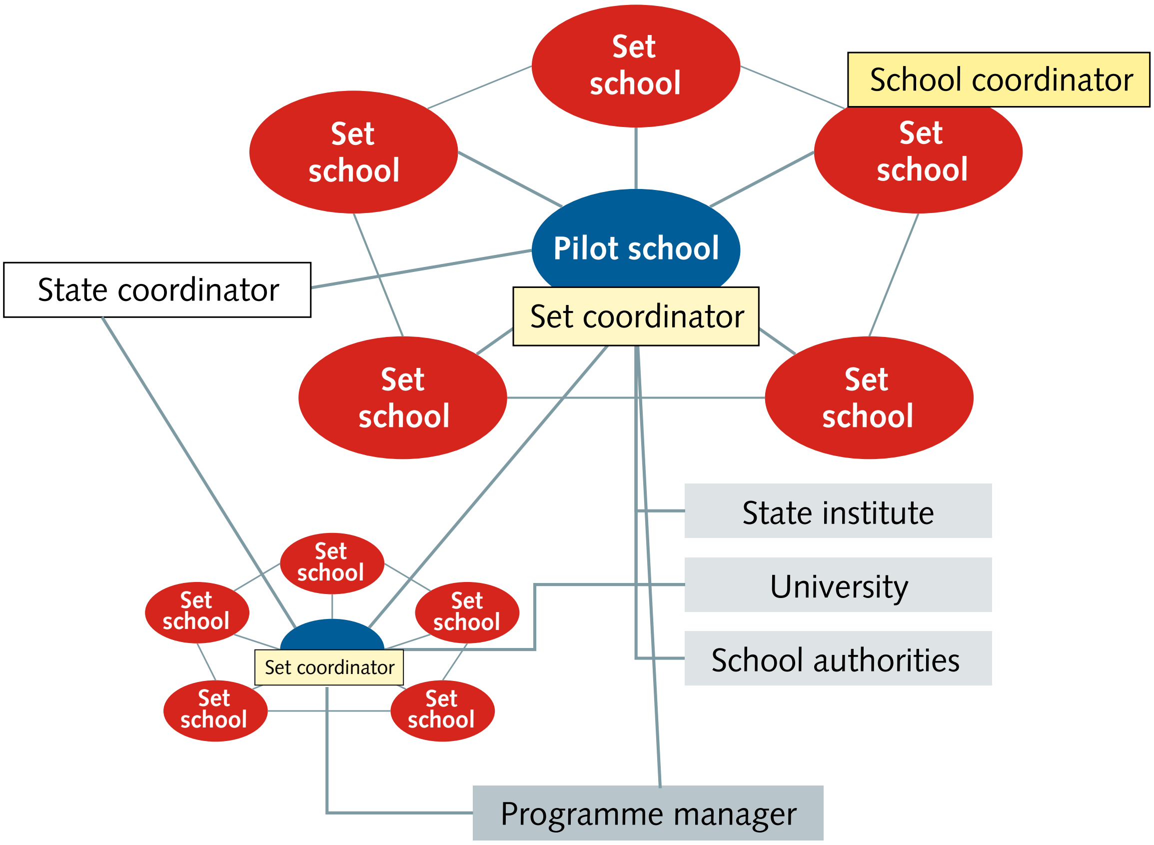


Figure 4: Presentation of the network structure in SINUS. As examples, two school networks (school sets) and their connections to state (state institute, university, school authority) and nationwide (programme manager) support structures are presented.

_The benefits of cooperation from the teachers' perspective

The teachers' perception of the benefits of cooperation was the object of a questionnaire survey which was regularly carried out. Many impressions could, however, also be gained from numerous informal conversations with those involved at seminars which took place within the programme.

A central finding of these surveys was that the participating teachers' experience in the programme was that professional problem-oriented cooperation is worthwhile. They clearly noticed that the cooperation was worthwhile for them in their everyday lessons.

The effort necessary for the subject-related cooperation was compensated by a reduction in the work load because teachers could use material which had already been tested by other colleagues and, furthermore, received tips about which examples function under which conditions and when this was not the case. Finally, teachers were able to approach their own work in a more structured manner and thereby gained more potential to try out new things.

The subject-related cooperation also led to more motivation because teachers were able to try out something new which their colleagues were also trying out and they could then exchange experiences. Furthermore, it became noticeable that instruction gradually improved and the quality increased. This led to the teachers experiencing a competency increase in their own professional work.

The subject-related cooperation resulted in a reduction in the mental work load as teachers could see that others also had to "struggle" with problems (instruction problems, didactical problems) and even with problems similar to the ones that they were experiencing.

It was also important that, through their work with SINUS and SINUS-Transfer, the teachers became aware of the fact that they were now (once again) talking about their main area of work – instruction.

Apart from all these worthwhile aspects of the cooperation, it cannot be denied that there were and are also some obstacles with regard to the professional cooperation of teachers. For example, the question of how colleagues who are not yet involved in further development processes can be won over to get involved will always be topical. It must be understood that teachers cannot be forced to cooperate. Rather, the individual advantages of cooperation must be made visible to those involved and to those persons who are to be won over in the future. In this regard, the conception of SINUS and SINUS-Transfer which initially refers to the subject group and works on concrete work-related tasks and problems seems to have a beneficial effect on teacher cooperation.

Coordination

Coordination – how much guidance does a programme like this need? What can and what must coordination accomplish?

Coordination in SINUS – what does this really involve? Who coordinates what, how did coordination take place in SINUS? How much coordination does a programme such as this require and what does it have to accomplish? This section deals with these questions. But one thing can be revealed beforehand: there is no easy recipe for good coordination – not even in SINUS, as many factors play a large role. However, interesting and informative experience from SINUS and SINUS-Transfer reveal how coordination can work in different styles and ways and on what it depends.

First of all, the SINUS coordination model will be discussed. In the second section, we then take a look at the dissemination programme SINUS-Transfer and the associated changes with regard to the coordination.

_The coordination model of SINUS – what were the success factors?

The main idea behind SINUS was to change and improve instruction through the teachers. They themselves were asked to further develop their mathematics and science instruction in cooperation with each other. Central aspects in SINUS were:

- providing a lot of freedom and possibilities for those involved,
- using their competencies, and
- seeing teachers as the major players.

The motto of the programme was to let teachers act without any pedantic restrictions from the school authority or curriculum specifications. In order to activate and support this process in all of Germany, the coordination of the programme at various levels was of central importance. Coordination levels which played an important role were:

- The central coordination of the programme manager and the cooperation partners
- The regional coordination at the federal state level
- The local coordination at the level of the schools working together in a network (set)
- The coordination at the school level (school coordinator)

Let us now take a look at the individual levels of coordination.

_Which work must be performed at the central coordination level?

In order to encourage processes of cooperative instruction development in a nationwide programme such as SINUS, the support which was provided by the central coordination level proved important. First of all, a convincing project conception which defined a clear framework and provided an organisational structure and content-related goals was particularly important for the implementation of SINUS. Even if the various conditions present in the federal states and regions are different and these have to be considered, it is necessary for the work to be based on a uniform structure. Yet, this must be flexible enough to allow different alternatives and provide freedom of movement for the respective states, sets and schools. This was achieved through the content framework of the modules and the establishment of school networks.

The central coordination level was responsible for offering suggestions, support, material, advice and expert accompaniment in order to help teachers to successfully implement the framework conception. The following bodies made up the central coordination level: the programme manager (IPN – Leibniz Institute for Science Education), its cooperation partners (ISB in Munich – State Institute for School Quality and Educational Research, The Department of Mathematics Education at the University of Bayreuth), the executive committee and a scientific advisory board. The executive committee was the central steering element which combined the perspectives of science, the federal states and politics in its composition and was responsible for advice and decision-making with regard to the programme's activities. The scientific advisory board was comprised of designated representatives from the field of empirical educational research and subject didactics and had the task of providing expert advice during the whole project and organising the external evaluation.

The programme manager – along with the cooperation partners – was the decisive contact point for the federal states, schools and teachers right from the beginning of the programme. Neither in the federal states nor in the schools was any expertise available on the modules or the organisational structure at this time. The network structures also first had to be designed and established.

Thus, the programme manager[1] was the central service provider in the coordination of all groups and the construction of a nationwide cooperation network and quality assurance system in the first years of the SINUS project. The focus of its tasks lay in providing handouts and material on the modules and providing advice and further training seminars for the participating teachers. The Leibniz-Institute for Science Education provided advice on questions about science didactics, general didactics, teaching and learning research and evaluation. The ISB and the Department of Mathematics Education in Bayreuth were responsible for advice in the area of mathematics didactics. During the first years, their work concentrated on the development of material and explanations of the modules. Handouts for the teachers were developed. These handouts contained scientifically well-founded suggestions and starting points for the work on the problem areas of instruction. For example, explanations and handouts were developed for the following topics: "How to proceed in SINUS", "Perspectives for teaching", "Elements of a new task culture", "Making subject boundaries visible". In order to ensure that information was exchanged between the different levels and to prepare the coordinators for their tasks, two nationwide training events were organised each year. The topics which were focused on at the beginning were evaluation, documentation and cooperation and module-related training seminars. Furthermore, a central Internet server was set up which made the exchange of information and material possible. At the beginning of the programme, the programme manager also undertook coaching tasks and advised individual school sets and teachers. However, this function was gradually passed on to the coordinators whereby the programme manager's function of providing further training seminars came more to the fore. The programme manager's service functions were thus adapted according to the demand and the current conditions. This procedure proved to be successful in working towards the aims of the programme.

_Why regional and local coordination was so important

SINUS aimed to encourage and support instruction development processes which should then become firmly established in the subject groups, schools and federal states and should also continue to exist in the regulatory structures after the programme was completed. In order to achieve this aim, it is indispensable to, on the one hand, make it possible to take regional and local conditions into consideration and, on the other hand, use the existing infrastructure and the competencies and possibilities connected to it. This is where the *coordination at the federal state and school set level* comes into play.

_Regional coordination

The initiative to participate in the programme, the selection of schools, the planning, as well as the guidance and primary supervision of the work in the schools, was the responsibility of the federal states. They decided how the sets should be distributed across regions and how they should be composed with regard to the different types of schools. The coordination at the federal state level was responsible for these tasks. Although the central coordination level provided broad content-related and organisational support at the beginning, it was the federal state coordinators who encouraged and supported the cooperation between the school sets of a federal state, undertook the task of providing advice in the agreement on focal points and made sure

1 When the programme manager is referred to in the following sections, both the programme manager and the cooperation partners are meant if a specific institute is not explicitly referred to.

that the programme was included in the area of educational politics. They were central when it came to initiating cooperation between the school sets and the federal state institute and universities. 180 schools in 30 school sets took part in SINUS. Thus, in some federal states, only one or two school sets existed. This led to the set level being partially identical with the state level at the beginning of the programme. The coordination at the federal state level then also undertook the tasks of the local coordinators (set coordinators).

_Local coordination

The local coordination was organised differently in the different federal states. For example, the school set coordination was carried out either by teachers at pilot schools, by university staff, by employees of state institutes or by representatives of the school authority. The time necessary for the set coordination was planned to be equivalent to a half-time teaching position. The tasks included, in particular, the organisation of the sets' work on the programme, providing didactical and methodological advice for the teachers at schools, and facilitating the information exchange between state coordinators, the programme manager and schools. The local coordination level thus provided a connecting link between the schools of different sets.

An important aspect of the set coordination was the encouragement and support of the teachers in their working and learning processes at schools. However, the set coordination tasks were interpreted differently in the federal states. Thus, for example, some coordinators held back completely when it came to didactical questions while others provided finished products. In order to guarantee relatively uniform support from the state and set coordinators despite the regional differences, the states agreed on common tasks for the coordinators.

Alongside the coordinators at the local level, an additional contact person was nominated for each school – the so-called school coordinator. This person was supposed to facilitate the flow of information at the school and the exchange of information with the set coordinator. This function was used to different degrees in the states. For example, the function was given a very important role in some states. The individual school heads also represented a further important supportive factor. The school head can contribute towards the general promotion of an innovative atmosphere in the subject groups at a school and thus to the success of a programme like this.

_What does the experience show?

The experience with the programme shows that the procedure described was successful. The coordinators assumed important functions in the forming of local, regional and national networks. They provided assurance and assumed a multitude of tasks. Through their connection to the respective region, they were able to quickly and concretely assess the regional and local particularities and requirements. However, differences also became clear in the quality of this support. The quality of the set coordinator's work proved to be a central aspect in their support. Coordinators must be trained in all aspects of the programme, for example, in leading groups, dealing with opposition, in subject-specific educational competencies, in modules, in quality assurance, the server, in resources/support systems and in state-specific particularities. Only when this is the case can qualitatively high support be guaranteed for the schools. In this respect, the following abilities and characteristics proved particularly important: making content-related suggestions, being interested in the work on the programme, supporting autonomy and competency, facilitating social integration and providing structuring support.

What does this actually mean? Coordinators must provide the teachers with freedom by offering them alternatives and not providing complete solution steps. They should give the teachers tips about further development possibilities and provide them with constructive feedback, give them the feeling that they are an accepted and equal partner in a working community. They have to take problems and difficulties seriously and both offer the teachers a clear structure as a framework for their work and provide advice on content-related questions.

_From SINUS to SINUS-Transfer – coordination changed

After the successful completion of the SINUS programme, it was to be further disseminated in two phases. The aim of this dissemination was to establish cooperative quality development processes at further schools and, in the long term, to integrate them into the regulatory structures of the federal states. In order to achieve this aim, the programme was not to simply be implemented once again, but rather be conveyed to a wider target group. Thus, in contrast to SINUS, a completely different starting point was formed which also changed the tasks of the different coordination levels.

- At the beginning of the dissemination phase, the coordinators at the state and school set level already had extensive experience and competencies.
- Furthermore, a well-functioning cooperation and communication network existed at the national, state and local level, along with a rich range of developed material and handouts.
- Many of the concepts and methods developed in the initial phase now belonged to the standard repertoire of the teachers involved.

These resources could be used in SINUS-Transfer. Here too, it was important to have an agreed procedure at the national level which could be adapted to the respective region. In this phase, the original tasks of the programme manager were partially transferred to the level of the state coordinator. The content-related input on the modules thus took a back seat. Although the organisation of the training measures for the set coordinators, the supervision and maintenance of the server or the advice on content-related, organisational and technical questions were still important at the level of the programme manager, further aspects were also added. These included the support of national cooperation models or the integration of current qualitative topics such as 'supporting students who are at the lowest performance level' or establishing the importance of SINUS-Transfer in the implementation of educational standards. Due to the larger number of schools, the amount of work associated with the support and supervision in the states increased and the organisation at the state level became more complex and much more time-consuming. The state coordinator assumed a special role in this phase. What was important here was, in particular, the involvement of further support systems (state institutes, state universities) and the linking with other instruction-related innovation programmes within the respective state. Teacher training institutes which were involved in the didactical monitoring of the programme from the beginning assumed supervisory tasks where necessary which had previously been undertaken by the programme manager. The states became much more independent in their coordination of the programme and different coordination models were developed at the set and school level. For example, in Bavaria, a coordination model was chosen in which pairs of experienced teachers assumed the role of the set coordinator. Not all of the state models can be mentioned here. However, it is important to highlight the fact that it was exactly this freedom that led the states to assume responsibility and this, in turn, distinguished the success of the coordination model in SINUS-Transfer. Responsibility for tasks was transferred to the states, away from the programme manager, which strengthened the integration of the programme into the structures of the states.

_Conclusion

Coordination at different levels proved to be an important factor in the success of the model programmes SINUS and SINUS-Transfer. On the one hand, a uniform concept which provides the content-related and organisational framework is extremely important. At the beginning of the programme, the implementation of this should be coordinated from the highest level in order to underline the common goals of the programme and to initiate the process. On the other hand, possibilities must be created for responding to regional and local particularities and requirements, and for taking the creative leeway of teachers, schools and states into consideration. This can be achieved by coordination at different levels, namely, at the state and school set level (partially even at the school level). What is therefore important are the qualifications of the coordinator. Only coordinators who are well-trained and interested can contribute towards the success of a programme such as this one. A cooperation and communication structure which functions both within the individual levels and between the levels, while also involving the existing institutions of the supportive system, is the central element in this.

Training Courses

Increasing the efficiency of mathematics and science instruction (SINUS)

The role of training in the further development of instruction

The basic principle of the SINUS programme is to place the task of developing the quality of mathematics and science instruction in the hands of the teachers and to thus anchor it in the schools. The subject groups are given the task of identifying relevant problem areas, determining development aims, working on and testing solution approaches, reflecting on the results and deriving new initiatives from them.

This task is perhaps reminiscent of the picture of Baron Münchhausen who pulled himself up by his own bootstraps. However, SINUS did not leave the teachers alone with this task. Rather, it offered them support. The first form of support consisted of teacher cooperation, the second of the modules with their content-related suggestions. It is the task of training seminars – which are the responsibility of the coordinators – to make sure that this help is effective. They make the participating teachers familiar with the requirements, make suitable suggestions for their work with the programme, convey new perspectives on instruction processes and encourage cooperation.

The following text demonstrates how the training seminars are integrated into the SINUS programme and how the choices were changed over the course of the programme in order to better meet the specific working requirements of the individual programme phases.

_Status of training courses in SINUS

The choice of further training courses provided took into consideration both the size and the complex structure of the SINUS programme, which initially started with 180 schools in 15 federal states, as well as the aim of anchoring quality development in the schools. Therefore, right from the start, two levels were distinguished between, each of which addressed different players in the programme:

- Central training courses, organised by the programme manager, directed at the federal state coordinators as well as representatives of schools and potential facilitators in the dissemination of knowledge.
- Local or regional training courses which were designed by the federal states addressed the participating teachers in the schools and school groups.

_Central training courses in the SINUS programme

The central training courses in the SINUS programme initially had the function of providing information on the implementation of the programme and making content-related suggestions. This was necessary in order to get the schools going because the model concept was new to them and cooperation between teachers in everyday school life had also mostly been the exception up until then. In the first five years of the programme, two-day seminars took place twice a year. The first training seminar addressed the state coordinators and representatives of the pilot schools who were to assume a leading role within the school sets. They were informed about the aims that were to be achieved in the programme, how the organisation and progress were planned and what support was available for this. As regards content, by using the example of module 1 "further development of the task culture", concrete illustrations of how the subject groups could start with instruction development were given. The focus of the following seminars was also placed on questions of organisation and implementation. In detail, the topics of cooperation, and the documentation and evaluation of work were discussed and an introduction was provided to the programme's own Internet platform.
New content-related initiatives were then the primary focus of the fourth seminar. Four subject experts from Switzerland presented possibilities for how instruction can be designed in a way that promotes learning. The topics were dialogical mathematics instruction with travel diaries (learning diaries kept by the students), hands-on geometry with self-made paper models, open situations in mathematics instruction and student orientation in science. After a brief introduction, the participants had the opportunity to work intensively on the ideas and material in workshops. The extensive practice phases were part of the concept of the training seminars; by letting the teachers gather their own experience, it was hoped that good pre-conditions would be created for the transfer to lesson practice.

The approaches mentioned were chosen because they provide examples for how the aims of the individual modules can be realised. They come from renowned subject experts and scientists and were not well-known to teachers in Germany up until then. Nevertheless, they had been sufficiently tested in instruction and documented and were inspiring.

From the third seminar on, teachers from the regional school sets presented the results of their work. On the one hand, this acknowledged the teachers' work and increased their confidence. At the same time, the exchange of information about the approaches and the experience had provided an incentive to disseminate the well-proven practice to schools with suitable starting conditions and to expand the cooperation beyond federal state boundaries.

_SINUS-Transfer – new challenges

In the transition from SINUS to SINUS-Transfer, new challenges arose for the central training seminars. Due to the scale of the dissemination – more than 700 schools in the first wave and the doubling of this number in the second wave, the central training seminars were now aimed at the coordinators. As extensive experience was already available in the states with regard to the implementation of the programme, the choice of courses on organisational aspects was limited to the first seminar where four states introduced their concepts. This served the purpose of discussing the strengths of the different state concepts – such as the size and composition of the sets or the frequency and procedure of the set meetings – and letting the individual states reconsider their own concepts in light of the experience gathered.

Subject-specific workshops on different modules were also a regular part of the SINUS-Transfer programme. In order to satisfy both the needs of the experienced and the new coordinators, content from previous seminars which was considered to be particularly inspiring was mixed with new contributions. The coordinators thus regularly had the opportunity to learn about renowned subject experts' new approaches to the further development of instruction and to try them out in workshops. They were thereby placed in a position from which they were capable of passing their experience on to the teachers at their schools.

At the beginning and the end of the transfer phases, the seminars were used in a targeted way in order to present the focuses chosen in the federal states and to thereby encourage information exchange. In this way, cooperation occurred between states participating in the programme, for example, they continued work on the modules together. Approaches towards module 8 (Developing tasks for student cooperation) and module 9 (Strengthening students' responsibility for their learning) were disseminated in this way in a lot of the participating schools.

A further challenge for the central training seminars was to direct attention towards current developments which had an influence on the work at the programme schools, as well as problem areas not worked on much. Thus, two seminars provided information about educational standards and their importance for high quality instruction. Here, the participants again had the opportunity to discuss the concept of educational standards in detail with the experts involved in their development and to concretely understand them with the help of task examples. How important and successful the work with the educational standards was could be seen in the participants' reactions at both seminars. After initially dealing with the topic, some of the coordinators were still reserved towards educational standards. They feared that the standards would make instruction which is oriented towards the different conditions present in heterogeneous classes – as is the case in SINUS – difficult. At the second seminar with workshops on educational standards, a clearly reverse picture could be seen. The multi-faceted requirements of the standards which were revealed by task analyses were generally recognised and it was agreed that this should be taken into account in instruction – in a way that corresponded to the SINUS approach. At the end of the programme, the topic of educational standards had gained a foothold in all of the states and found its way into the training of the subject groups or school sets.

In a similar way, the extent of the work on promoting students with weaker performance was also increased successfully in the programme. The number of lower secondary schools (Hauptschulen), which were clearly underrepresented at the beginning of the transfer programme, increased considerably in the second wave. Furthermore, several states formed an overarching working group which worked intensively on the development of suitable approaches and material. This focus was supported in particular at the first seminar of the second wave with a whole range of contributions: experimenting in the mathematics instruction of lower secondary schools, independent learning in lower secondary schools, open tasks for lower secondary schools, tasks for diagnosis, tasks with different levels of learning support, supporting weak students. Subsequently, these contributors were repeatedly invited to present their work in the federal states.

_Training of subject groups and teachers in a school set

The second part of the training courses offered in the SINUS programmes addressed the regional and local level. The seminars directly addressed the subject groups or the teachers of a school set and were to have a direct influence on the implementation of the SINUS ideas in the participating schools. The teacher training courses were structured similarly in the different programme sections. The focus was always on prompting and monitoring processes for developing instruction quality. The local training courses were mainly organised and carried out by the coordinators as they were in a position to respond better to the different needs of the specific schools and regions.

At the beginning of the set work, the aim of the meetings was to initially provide teachers with the information that was necessary for starting work. In particular, this comprised information on the modules, initially as a brief description in the SINUS experts' report and later in the form of extensive explanations, and on the state-specific implementation concepts. After choosing the modules to be worked on, the groups formulated the aims that they wanted to achieve, based on the respective problem situations. In the meetings – between two and four per year, depending on the state – materials were developed and their trials in lessons were agreed on. In each follow-up meeting, the experiences had were exchanged and reflected upon and the further work was organised.

In the further training courses for the school sets, the subject groups received the support which they needed in order to be able to autonomously further develop the quality of their instruction. With custom-made proposals, for example, in the introduction of a new module, in the evaluation of the lesson trials or the effective organisation of the group processes, the coordinators reacted directly to the needs of the individual schools. Together with the long-term installation of these measures and the interlocked meetings, this was to guarantee that the training courses would also be effective in lessons.

_The importance of the federal state level in SINUS-Transfer

In SINUS two levels, as described, were important in the training programme: the central and the regional training levels. In addition to this, in the SINUS-Transfer programme, the federal state level also acquired an important support function. This can be traced back to the growth of the school numbers which led to a more complex structure in most of the federal states. Whereas in SINUS there were one or two sets each consisting of six schools in each federal state, in the transfer programme both their number and their size increased. Under these conditions, a meeting of the teachers from all of the sets in a federal state was so big that it was no longer really suited to provide guidance and support for the subject groups' work although it was still suitable for coordination at the state level. However, the meetings which took place one to two times a year were still useful and important for the subject groups. They profited from the information exchange between the school sets with their different focal points as they could thus learn about approaches – and teachers' experience with these approaches – which they had not worked on themselves.

Furthermore, the meetings provided the possibility to invite the contributors from the central training seminars to speak at this level and, in this way, teachers were able to gain even more information about approaches which they had worked on. The teachers thereby experienced an appreciation of their work and had the opportunity to receive feedback and in-depth suggestions about these procedures. In addition, these meetings put the federal states in a position to focus on state-specific developments and requirements (for example, school programmes and school curricula) and to discuss their best possible implementation in the interest of the SINUS programme.

_Effective training courses are possible

The experience with SINUS has shown how teacher training courses can become effective: their design is long-term and they have a conceptual framework which is accepted by the teachers. The framework allows them the freedom which facilitates an adaptation to the individual situations on site. Successful training courses take existing knowledge and skills seriously and support their further development in a targeted way. They are concrete, are oriented towards important subject-related educational problems and increase the teachers' autonomy. They develop the skills of reflecting on, exchanging experience with, and information about, instruction and also expand teacher cooperation.