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## Towards New Teaching in Mathematics

Peter Baptist

# A Brief Introduction to the SINUS Philosophy for Mathematics Teachers

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# First Steps towards New Teaching in Mathematics

## Why Teach Mathematics in School?

### The Significance of Mathematics

> *Too few people recognize that the high technology celebrated today is essentially mathematical technology.*
>
> *Edward B. David*
> *Former President Exxon Research*

Mathematics is one of the oldest, most important, consistent, and at the same time highly relevant cultural achievements of humankind. When people working in the natural sciences or economics analyze something with a view to understanding it better or create a model of it, it would be inconceivable for them to do so without recourse to mathematics. Our day and age is increasingly determined by high-tech computers and unprecedented scientific and technological progress. This is why mathematics is gaining an ever more important position. Many forms of culture and communication determining modern society are essentially based on mathematical insights and methods often resulting from the latest research findings.
Mathematics cannot be reduced to the mechanical application of rules. Mathematics is a highly creative activity requiring both specific thinking skills and specific methods plus, not least, a great deal of experience. However, as a rule, this genuine core characteristic of mathematics is not being communicated with sufficient urgency in German schools. Too much emphasis is still being put on formal calculation methods.

### The Cultural Value of Mathematics

> *Beauty is the first test: there is no permanent place in the world for ugly mathematics.*
>
> *Godfrey H. Hardy (1877–1947)*

Applying mathematical skills is an intellectual adventure requiring imagination, ingenuity, logical thinking, perseverance and critical faculties. Comparable with artwork, mathematical theories, problems and solutions not only address the intellect but also feelings and aesthetic perception. Like poets, painters, and composers, mathematicians are creators of motifs, structures and patterns that are fresh and vital enough to survive for centuries. Such long-lived mathematical creations are based on outstanding ideas, and they also satisfy aesthetic demands.
The beauty of mathematics can be demonstrated in a variety of ways. It is neither dependent on the degree of difficulty nor on the level of the results or theorems considered. The aesthetic content can also be cultivated on an elementary level. The Theorem of Pythagoras is probably the best known example.

## Mathematics as a Key Technology

*The book of nature is written*
*in the language of mathematics.*

*Galileo Galilei (1564–1642)*

On the other hand, mathematics is an irreplaceable technical tool used in natural and computer sciences, in engineering and economics. Without mathematics there can be no such thing as technical or medical progress. This also needs to be recognized when teaching mathematics in school. Traffic light-control circuits and intelligent transportation systems are inconceivable without mathematics. Without mathematics we would not have notebooks, mobile phones, DVD or MP3 players, navigation systems, CAT scans, cash cards or scanner checkout counters. This list of examples could be extended indefinitely, the reason being that ultimately mathematics is at the root of all electronic components embedded in devices and vehicles. Even if mathematics is mostly invisible in the finished product, it had to be developed in the first place and had to be applied to the respective problem. One of the school's tasks is to convey the cultural and technological value of mathematics and encourage its appreciation.

## Summary

*Mathematics is not everything.*
*But without mathematics everything is nothing.*

*Hans-Olaf Henkel*

We are not suggesting that everybody should deal with mathematics in the way mathematicians do. We enjoy Beethoven, Mozart or Freddy Mercury without entertaining any idea of writing masterly compositions ourselves. Guidance and experience are required to understand Wagner's operas and Picasso's paintings. Guidance and experience are also required to achieve a profound appreciation and evaluation of mathematics. Society needs to become much more aware of how significant mathematics is for our lives. This is also an important and urgent goal for the teaching of mathematics.
Together with teachers from almost all of Germany's federal states, we have made the SINUS pilot study successful in demonstrating and testing approaches on how to achieve the cited goals and how to narrow or even close the gap in education with regard to mathematics (cf. Frankfurter Allgemeine Zeitung (FAZ), German daily newspaper, January 2007). However, pilot studies can only prepare the ground and point the way. Accordingly, general acceptance of these ideas among the teaching staff and their implementation in as many schools as possible will be crucial for the ultimate success of the project.

## Focus on Classroom Teaching

*Naturally I don't know if it would be better if it were different,*
*but it has to be different for it to be any good at all*
*Georg C. Lichtenberg (1742–1799)*

"The success story has a pretty bulky title: *Increasing Efficiency of Mathematics and Science Education*. The ambitious program has demonstrated that even in Germany something can be done that many people believe the allegedly slow Germans to be incapable of, i.e. rapidly responding to a deplorable state of affairs in schools; reforming classroom teaching, the core business of educational institutions; mobilizing the much-berated teaching staff to embrace change – and all this via cooperation between federal and state governments."
(DIE ZEIT, German weekly newspaper, 20/2003)
"True-to-life problems rather than schematic arithmetic, individual learning rather than swatting up on formulas at one pace for all. Such a reform in teaching mathematics is what SINUS stands for (*Increasing Efficiency of Mathematics and Science Education*). In Germany a few hundred teachers were involved at the start of the advanced training program. After the PISA shock, their number increased tenfold. SINUS has shown how to change instruction successfully." (DIE ZEIT, German weekly newspaper, 50/2004)
Supraregional and local print media also joined in with a unanimously positive appraisal of the BLK*) pilot study. However, they express regret that despite all progress made "SINUS is still far from reaching every single classroom". In the past years the number of SINUS schools has increased considerably. However, we should only be satisfied when we have reached as many schools as possible. How can we achieve this? To begin with, we would like to intrigue teachers who are not yet fully aware of this pilot study and also reach the interested general public. We hope you will be keen to find out about how SINUS schools operate in teaching mathematics.

*) BLK: Bund-Länder-Commission for Educational Planning and Research Promotion (until 2007)

## In the Beginning there Was an Expertise: How SINUS and SINUS-Transfer Developed

*A country's competitiveness starts not on the*
*factory floor or in the engineering lab.*
*It starts in the classroom.*
*Lee Iacocca*

In 1997, after the TIMSS shock, the BLK commissioned an expertise to find ways for improving mathematics and science instruction. Issues connected with the learning and teaching of mathematics and science subjects were analyzed. Furthermore, the experts suggested how to organize a Germany-wide pilot study and defined its content-related concepts.

Sustainable changes in learning and teaching cannot be decreed „from above“. They must develop „from within“, at the grass-roots level, in every individual school, for every individual teacher and student. This was the fundamental idea underlying the SINUS project, and it served as a guideline for action. 180 schools of all types offering Secondary Level I education (1 April 1998–31 March 2003) participated in this pilot study. The objective of work in schools has been to refine instruction in mathematics and science. Initiative and responsibility on the part of the schools were as significant as close communication and cooperation within and between participating schools. In terms of teaching methodology and organization, the schools were supported by the IPN (Institut für die Pädagogik der Naturwissenschaften – Institute for the Pedagogy of Natural Sciences) in Kiel as the organization in charge; the Chair of Mathematics and Mathematics Education and the Centre of Mathematics and Science Education (Z-MNU) at the University of Bayreuth; and the ISB in Munich (Staatsinstitut für Schulpädagogik und Bildungsforschung – State Institute for School Quality and Education Research).

In order to disseminate the ideas, approaches, and results connected with SINUS and to establish a broad basis for innovations and quality improvement in instruction, the BLK launched the SINUS-Transfer program. Starting at the beginning of the 2003/2004 school year, additional schools were included in the SINUS work in two tiers of two years each (totalling about 1,800 schools). In 2007 SINUS-Transfer had to be finished as a consequence of the federalism reform in Germany.

## Quality of Instruction – What Are the Basic Prerequisites?

> *It is their own teaching methods that teachers have most influence on. They should exert it.*
>
> *Andreas Helmke*

It is clear to anyone concerned with education that innovative curricula and educational standards alone offer no guarantees for positive changes in teaching. The quality of instruction stands and falls with the teacher as a person. Instruction depends on the professionalism and motivation of the instructors themselves. Effective changes are possible – as is proven by the SINUS pilot study. We have achieved this by instituting many small changes over a certain period of time. The basic prerequisite, however, consists in successfully convincing the participating instructors of the relevant ideas and actively involving them in the processes of change.

Fundamentally, change does not necessarily mean changing the mathematical concepts used in schools. But it does mean changing the way mathematical concepts are dealt with. It means changing the method of instruction. The teacher is not an entertainer, and the student is not a mere consumer. Learning is an active, constructive, cumulative and goal-oriented process; this is something that must also be perceptible for the students. Accordingly, the transfer of knowledge from teacher to student is not unilateral. Instead, teachers must enable (empower) their students to find their own access to knowledge. In an article about how this concept was implemented at SINUS schools, the German weekly DIE ZEIT (41/2006) reported on the example of a school in the state of Brandenburg, using a sensationalist, but

appropriate headline: “The Math Revolution“, followed by the subheading “SINUS is changing mathematics education in German schools“.
However, the commitment of teachers alone is not enough to bring about or spread the “math revolution“. Certain framework conditions must also be fulfilled. This means

- that the school administration and supervisory authorities must expressly support and promote the required reforms;
- and that students and parents must accept the fact that there cannot be scholastic achievement without effort and dedication.

It is a truism that a competitive school will not succeed without the support of society. SINUS does not provide the single, all-purpose solution for teaching mathematics successfully. Many paths lead to this goal, some of them quite different from one another. Successful mathematics teachers tend to be markedly individual. However, there are certain fundamental guiding concepts that are presented in this brochure.

## Guiding Concepts – Reconsidering One‘s Own Teaching

International comparative studies attest that the average level of math instruction in Germany is high. However, deficiencies have been detected in the way in which contentis communicated. To improve classroom instruction, we do not need to change the content, but we need to change the way we deal with content, i.e. we need innovations in the classroom.
What is it that distinguishes successful mathematics instruction at SINUS schools? How can the small steps set out above be given a concrete form that will lead to a new form of instruction? Access to the “SINUS philosophy” is best achieved through conscious consideration of one’s own teaching. Here certain central themes can serve as a means of orientation. These themes take five different aspects of teaching into consideration:

1. Teaching style
2. Work with problems/tasks
3. Technical content
4. Type of achievement testing
5. The role of mathematics teachers.

Reflection on these central themes also makes sense for education degree students and probationary teachers. Although first-time instructors usually have only very limited teaching experience (if any), these central themes clearly point to areas that are crucial for subsequent instructional activity.

### 1. Reconsider your teaching style

- You do not represent the focus of instruction, your students do.
- Support your students in their learning, avoid lecturing them.
- Encourage your students to explore their own paths to learning.
- Provide suggestions and assistance towards self-help.
- Clearly separate learning and testing situations.
- Vary forms and methods of classroom teaching.
- In the final analysis, it is not you but your students who are responsible for their learning progress.

### 2. Reconsider your work with problems

- Do not have your students simply produce answers, make them get involved with the respective questions. The journey is the goal.
- Enable active and productive work with problems:
  - initiate problems and tasks;
  - vary problems;
  - recognize patterns;
  - prepare strategies for solutions.
- Find different paths towards solutions and then take them.
- Link everyday knowledge and mathematical knowledge with one another in a meaningful way.
- Have students keep study journals. Teach them how to express problem-solving and learning processes in written form.

### 3. Reconsider the subject matter

- Limit yourself to the fundamental content.
- Emphasize the essential ideas of the respective subject matter.
- Treat the contents in an appropriate and interesting context.
- Attach value to discovering and working out relationships involving content and structure.
- Reduce the prevailing orientation towards calculation in favour of a focus on understanding.

### 4. Reconsider your conventional manner of testing

- Does testing always have to involve calculation?
- Can a test item take the form of a description?
- Can explanations and justifications be built into a “traditional problem”?
- Can problems be prepared in such a way that various solutions are possible and make sense?

- Variation of test items can be more demanding than formal application of a calculation method.
- Evaluate how study journals are maintained.
- Include checks of learning objectives in planning your teaching units.

**5. Reconsider your own role as a mathematics teacher**

- Express your enthusiasm for mathematics.
- Repeatedly emphasize the importance of mathematics, particularly in terms of culture, technology and industry.
- Show personal interest in the subject matter that you teach.
- Continue to be actively involved in mathematics: problem-solving, competitions, popular science literature, etc.
- Avoid being a "lone wolf", rely on cooperation among the student body and/or teaching staff.
- Through your teaching show that mathematics is a vibrant, constantly developing discipline.

## Perspective

These guidelines are meant to induce a reconsideration of one's teaching style by setting specific priorities. SINUS places great emphasis on encouraging students to explore their own learning resources. But it is not only the students who need to explore their own resources. We have already suggested that successful education has an individual face, primarily that of the individual teacher. Ideas and materials from SINUS provide inspiration, but their implementation will always have a personal touch.
The first step is to reconsider one's own teaching on the basis of the central themes indicated. This lays the foundation for a change in teaching. In the next stage we need comprehensive information about SINUS ideas and contents plus tried and tested materials. The central SINUS server at http://www.sinus-transfer.eu can be used for instance for these purposes.

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