Born to Teach?

Mathematics is considered difficult material to convey – and math lessons are typically unpopular. Could it be partly because of the teachers? At the **Max Planck Institute for Human Development**, *a team working with* **Mareike Kunter** *is investigating what makes a good math teacher.*

Teachers can be authoritarian or insecure, strict or patient, generous or pedantic. And then there are those who seem to be born teachers. Their classes are easy to follow, they explain things well, and they make learning fun. For Mareike Kunter from the Berlin-based Max Planck Institute for Human Development, however, the born teacher – especially the born mathematics teacher – is a myth. Instead, she prefers to talk about "good teachers" and clarifies: "There is no evidence for the hypothesis that good teachers are endowed per se with certain qualities that set them apart from other people. Nor is there any evidence for their personality being responsible for better student outcomes."

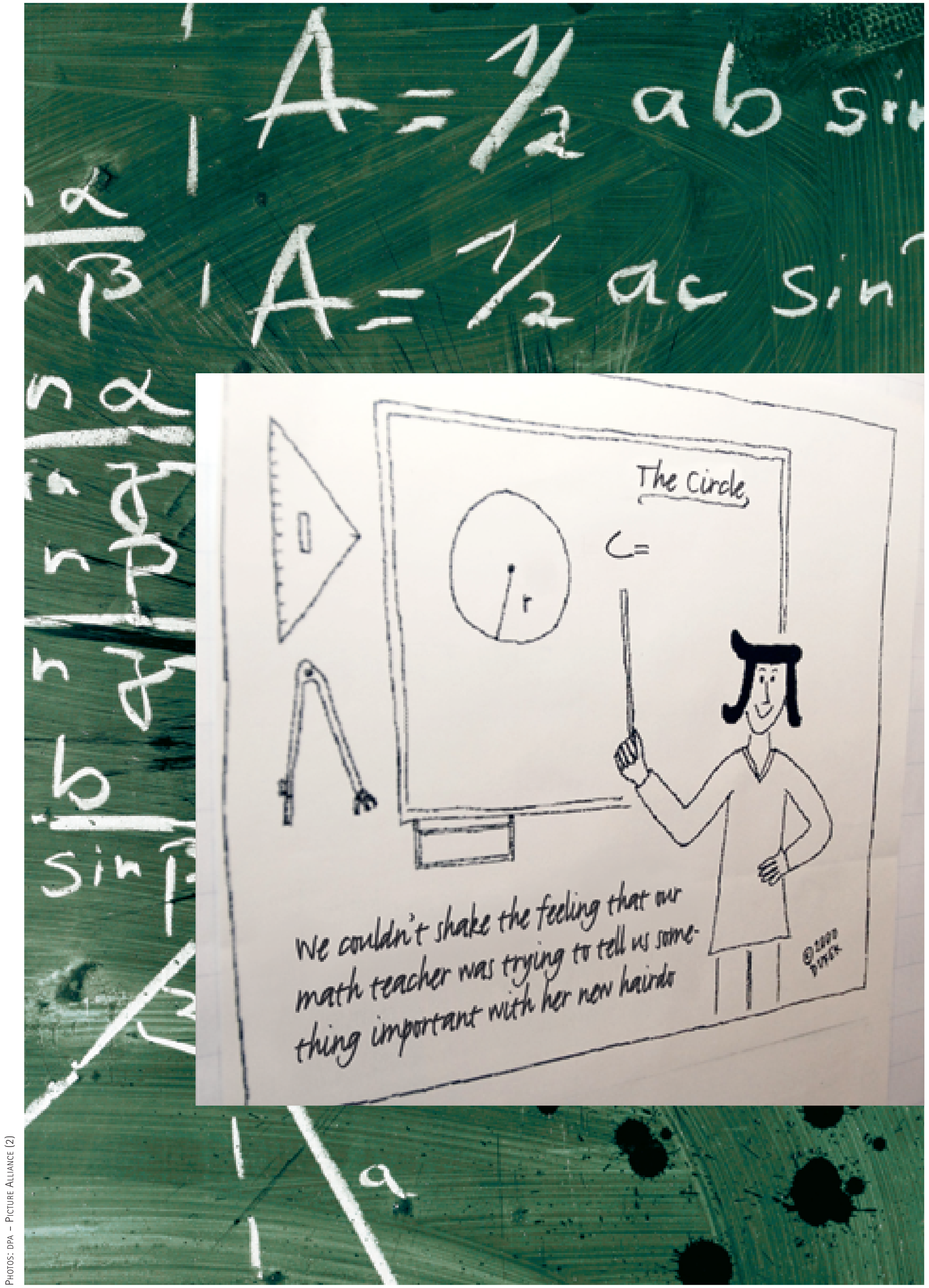
At the Center for Educational Research, under Director Jürgen Baumert, Kunter collaborated on the COACTIV study, which focuses on mathematics instruction at the lower secondary level, or grades 5 to 10. She and her colleagues aim to provide a scientifically substantiated answer to the question of what makes instruction successful. What characterizes teachers who are successful in their profession? And how can the quality of instruction be improved? "Being a good teacher is not an innate personality trait," says Kunter: "There are very specific, typical skills that teachers can learn, just as surgeons can learn particular surgical techniques."

Between Competence and Performance

COACTIV stands for Professional Competence of Teachers, Cognitively Activating Instruction, and the Development of Students' Mathematical Literacy. The study focuses on teachers whose students participated in the PISA study on mathematics in the 2003/2004 academic year. This allows the researchers to directly examine the link between teacher competence and student performance.

However, the idea for COACTIV first came about as early as the end of the 1990s in connection with the international TIMSS study (Third International Mathematics and Science Study), in which Germany placed in the lower midrange.

The TIMSS Video Study that was carried out in parallel provided first indications of possible causes. In this international benchmark study, approximately 100 hours each of mathematics instruction in Germany, the United States and Japan were recorded and analyzed. Typical patterns in teachers' approaches to instruction were found in each country. The German pattern consisted in structured discourse: the teacher presented a problem to the entire class and then walked students through a tightly sequenced



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set of questions and answers to find the solution.

On the surface, this gives the impression of activity and student participation. In reality, this approach is strongly teacher-driven, since the teacher often already has a very clear idea in mind of how the problem should be solved. The students are only really expected to respond appropriately to their cues. If their answers are correct, but would not lead directly to the desired goal, they are not explored any further in the classroom discussion. This approach poses no conceptual challenge for the students; they are not required to independently apply their prior knowledge to the available information to find a solution.

The notion that mathematics instruction at German schools promotes independent thinking and the ability to solve problems was already revealed to be a myth in the TIMSS and TIMSS Video studies. And then came the PISA study: after a focus on reading skills in 2000, the 2003 cycle of the study concentrated on mathematics. On the whole, PISA confirmed the TIMSS findings: in international comparison, the mathematical literacy of German students is just average.

Other particularly interesting findings are those that describe the strengths and weaknesses of German students: they are relatively good at solving problems that require the application of mathematical techniques and routines or the recall of mathematical knowledge. But they have difficulty using math autonomously as a tool for solving problems. A comparison of the 2000 and 2003 PISA results showed slight improvements in the mathematical literacy of German students – findings that remained stable in the 2006 cycle of the study.

Drilling Routines rather than Solving Problems

"This small improvement could be a first result," Mareike Kunter speculates, "of the attempts seen in the wake of TIMSS to improve the quality of mathematics instruction through systematic teacher education and training." For example, the SINUS program – a German acronym that stands for "increasing the efficiency of mathematics and science instruction" – has been introduced in schools throughout Germany, with researchers and teachers developing new lesson formats and materials.

TIMSS and PISA also sparked a flurry of research activity. Why are German students so much better at following set routines than solving problems? It wasn't even clear where researchers should begin searching for reasons. "Previously, empirical education research had largely ignored the teachers themselves – they were considered a given, and the focus was exclusively on instruction," says Mareike Kunter. Empirically grounded studies of teacher competence were rare. Theoretical papers and everyday opinions based on personal experience predominated.

Yet students and parents are sometimes quick to place the blame on the teacher when a student is in danger of failing. To remedy the shortage of data, researchers from various disciplines are working on the COACTIV study. Mareike Kunter, for example, is a psychologist, and project director Jürgen Baumert, an educational researcher. The two are working with experts in mathematics education, such as Werner Blum from the University of Kassel and Michael Neubrand from the University of Oldenburg. There are also math teachers on the COACTIV team – and not only as study participants whose knowledge was assessed.

According to a model established by Kunter, Baumert and their colleagues, there are three main aspects to the specific professional skills that typically make a good teacher: the teachers' underlying beliefs about how knowledge is communicated, their motivation and self-regulation skills, and their professional knowledge itself. Of course, these qualities are all interlinked and cannot be considered in isolation.

Photo: Private

I'm a math teacher through and through. I enjoy working on the Committee of the German National Mathematics Competition, and developing new and exciting problems for the students each year.

Cornelia Wissemann-Hartmann, math, physics and computer science teacher

Photo: Private/Background: Mathematikum Giessen

My primary aim as a teacher is to convey to my students that math relates to us personally, and that our lives would be very different without it. (...) And I love the opportunities modern software affords to bring math to life and make it colorful.

Monica von zur Mühlen, academic-track teacher for mathematics, computer science and social sciences

The COACTIV researchers developed various instruments to test these three aspects of teacher competence: they surveyed teachers and students, analyzed the problems assigned in class, and developed tests of teachers' knowledge. The researchers were thus able to test the extent to which teachers differ in the areas of competence, and whether these differences were relevant for their success in the classroom.

Teachers' beliefs about how knowledge is communicated are a key determinant of how they approach instruction, and thus of active student participation. Education research distinguishes two main views on the question of knowledge communication. The transmission view, in which learning is considered to be the result of knowledge transfer and frequent repetition, is reflected by endorsement of the statement: "The most efficient way to solve a given type of problem should be ingrained through practice."

In contrast, those who tend toward the construction view, in which learning is considered the result of mental – that is, cognitive – activity on the part of students, endorse the statement: "Students should have the opportunity to explain their approach in detail, even if it is wrong." And indeed, the researchers found that the students of teachers who tended toward the transmission view learned less.

To succeed in their jobs, teachers must not only be well versed in the subject they teach, but they must also be motivated to apply this knowledge and to continually refine it. The research team therefore took a closer look at one particular trait that many laypeople consider to be the mark of a good teacher: enthusiasm. But as they discovered, a teacher's enthusiasm does not guarantee good instruction. Only if they are enthusiastic about teaching will there be positive effects on the quality of instruction. Enthusiasm for math alone is not enough.

Little Feedback from Colleagues

Attempts to systematically improve the quality of instruction are further hampered by the fact that teachers receive little external feedback, for example from supervisors or colleagues. It is left to them to decide how much energy to put into their work and when they need to distance themselves from it. This aspect was analyzed on the basis of teachers' self-reports.

The study found that precisely those teachers who thrive in their work, but are at the same time resilient and able to maintain a healthy distance from the job, are clearly at an advantage. Furthermore, surveys among students showed that these teachers provide a positive instructional climate. Relative to less dedicated or less resilient teachers, students described these teachers as fairer and as better at encouraging autonomy, and their teaching as better paced.

The central aspect of teacher competence, however, is professional knowledge, which has both subject-specific and general components. The former include subject knowledge or "content knowledge" as an in-depth understanding of the mathematics taught at school, as well as three aspects of what is known as "pedagogical content knowledge": knowledge of students' mathematical thinking, allowing teachers to see problems from the students' perspectives; knowledge of suitable problems that challenge students' understanding; and knowledge of various ways to explain concepts, allowing teachers to adapt their approach to individual students.

Assessing teachers' content knowledge was not easy. The researchers did not want to test material taught at university. At the same time, they wanted the problem set to go beyond the knowledge typically taught in school. This is where experts in mathematics teaching contributed their experience. The test items developed "cover background knowledge that we assume teachers need in order to convey the material to their students," as Mareike Kunter explains.

In addition, problems were developed that students could solve in different ways. Unlike the problems relating to content knowledge, the researchers were not looking for a single correct solution here. Rather, the more approaches the teachers suggested, the more points they scored.

Teachers must also be able to put themselves in the typical mindset of students in order to recognize where difficulties arise. People often seem to think that only born teachers are able to understand how their students think. "But in fact, it's simply another form of professional knowledge that can be acquired," says Mareike Kunter. She and her colleagues tested this aspect using problems such as the following: "The area of a parallelogram can be calculated by multiplying the length of its base by its height. Please sketch an example of a parallelogram to which students might not be able to apply this formula." One possible answer here is that students might have difficulties when the parallelogram is so strongly slanted that the foot of the altitude falls outside the parallelogram. To answer this question, teachers have to know what mistakes students typically make and where the limits of their understanding lie.

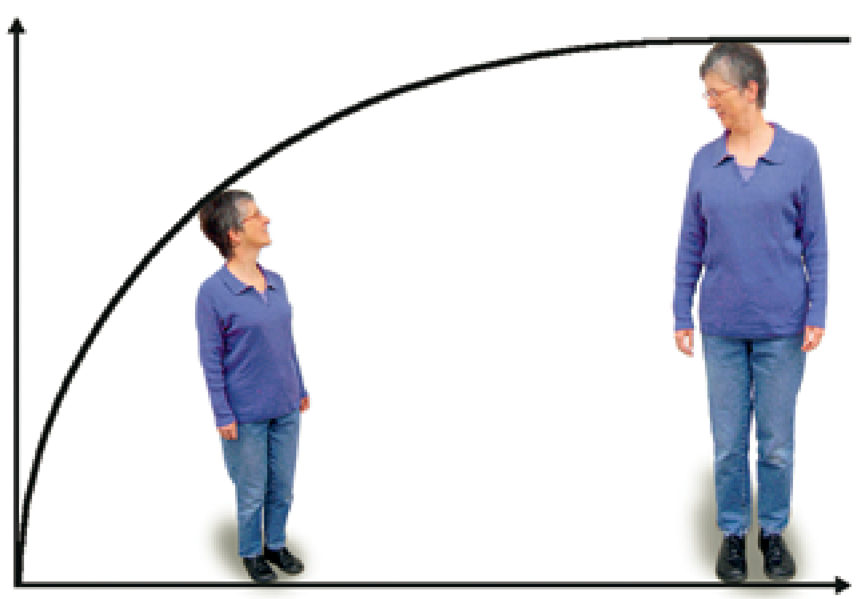
Three Explanations Are Better than One

The third key aspect of teachers' pedagogical content knowledge is their repertoire of approaches for explaining mathematical concepts. Students are known to understand these concepts more easily if they are explained in a second or third way in the event that they didn't follow the first. In one of the test questions, teachers were asked to outline as many different ways as possible to explain to students why (-1) x (-1) = 1.

And indeed, students of teachers who did well on the tests of pedagogical content knowledge performed better than those of teachers who performed less well. Notably, they were the students who made the greatest progress over the school year in the PISA study. This was largely due to the fact that teachers with high pedagogical content knowledge were more likely to give cognitively activating instruction, as was confirmed by analyses of the task set in classroom instruction.

This effect seems to be specific to teachers' pedagogical content knowledge: the research team did not find a corresponding relationship between teachers' scores on the test of content knowledge and their students' learning outcomes. In other words, an expert in the field does not automatically teach the subject well.

Overall, the teachers tested showed a wide range of performance – in all areas investigated. The COACTIV researchers noticed systematic differences, particularly in terms of professional knowledge, depending on the type of teacher training course a teacher had attended. For example, academic-track teachers had better knowledge of their subject – which was to be expected, since their training places greater emphasis on the subject itself. But academic-track teachers were also at an advantage in terms of their pedagogical content knowledge, even though they receive less training in this aspect than teachers training to teach at other types of schools. "The findings indicate that a certain level of content knowledge is needed in order to acquire pedagogical content knowledge," concludes Mareike Kunter. The COACTIV team is investigating this issue in follow-up studies.



Concept and photo: Josef Günnewicht

In the Year of Mathematics, I hope to take math out of the chamber of horrors. I don't want my students to learn formulas by heart and forget them again just as quickly; I want them to really understand math and see that it is directly relevant to their lives. **Merle Porta, provides individual tutoring in math**

Photo: Private

I hope to help the mathematicians of tomorrow see beyond the basic mathematics taught in school, and I try to convey to my students that math has more to do with creativity and learning how to think and solve problems than with applying routines. **Reinhard Schmidt, teacher**

In addition to the professional knowledge specific to mathematics teachers, there are also skills that all teachers need, regardless of whether they teach Latin, sports, or biology. The COACTIV team has recently begun to address this generic "pedagogical knowledge" by assessing teachers' grasp of developmental psychology and pedagogy. In these tests, teachers are, for example, shown video clips of critical teaching situations and asked to propose solutions. For example, they may have to quickly gain an overview of a rowdy classroom situation or suggest how the lesson could be organized better. The results of these assessments are not yet available.

However, it is already clear that professional experience does not necessarily help when it comes to teaching well. Teachers with many years of experience did not score any better on tests of content knowledge and pedagogical content knowledge than their younger colleagues. This finding has influenced the direction of future research in the COACTIV project: "Teacher competence is not an innate quality, nor does it seem to be a matter of professional experience," she says: "Instead, our findings show that core aspects of competence are acquired during formal teacher training – but to different degrees, depending on the type of training." Consequently, in their follow-up study COACTIV-R, the researchers are now focusing on the compulsory two-year teaching placement that follows the first, university-based phase of teacher training in Germany.

Radical Changes in Teacher Training

Kunter and her team also want to look at in-service teacher training. They did not find any clear connection between teacher knowledge and participation in continuing education, even for teachers who had participated in many such programs. "This may be due, at least in part, to the fact that most of these programs do not cover specific aspects of content knowledge or pedagogical content knowledge, but deal with general pedagogical topics or aspects of school organization," surmises Kunter. Now she would like to find out which teachers are particularly dedicated to furthering their training.

Initially, however, research will focus on the first steps in the teaching career: What skills and expertise do future math teachers have when they begin their teaching placement? How do they develop their abilities, knowledge, beliefs and motivation during this period? Which factors, both individual and institutional, influence competence development? These questions will be addressed in the new study.

"Teacher training in Germany is currently undergoing radical changes," says Mareike Kunter, "but the reforms are based largely on assumptions for which there is still too little empirical evidence." For example, it is often said that the university phase of teacher training is much too theoretical and that future teachers start out more or less from scratch in terms of practical competence when they enter the classroom – or that the teaching placement is so demanding that many beginning teachers lose their enjoyment of the profession during this phase. With COACTIV-R, the education researchers again aim to distinguish fact from opinion. Stefanie Hense