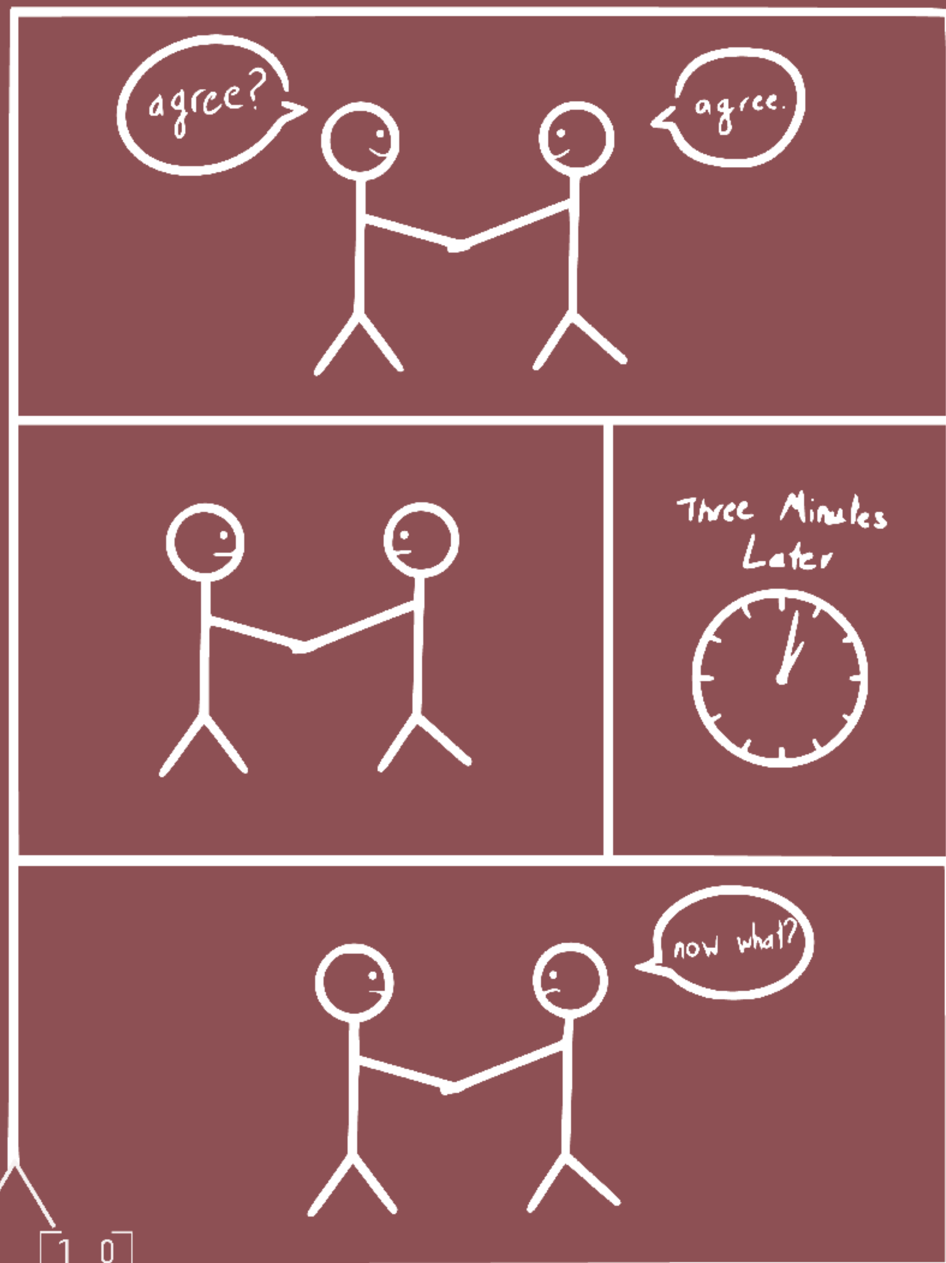

agree?
agree.
Three Minutes Later
now what?

Research Report **PRISMatrix**

The mathematical performance of students in Germany has noticeably decreased in the past few years. Given that mathematics is important in our daily lives, we, team PRISMatrix, set out to get a deeper understanding of what causes this issue. While there exists a lot of quantitative research done on this matter, we opted to look into the understanding of the issue of individuals in different stakeholder groups. We interviewed students, teachers in training, public figures, and scientists to focus on their personal experiences and assess their representation in the data we have. We hoped to find disagreements or gaps in their views, which point to a root cause of the declining mathematical performance.

Team: Abhirami Sreeprakash, Bushra Demyati, Elke Haldmaier, Konstanze Maria Dietlmaier, Lucia Arens, Marius Prock, Praissya Nathania

Tutors: Andrea Schittenhelm, Altan Birler

Supervisor: Prof. Dr. Jörg Niewöhner

Preface by the Supervisor

Prof. Dr. Jörg Niewöhner

Dear Readers,
Were you one of those people who really did not enjoy maths at school? Did you feel that numbers simply weren't for you, and you lost touch before you really knew what was happening? Or, perhaps more likely if you are now a member of the TUM family, you liked maths but lessons seemed so out of touch with real-world problems, just going through calculation after calculation?

Well, you are in good company because, apparently, that is how many kids feel about maths at school these days. And in particular, girls. Grades in Germany are in decline accordingly. Combine that with more general discourses about gendered roles, preferences, and abilities, and you have part of your answer to why STEM subjects at university struggle to attract more women.

The PRISMatrix group of scholarship holders at TUMJA started to wonder about this, too. And they set out on an empirical path to better understand why this might be happening and, more importantly, what kinds of solutions to this problem are on offer. They embarked on an empirical journey to meet the experts: in teaching, in the science of teaching, and in politics. They asked, listened, interpreted, mapped, analyzed, and argued.

The results … but I do not want to spoil it for you. Just to say that they are somewhat surprising to the group and perhaps also to you. PRISMatrix did not at all end up where they thought they would. I guess that is what research is all about, and that is what working in a collective is all about.

I sincerely thank the team for having the courage to explore territory unknown to them conceptually, methodologically, and disciplinary. They stuck with it, did not lose sight of their goals despite busy schedules and the madness that is the world these days. Well done to all of you!

And to you, the readers: Enjoy the results and maybe have a quiet moment to think about how that can be true and what this means for how we organize our society, our education, and our future.

Thank you and all the best, Jörg Niewöhner.

Supervisor Insights

I have been educated as a scientist in an interdisciplinary environmental science department that, since the 1960s, insisted that environmental issues and problems do not fall neatly into disciplinary categories. Ever since, I have been interested in how science organizes itself, its thought styles, its practices, and its everyday life. Now, I call myself an anthropologist of science & technology, and TUM's everyday life is my object of research. What do we need to change to ensure that everything we do furthers a public good, social-ecological integrity, academic freedom, and just ways of living together?

Taking questions of justice, of fairness, of sustainability, and of shared futures into a technical university is an important challenge. If we wait for technology to reach markets to assess their impact, it is too late. We need engineers and scientists to consider the broader implications of every choice they make during their exciting journey into new territories. This is a matter of early education, and it is a collective effort across disciplinary boundaries. That is why the work that the Junge Akademie does is so important. It exposes bright students at an early stage of their education to wildly different ways of working, worldviews, and scientific practices. Who knows what will come of this. Most likely lots of different things. This is about praxis, not poiesis – it is about doing something together with others.

Jörg Niewöhner, Chair for the Anthropology of Science & Technology (SOT/STS)

The Journey of PRISMatrix

Understanding Math Education: Why Agreement Isn’t Enough to Solve the Problem

The sun is shining through the window on a group of 4th graders huddled around a table in the center of the classroom. Four heads lean over a sheet of encrypted text. One student is holding a paper coding disc, turning it carefully in his hands. While the atmosphere is one of concentration, soft yet excited chatter fills the room. There are other groups scattered on sofas and on the floor, discussing their next steps. My teammate and I walk around and listen in on their conversations. Soon, the energy shifts as eyes start darting around the room, searching for help. The excitement about the task fades and a few shoulders sag. Some students grow restless and start fidgeting. In a small group of four, one boy slumps onto the couch. I head over. “How is it going? How far are you?” After a mere three minutes of unsuccessful trying, his initial motivation is worn out. He comments on the difficulty of the task and concludes that he won’t be able to decipher the text anyway, no matter how much time he puts into it. We rejoin his group, and I guide them through the next step by offering a small hint. They begin testing their decoding disk. Once their confidence has rebuilt, I step back, allowing them space to work on their own again. Why do students give up so easily and how can they be motivated? This is a question that is typical within the education field. It’s on teachers to keep their students motivated and teach new concepts, while still managing to keep good order.

But is it the only challenge? The latest PISA study in 2022 showed a decline in the math performance of ninth graders in Germany. These results intensified the debate about the reasons for our pupils’ increasing difficulties in mathematics. In order to find out more about the current debate around mathematics education, we created our research project, “PRISMatrix.” Supported by TUMJA, our team explored and compared different perspectives on factors that influence the math performance of German students. We conducted 28 interviews with students, teachers in training, scientists, and politicians, and we performed a qualitative analysis to find agreements and disagreements between the groups. While politicians and scientists adopted a systemic perspective and addressed overarching challenges, the future teachers and students focused on conditions within their profession or classroom experience. Interestingly, all stakeholder groups shared a common understanding of problems and factors within the debate: They had a clear and similar vision of ideal math lessons and suggested new teaching concepts, as well as more tasks with real-life relevance. For our 90-minute workshop at the Schülerforschungszentrum Berchtesgaden in January 2025, we therefore planned an interactive detective story. It guided the kids through creative, open, and challenging math tasks.

Back in the classroom, the students continue with the next task. The girl sitting next to me barely answers my questions. Her teacher had informed us that she did not talk much in general. She sits listlessly and watches her teammates solve the riddle. Her language barrier further complicates active participation in the group’s discussions. In our interviews, students often preferred group work since it provides mutual support and motivation. Still, in this case, the girl could neither participate nor benefit from those advantages. While I am still trying to help her to engage in the group, another student yells from the other side of the room “We’re ready. We know the solution.” The group was way faster than we had expected them to be. We had prepared additional tasks, but they still finished before everybody else and soon got bored. A situation that the interviewed teachers in training knew well since they deal with a high heterogeneity in students’ competencies every day. Our interviewees suggested differentiation and individual support as solutions. However, large classes, lack of time, and missing teaching personnel make this challenging.

Our interviews showed that all stakeholders understand the problems and possible solutions. So why do the problems persist? Is it a question of priority? As one of our interviewed politicians said: We talk instead of acting. Employing more teachers, reducing the workload or developing new class concepts seem feasible. If we truly wanted to, couldn't we increase the public funding for education, adapt the teaching study program or offer more individualized support to the students? As we all know, the children of today are the future of tomorrow. Shouldn't we give our best for their future now? The question of priority shows similarities to the climate change debate: Science is clear on consequences. However, according to the EIB climate survey[1] from 2024, 92% of people living in Germany think changes are needed, but only 40% feel it is a priority in the next year.

Maybe real change is too complicated. Influencing factors are strongly intertwined, which complicates the prediction of consequences. Our interviewees described vicious cycles. Students and teachers recognized bad grades as core to negative self-enforcing patterns, like losing motivation and stopping work on math skills. Here, teachers in training also saw missing teaching personnel or the teachers' lack of time and resources as barriers to providing individual support for those students. Politicians further mentioned that staff shortage leads to time pressure and increased workload, making the teaching profession unattractive. Additionally, the high heterogeneity in competencies among students requires differentiated tasks and teaching, which demands more preparation and exhausts teachers notably. As individual support is lacking, the gaps widen, worsening the situation for teachers and students alike and ending in a vicious cycle. Changing one element in this cycle could influence other factors in an unforeseen way. So, do we simply not know where to begin and which adjustment to make first? Are we too stuck and too confident in the current system to pursue significant systemic changes? In the current education field, a creative and progressive lesson design depends on the commitment of individual teachers. While their initiative is certainly commendable, having a system that inherently supports the math education that all stakeholders wished for would still be beneficial.

It is almost noon now on this sunny day in Berchtesgaden. The groups have just completed their last task, so we wrapped up our detective story: They solved the case and, as a reward, became

honorary members of the secret Mathematics Society. They seemed to have enjoyed the task that involved drawing and symmetry the most. A few cheers and other expressions of joy echo through the room. At least on that day, we succeeded in exciting them about math by giving them creative and active group exercises. It likely won't change much in how many will eventually lose interest and enjoyment in mathematics, but it was a start. Implementing some of the interviewees' ideas on solutions worked. It showed that change is possible, and the necessary knowledge already exists. Creatively taught classes full of fun and excitement about math can become the rule, rather than the exception. Ideally, we could have an education system that ensures the best for our children – the future of tomorrow.

1 European Investment Bank. (2024). The EIB climate survey: Attitudes towards climate change adaptation : 7th edition 2024. Publications Office. https://data.europa.eu/doi/10.2867/4661519

Research Report – PRISMatrix

Controversy or Consensus? – A Qualitative Analysis of the Debate on Math Education in Germany

Table of contents:

Abstract

The 2022 PISA study showed a significant decline in the mathematical performance of German pupils. We aimed to gather the opinions of different stakeholders on the causes of this decline and possible solutions. We compared the broad categories of these factors between the stakeholder groups.

We conducted 28 semi-structured interviews with students, teachers in training, scientists, and public figures. We used a grounded-theory-based methodology. All factors were categorized and mapped to show overlaps and connections.

The stakeholders identified problems such as outdated teaching methods, lack of practical applications, and pressure caused by overloaded curricula and understaffing. Politicians, teachers in training, and scientists agree on a pedagogically versed use of digital tools. The former two criticize the education of future teachers and the exclusion of teachers and scientists in finding solutions.

Our results indicate a shared understanding of the factors and potential solutions for the declining mathematics performance of students. Interdependencies between the factors may cause the issue to remain unsolved despite general agreement.

1 Background

The Program for International Student Assessment (PISA), conducted by the Organization for Economic Co-operation and Development (OECD), assesses the skills and knowledge of 15-year-old students in mathematics, reading, and science. Comprehensive and sufficient knowledge in mathematics, computer science, natural sciences, and technology is crucial for future Science, Technology, Engineering, and Mathematics (STEM) professionals (acatech & Joachim Herz Stiftung, 2024). However, the results from PISA 2022 revealed a significant decline in the mathematics performance of ninth graders in Germany compared to previous PISA cycles (OECD, 2023). Although Germany scored slightly above the OECD average in mathematics and reading, only 70% of German students achieved at least level two proficiency in mathematics, at which students can use mathematics in simple real-life situations.

In comparison, over 85% of students in Japan, Chinese Taipei, and Estonia reached level two or higher. Moreover, performance trends have been steadily declining since 2012, with a significant drop in mathematics in 2022 (OECD, 2023).

To find and implement customized solutions, it is important to identify the factors responsible for the students' decline in mathematical performance. Several studies were conducted globally to find possible factors influencing mathematical performance (Aldon et al., 2021; Forsa, 2020; Sturzbecher et al., 2021; Ramirez et al., 2016; Schillinger et al., 2018; Svraka et al., 2024; Algani & Eshan, 2019). Wang and colleagues (2023) suggest that the factors emerge across various levels, ranging from individual characteristics to broader societal influences (Wang et al., 2023).

Education systems are complex and involve many stakeholders. Varying interests, societal values, and economic demands make different educational priorities inevitable. Policymakers commonly focus on performance metrics and international competitiveness when considering the available budget. For instance, as a response to the results of PISA 2022, Bavaria's education minister, Anna Stolz, introduced additional German and math lessons in primary schools. However, this resulted in cuts of art, music, craft, or English lessons (Günther, 2024). On the other hand, teachers often focus on classroom dynamics, student well-being, and individual needs. These differing priorities may result in fragmented and ineffective solutions, as stakeholders' needs are overlooked or fail to align.

According to the literature, the factors responsible for the declining mathematical performance and interest among the students over the years can be due to the COVID-19 pandemic (Aldon et al., 2021; Forsa, 2020; Sturzbecher et al., 2021), mathematical anxiety (Ramirez et al., 2016; Schillinger et al., 2018; Svraka et al., 2024), gender differences, socio-economic factors of the family, teaching methods, school and curriculum differences, and many more (Algani & Eshan, 2019; Wang et al., 2023).

The COVID-19 pandemic impacted the German education system due to school closures and distance learning. The quality of distance learning was inadequate to support lower-performing students and students whose parents have no academic background (Aldon et al., 2021). Students and parents reported a decreased effective learning time (Sturzbecher et al., 2021).

Math anxiety is a feeling of stress or worry when dealing with math, leading to negative thoughts, avoidance of the subject, and lower confidence and motivation. Higher anxiety is linked to poorer math performance (Schillinger et al., 2018). Often, students feel anxious because they believe they already struggle with math, creating a cycle where anxiety and low performance reinforce each other. Research shows that students with moderate to less math anxiety exhibit better performance than those with high anxiety (Svraka et al., 2024). Math anxiety makes it harder to focus and use problem-solving strategies. Students who tend to use simpler strategies are less impacted by anxiety but usually achieve lower math scores overall (Ramirez et al., 2016).

Algani and Eshan (2019) categorized the factors for low math achievement as follows: student-related (e.g., limited mental abilities, health/psychological challenges, and poor social adjustment), teacher-related (low scientific competence, inadequate teaching methods/experience), curriculum-related (unclear objectives, poorly presented material, weak assessment tools), school-related (outdated infrastructure, insufficient labs/ classrooms), and family-related issues (financial instability, low cultural/scientific support). Students' deficits hinder knowledge acquisition, while ineffective teaching and disorganized curricula foster disengagement. Poor school environments limit learning opportunities, and family hardships shift focus from education to survival needs, collectively undermining academic performance (Algani & Eshan, 2019).

To investigate major factors driving PISA math achievement for all OECD countries, Wang et al. systematically reviewed 154 research papers. Unlike the previous study conducted in Israel, this review adopted a broader perspective by categorizing the influencing factors into five hierarchical levels: individual level, household context, school community, education systems and macro society (Wang et al., 2023).

Previous studies have primarily focused on generalizability or quantitative data, often overlooking a deeper exploration of the underlying reasons behind educational trends. Given the complexity in the education system, including the diverse scopes of work and limitations faced by each stakeholder, it is crucial to see both agreements and disagreements among these groups. Thus, this research adopts an exploratory approach using semi-structured interviews to gain personal insights from each stakeholder. By mapping the factors' interdependencies and discovering connections between stakeholders, we seek to answer the following research question: "What are the agreements, disagreements, and gaps between the reasons for the decline in mathematical performance among ninth graders identified by scientists, public figures, teachers in training, and students?"

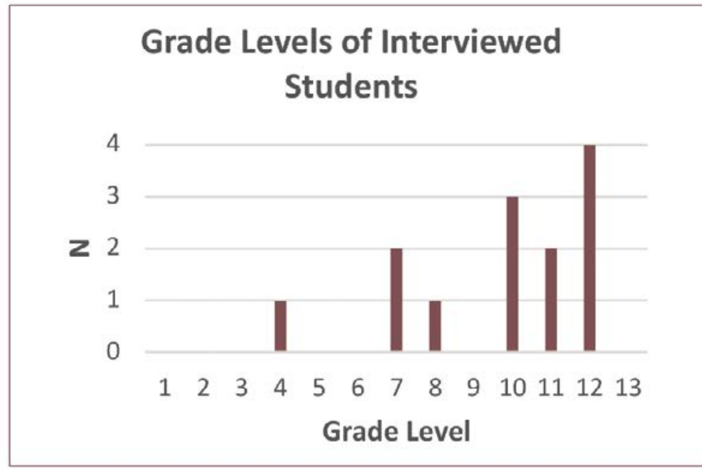
2 Methodology

2.1 Participants and Interview Guide

To gain insight into the perspectives of the different stakeholders, we conducted 28 interviews with 13 students, seven teachers in training, five scientists, and three public figures. The interview process began in October 2024 and lasted until January 2025. Participants among students and teachers in training were found through advertising at events in Munich (Münchner Wissenschaftstage, 28-30 June 2024, TUM student club fair, 23 October 2024), on our website, and through personal contacts. Scientists and public figures were contacted directly. All interviewees gave their written consent to participate in the study and to process their data.

2.1.1 Students

Interviews with 13 students with an average duration of 19.84 ± 6.32 minutes (range: 9 to 30 minutes) were conducted. The students had an average age of 15.1 ± 2.69 years and attended schools in Bavaria (N=6), Baden-Württemberg (N=6), and Niedersachsen (N=1). While more than half of the students attended Gymnasium (N=7), other school forms were represented, including primary school (N=1), Realschule (N=2), Fachliche Oberschule (N=1), berufliches Gymnasium (N=1), and Waldorfschule (N=1). Since school lessons are the students' main exposure to mathematics, questions focused on their former and current experiences in math class. Students were asked to recount their last math lesson. They described what they like or dislike and what their ideal math lesson would look like. To change perspective, every student was asked to imagine being a math teacher and planning their own lesson, with complete creative freedom and no restrictions regarding time, topic, or material. Further topics included the applications of mathematics in other fields and jobs. We opted to ask the students to self-assess their performance and interest in math. We did not ask for specific grades, allowing the students to talk about their actual experience in class without feeling judged by their performance. 53.8% of students said they enjoyed math class (n=7), and 61.5% declared math to be easy for them (n=8).



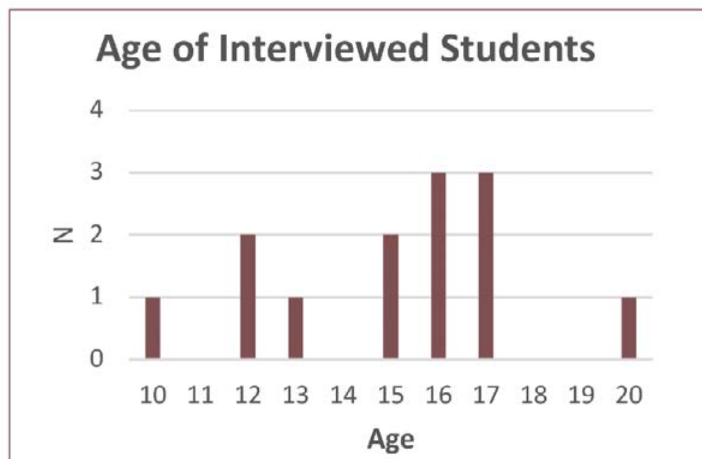


Figure 1. Grade levels and ages of the students interviewed for our research.

2.1.2 Teachers in Training

Due to legal restrictions, interviews with active teachers were not possible, so we instead interviewed teachers in training. Seven interviews with an average duration of 49.28 ± 21.24 minutes (range: 25 to 93 minutes) were conducted. Five studied for a teaching position at the Gymnasium level and two for primary school. Overall, five studied in Bavaria and two in Baden-Württemberg. All were in advanced semesters and had already completed mandatory internships in schools for at least three months. The internships included unassisted teaching and observing experienced colleagues. Four interviewees had additional experience from tutoring and voluntary help in schools. The interview questions focused on their perception of the PISA study based on their personal opinions and discussions in their studies. Furthermore, possible factors influencing mathematical interest and performance, the structure of math lessons, and teacher-student interaction were discussed. Finally, they were asked about the connection between creativity and math and its implementation during lessons.

Questions about lesson structure, introduction of new mathematical topics, and teacher-student relationship were asked in student and teacher interviews to compare both perspectives.

Variable		N
Current Study Semester		
	3	1
	6	1
	7	1
	9	3
	14	1
2nd Teaching Subject		
	Physics	3
	Philosophy	1
	Computer Science	1
	French	1
	Religion	1

Table 1. Study semester and second teaching subject of interviewed teachers in training

2.1.3 Scientists and Public Figures

Interviews with four scientists and four public figures were conducted. The interviews with scientists had an average duration of 67 ± 29.19 minutes, and those with public figures had an average duration of 40 ± 8.16 minutes. Interviewed scientists specialized in educational research, focusing on school education and learning psychology. All public figures were actively engaged in educational policy and advocacy in Bavaria, with two individuals having past teaching experience. The representatives came from associations concerned with school policy and educational reforms, while the politicians were members of Bavarian education committees. The interview questions of both groups focused on the perception of the PISA results, the factors responsible for the decline, as well as the possible solutions. Additionally, educational policy frameworks and the role of creativity in mathematics education were discussed.

2.2 Data collection

The interviews were conducted in person or virtually via the videoconferencing application Zoom (Zoom Video Communications). The language varied between German and English, depending on the interviewee's preference. Direct quotes in the following chapters were translated from German. The interviews were semi-structured, i.e., the interviewers had a pre-determined set of open questions while staying flexible to explore responses and bring up new ideas. This allowed the interviewees to express their opinions and give reasons for their answers more freely.

2.3 Data analysis

To answer our research question, we applied a grounded-theory-based methodology. We did not start with a preconceived notion of what factors influenced mathematical performance but allowed theories and hypotheses to emerge from the raw contextual data. The main idea of the coding process is the iterative "constant comparative method." Data collection and analysis occurred simultaneously, each enhancing the other. This cyclic interaction between data collection and analysis ensured that the emerging theory is deeply rooted in the data (Strübing, 2021). Thus, the interview guides were also adjusted iteratively to consider the experience from former interviews and the results of the interview coding.

2.3.1 Interview coding

All interviews were recorded and auto-transcribed verbatim using the software f4 (f4transkript, Dr. Dresing & Pehl GmbH). Each interview was coded by one group member. We had five coders in total. We applied an inductive approach during the initial open coding phase. During the process, each coder developed their own categories that fit best for the given dataset. We only fixed three overarching categories: Factors, Reasons and Problems; Solutions and Changes; PISA-related statements. The smallest entity to which a code could be assigned was one sentence. The relationship between the different categories was explored during the axial coding phase. Related codes were clustered into larger categories.

2.3.2 Mapping

To integrate the different categories into an overarching concept, we initially used the method of controversy mapping from science and technology studies, allowing an analysis of complex debates where science and society intersect. The goal is not to determine "right and wrong" but to understand how the debate functions by mapping it objectively. Claims, counterclaims, and opinions were collected from the interview codes. Due to the stakeholders' high agreement, we changed to analyzing the relationship of actors and factors based on the situational mapping of Clarke (2005). To improve visualization, each stakeholder group was mapped separately using the digital collaboration platform Miro (RealtimeBoard Inc. dba Miro). Factors and their overarching categories were visualized, with arrows or colors resembling connections. To compare opinions and identify gaps or contradictions in factors, we compared those categories across the mapping of different stakeholders.

3 Outcomes and Discussion

3.1 Results of Student Interviews

The students interviewed on the decline in mathematical performance emphasized the influence of the lack of applications and purpose of exercises; the student-teacher relationship; the teacher's behavior and attitude towards teaching and towards the students; the pressure to perform well; time constraints; and incompetent teachers..

The students stressed how lacking real-world context for the materials taught influences their motivation, especially in more advanced, and often more abstract, levels. The students mentioned how they would incorporate creative and practical introductions, involving physical objects, if possible, if they were the ones teaching mathematics (S2, S8, S9). They were able to recall classes with collaborative and imaginative tasks, such as songs, paper-folding competitions, and group work (S3, S7). A very interesting project incorporated informatics to implement the mathematical algorithms learned (S4). Much to the student's dismay, this initiative was stopped due to a lack of time.

Most students favored group work due to the mutual support, motivation, and alternative explanations by classmates it provides (S3, S4, S5, S7, S8, S10). Others mentioned the motivation and feeling of accomplishment doing tasks on their own provides (S3, S8). Moreover, the students were able to give a wide range of applications of mathematics (S3, S4), as shown in Table 2, while also not being able to relate the teaching materials with these applications (S2). Most mentioned how they never discuss the applications in class (S1, S4, S7, S8, S11, S13).

Application	Number of times mentioned
Everyday life (shopping, finances, taxes, etc.)	8
Construction and architecture	4
Further education	3
Economics	3
Computer science	2
Natural sciences (medicine, physics, biology, etc.)	2
Understanding natural phenomena (e.g., ebb and flow)	1
Meteorology	1
Logical thinking	1
Engineering	1

Table 2. Number of mentioned applications of mathematics by students.

Moreover, the student-teacher relationship often determined if the students looked forward to class and had fun with the subject (S6, S7, S9, S10, S12, S13). The students' favorite subjects depended heavily on the teacher (S8, S9). Showing interest in the students' learning process, regularly collecting feedback, and asking about the students' well-being are desirable teacher traits (S6, S8). Students mentioned how devoting time to individual support and feedback sessions is limited due to the teachers' workload and overloaded curricula.

It is often the case that a cycle forms for students, either positive or negative. Depending on the grades, the motivation of the student changes, which in turn affects their participation and willingness to learn and put in effort in learning. This, consequently, affects their grades, which starts the whole cycle again (S3, S8, S9, S10, S13). Therefore, it is possible to influence one of these factors to affect the other ones, and lead to reinforcing a positive cycle of cause and effect.

To combat the factors previously mentioned, students proposed that teaching methods should involve more relevance and significance to real-life situations (S2, S8, S9, S10). This requires more creative teaching strategies such as: well-chosen case examples (S5, S6, S7, S9, S13); repetition and linking to past topics (S6, S9); and visualizations with the help of objects and sketches in exercise (S6, S7, S9, S10). Having smaller class sizes would also increase student-teacher interactions (S5, S6, S8).

3.2 Results of Interviews with Teachers in Training

The teachers in training interviewed viewed the main factors causing the decline in mathematical performance to be the lack of practical guidance in their training; time constraints due to tight timetables and shortage of teachers; and teacher-centered instructions with little student interaction and outdated teaching methods. Some see the parents and their influence on students' attitudes to the subject as a problem. The teachers in training also mentioned how ill-prepared the school system was to online teaching during the COVID-19 pandemic, due to poor organization of online classes and missing technical equipment, leading to a decrease in the students' interest and participation (T4–T6).

Teachers in training said that their studies were mainly theoretical with insufficient practical guidance and preparation for dealing with real-life problems in classrooms. They wished for more practical insights through longer internships or dual courses of study (T1, T3, T4, T5, T7), since a dual course of study would lighten the load of schools with teacher shortages (T3). In Thuringia, a pilot program of dual studies for teachers started in the winter semester 24/25 at the university of Erfurt. In this program, the teachers in training were a part of partner schools' teaching staff throughout their studies (Ministerium für Bildung, Wissenschaft und Kultur, n.d.). The teachers in training wished that this program would be made more widely accessible (T3).

All interviewees saw digital technologies as positive. However, it was stressed that they must be used in the right way to be effective (T1, T3, T5). Even though implementing digital technologies is discussed theoretically at the university, no practical experience in real-life settings is gained (T5) or the school lacks the necessary equipment (T3).

Moreover, the teachers in training mentioned how the motivation and interest of students in mathematics depend heavily on the teaching style (T1, T3). The age distribution of teachers was seen as a problem in this context, as older teachers are often unwilling to adapt their methods (T1). They also stressed how difficult it is to implement creative methods that would make the lessons more fun and motivating, due to lack of time and resources (T1, T3, T5).

In addition, the teachers in training agreed that the gaps in mathematical knowledge and interest require varied teaching approaches; individual support (T2, T3); free learning platforms and targeted tutoring (T5); and allowing students to make mistakes and learn from them. They see creative methods and a positive classroom environment as key to motivating students; they emphasize the importance of stimulating the students' interest and curiosity from primary school levels.

Moreover, giving teachers more time and resources to help students individually was seen as the most pressing issue (T3). The teachers in training were willing to implement new approaches and plan motivating and creative lessons if given the opportunity. They also suggested having a clear differentiation between the students' levels in mathematics in order to have more compatible teaching methods and materials (T1–T7). Establishing networking and platforms for fellow teachers to share materials and experiences would be helpful as well (T5).

Lastly, the recent results of the PISA study are very present in the studies of prospective teachers. This began with the "PISA Schock," the strong reactions of the German public to the publication of the first PISA results in 2001 when German students performed below average and significant differences between German states were shown (Tillmann, 2015). The current PISA results were frequently discussed in lectures concerning psychology and didactics (T1–T7). One often discussed development was

PRISMatrix

the introduction of a competency-oriented curriculum after the first PISA results (T3, T5). This new curriculum would no longer be exercise-oriented but it would rather focus on applications and problem solving (PISA 2022, 2023). It was stressed that the PISA study measures certain mathematical competencies, but neglects social and emotional competencies, which should be taught in school and are closely linked to learning success (T2). Teachers in training emphasized the need for support from politicians and collaboration with scientists to develop effective teaching methods in response to PISA (T1–T3).

3.3 Results of Public Figures Interviews

Regarding mathematics education, our interviewees saw problems related to the teaching profession (P1, P3, P4), social aspects (P2–P4), classroom realities, political decisions, the educational approach and lesson design (P1–P4).

They are aware that the teaching profession is unattractive due to time pressure and high workload, rooted in a shortage of teachers (P1, P4). Pressure to complete the curriculum limits comprehensive teaching (P3). Proposed solutions include hiring additional staff, offering professional development, and increasing practical components in teacher education (P4).

In classrooms, the heterogeneity in student competencies necessitates differentiation (P3). The associated time-consuming preparation and exhaustion during teaching push teachers to their limits (P3), leading to a vicious cycle: The time pressure hinders differentiation and individual support (P1, P4), thus widening the skill gap. The COVID-19 pandemic (P1, P3, P4) has exacerbated the gap. An intermediate level approach is often ineffective in meeting both groups' needs (P2). Sharing teaching material and concepts across schools (P4) promises higher quality with reduced work.

How to engage the students and sustain a positive classroom atmosphere are further considerations (P4). More practice time (P2–P4) and new shared, scientifically evaluated teaching and performance concepts are needed (P1, P4). Instead of memorizing and repeating (P1, P2), interdisciplinary, project-oriented, and holistic learning is suggested, including future competencies such as teamwork, creativity, and emotional intelligence (P1, P4). Digital tools are helpful if used in a subject-specific, goal-oriented, and pedagogically versed way (P1, P4). A frequent barrier is schools' technical infrastructure (P3). Long screen times are criticized for reducing attention span (P3).

Improving lesson quality involves giving students time to actively find their own solutions and focusing on applied tasks (P2). Although creative classes improve quality, they may overwhelm low-performing students and amplify math anxiety (P2, P3). This could be mitigated by consolidatory practice (P2) to increase the students' self-efficacy (P4). Carefully calibrating exams, e.g., starting with easy questions, counteracts blackouts (P3). On the other hand, applied tasks enhance the students' understanding of math's relevance (P1, P2). The students' motivation and attitude are influenced by personal responsibility (P4), and parental attitudes (P2).

Three interviewees mentioned societal issues, including stigmatization of middle schools and high performers (P4, P2), a partly critical attitude towards math, and a rising division of society (P3). Regarding the migration-related language barriers (P2, P4) and missing support for socioeconomically disadvantaged students (P1), all-day schools would be a good solution but are difficult to implement due to staff shortages (P4).

Reflecting on the role of politics, they criticized inappropriate, hasty reforms (P1), the Bologna process (P2), talking instead of taking action (P2), and limited expert involvement (P1, P4). They suggest nationwide approaches while keeping federalism (P3) and ensuring school autonomy within frameworks (P3, P4). This would prevent overly demanding standards and allow customized development and flexibility. The orientation towards future competencies of the new curriculum was positively mentioned (P3), while education standards and the G8-to-G9 transition were seen ambivalently (P3).

3.4 Results of Interviews with Scientists

The scientists agreed that the school curriculum is mostly exam-oriented with little to no focus on real-life application questions (E1–E4), whereas PISA focuses on the latter. However, the PISA assessment is seen as a reliable global marker of the decline in mathematical performance in Germany, even though it fails to assess the day-to-day learning progress of students. One suggestion was to include a criterion for assessing the student–teacher relationship as it relates to the students' interest and motivation to learn a specific subject, here mathematics (E3).

The COVID-19 pandemic (E1, E3), limited language comprehension among students with immigrant backgrounds (E1, E3), and reliance on traditional teaching methods (E1, E4) along with teacher shortages (E2, E3, E4) could be contributing to the decline in mathematical interest and performance among students in Germany. Additionally, insufficient digitalization and the inability to adapt to evolving learning environments (E2, E4) exacerbate these challenges. Overloaded curricula can overwhelm students, as the focus on quantity often overshadows quality (E3). Teaching methods frequently emphasize routine problem-solving over real-world applications, leaving students ill-prepared to connect mathematical concepts to practical scenarios (E1- E4). Furthermore, language barriers hinder students' ability to fully engage with instruction, particularly for those from immigrant backgrounds who may face difficulties integrating into society and developing essential comprehension skills (E2, E3).

To address the decline in mathematics performance in Germany, experts suggest several solutions. Modernizing teaching methods is crucial, shifting from traditional approaches that focus solely on topics to ones that emphasize understanding concepts and solving problems without fear of mistakes. This approach encourages learning through trial and error, fostering a deeper grasp of mathematical principles. Improving teaching techniques can also boost motivation among both students and teachers. Implementing project-based and creative learning methods can make mathematics more engaging and relevant, allowing students to learn from mistakes and improve their motivation. Additionally, integrating digital tools into teaching enables personalized support for students of varying abilities, accommodating both high and low performers (E2, E4). A proposed shift to four-day school weeks could provide teachers with more time to develop innovative solutions and be creative, thereby enhancing teaching quality (E3). Furthermore, language fostering programs and specific initiatives to promote mathematics can help address linguistic barriers and improve overall mathematical competence (E2).

3.5 Discussion

The stakeholders agreed on several levels, suggesting they share an understanding of the problems and factors within the debate. These problems concern the overloaded curriculum, time pressure, the pressure to perform, and outdated teaching methods. Identified factors are consistent with those found in other studies (Algani & Eshan, 2019; Borgstedt et al., 2024; Wang et al., 2023). Notably, many of these had been reported two decades ago (e.g., Papanastasiou, 2000). This suggests that the debate remains relatively unchanged and problems persist.

One reason may be the high interdependence between factors as visualized in Figure 2. Our interviewees described several vicious cycles: Students and teachers recognized poor grades as core to negative self-enforcing patterns, similar to the cycle of math anxiety (Schillinger et al., 2018). Public figures pointed out a downward spiral involving gaps in competencies and increased differentiation needs (see 3.3.). This intertwining of factors significantly complicates finding efficient solutions. Attempts to solve single factors may lead to unintended consequences or reduce effectiveness.

Another reason may be a lack of priority. In politics, education often competes with more immediate issues, such as economic growth. Similar dynamics exist in the climate debate. The EIB climate survey found that while 92% of German residents think changes are needed, only 40% feel it is a priority in the next year (European Investment Bank, 2024). This lack of political prioritization may hinder sustainable reform.

All stakeholder groups share a similar vision of ideal math lessons. They suggest more individual support, and new teaching concepts with a stronger focus on application-based or problem-solving tasks with real-life relevance. These ideas are supported by the SINUS study, which concluded that new approaches to teaching, learning, and assessment are necessary. It further found that students perceive mathematics as overly abstract and complex (Borgstedt et al., 2024). However, our teachers in training noted difficulties in reducing abstractness with higher grade levels.

The stakeholder groups differed in their focus. Scientists and political actors emphasized systemic, overarching challenges and implied solving them with structural measures such as improved teacher training and support systems for students and teachers. Teachers in training concentrated on lesson design and their working conditions. The students emphasized their personal classroom experiences. This, however, may have been reinforced by our questions. All groups except students mentioned missing teaching personnel or the teachers' lack of resources and time. Students addressed systemic issues indirectly, such as the curriculum's time

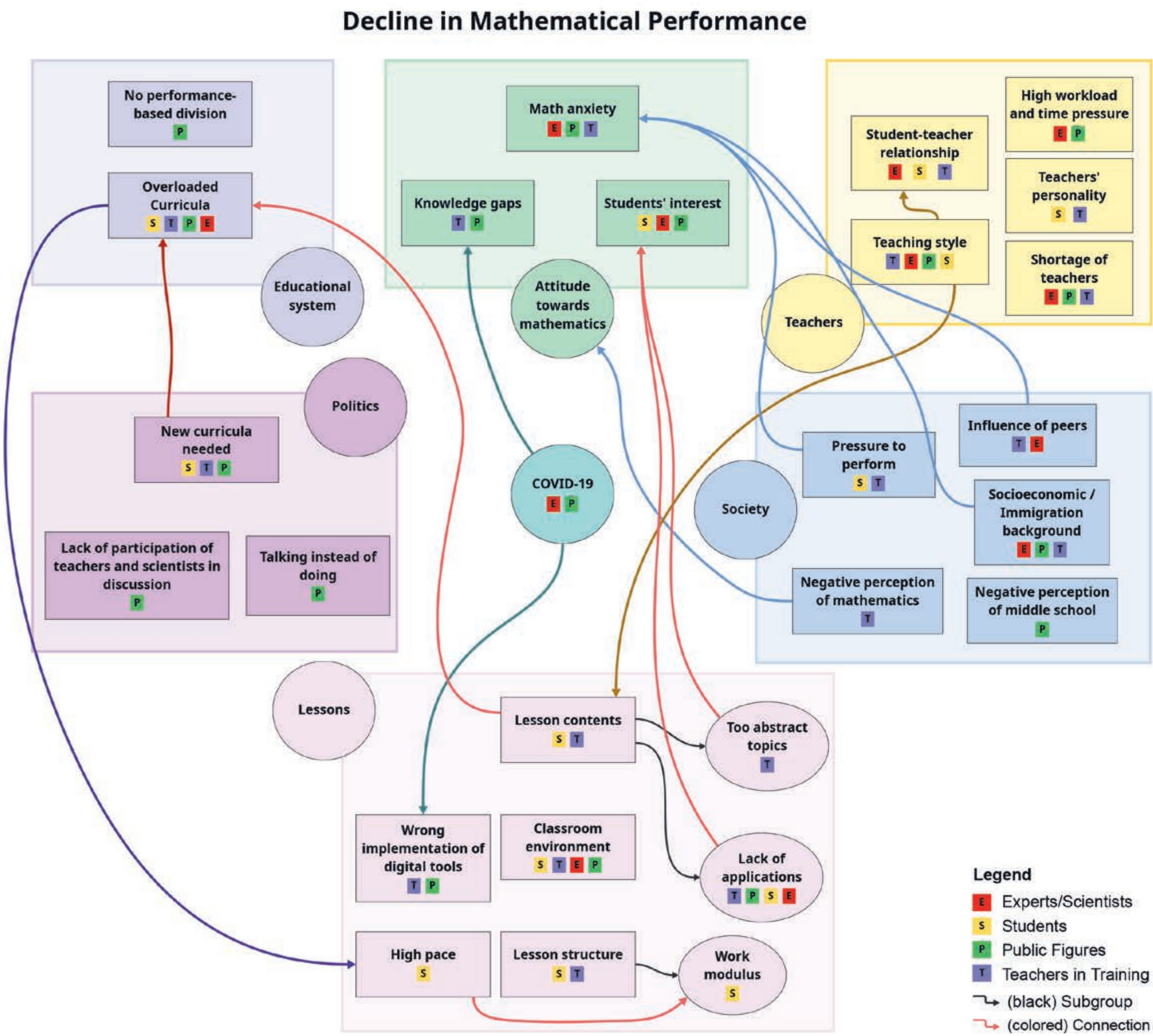


Figure 2. Situational mapping of the factors and their connections that the different stakeholders mentioned.

pressure. While the targeted use of digital tools was seen as a possible solution, students rarely mentioned it.

Both students and teachers in training stressed the importance of the student-teacher relationship and described it similarly: Teachers should show interest in their students' learning process and well-being, and be available outside of class. Both groups positively mentioned collecting students' feedback regularly and including it in the lesson planning. According to Deutsches Schulbarometer 2024, 41% are not actively asked for feedback by their teachers (Robert Bosch Stiftung, 2024). In line with studies confirming the influence of teachers (Borgstedt et al., 2024) and emotional and cognitive support (Robert Bosh Stiftung, 2024), interviewed students stressed the relationship in determining their motivation for a subject.

Our findings suggest that solutions need to target different factors simultaneously. Previous initiatives such as SINUS, EmMa, or the revised Bildungsstandards (2022) focused on isolated factors. While the current project QuaMath, meets the wish for more teacher support and further education opportunities to improve class quality, it leaves out hindering factors such as the high workload or time pressure to ensure a long-term implementation (QuaMath, 2025). The Startchancen program focuses on the financial side. It funds schools with a high percentage of socially disadvantaged students (BmBF, n.d.). In line with our interviewees' recommendations for customized solutions and school autonomy (P3, P4), schools can decide how they use the funding, such as for infrastructure.

3.6 Limitations

Our results reflect the interviewees' subjective perspectives and opinions. Thus, we do not claim to present objective factors or scientifically proven effectiveness. As opinions are dynamic, the findings represent a snapshot of the time the interviews were conducted.

Due to legal restrictions, active teachers could not be included in the data collection. Instead, teachers in training were interviewed, since they shape future education and have direct insights into school life within their internships.

A selection bias cannot be excluded, which limits the results' representativeness. Most students interviewed attended Gymnasium, enjoyed mathematics and were doing well in it. The teachers in training studied in Baden-Württemberg (N=2) or Bavaria (N=5). Statements about the structure of their programs were specific to those federal states.

4 Summary

Against the backdrop of the PISA 2022 results in mathematics, this qualitative study took an exploratory approach to investigate the perspectives of various stakeholders on the causes of declining performance of German students, and potential solutions. We conducted N=28 semi-structured interviews with students, teachers in training, scientists, and public figures between October 2024 and January 2025. We analyzed our data using a grounded-theory-based methodology. Furthermore, we used a situational mapping to analyze divergent perspectives among stakeholders.

Interviewees emphasized the need for more science-based decision-making and improved collaboration between teachers, scientists and policymakers. They also pointed to practical teaching content, innovative methods, and differentiated, tailored support for both high- and low-performing students as essential strategies. While public figures focused on systematic reforms, teachers and students emphasized classroom-level practical solutions. Overall, all stakeholders agreed on several levels, suggesting there is little controversy within the debate. The high interconnection between factors or a low priority may be the reason for why the problems within mathematical education persist. Building on this result, future research could try to understand the underlying barriers to the successful implementation of solutions, especially in the presence of stakeholder agreement.

Furthermore, further research on collaborative decision-making models or strategies to bridge differences in educational priorities could provide valuable insights for establishing more effective and practical solutions. Additionally, as highlighted in the PISA 2022 results, there is a noticeable gap between high and low performers. To address this imbalance, further research on assessment and teaching design as well as the development of enrichment programs for high performers would be essential to ensure their potential is nurtured alongside support for struggling students. Our findings point to a need for multi-dimensional, coordinated interventions instead of solutions at only the individual or systemic level.

This study provides an overarching understanding of the current debate on mathematics education in Germany. By bridging the gap between research and practice, it integrates diverse stakeholder perspectives on educational challenges. It points to a need for multi-dimensional, coordinated interventions.

5 References

acatech & Joachim Herz Stiftung. (2024). *MINT Nachwuchsbarometer* 2024 (p. 17 pages) [Application/pdf]. Acatech - Deutsche Akademie der Technikwissenschaften. https://doi.org/10.48669/ACA_2024-8

Aldon, G., Cusi, A., Schacht, F., & Swidan, O. (2021). Teaching Mathematics in a Context of Lockdown: A Study Focused on Teachers' Praxeologies. *Education Sciences*, 11(2), 38. https://doi.org/10.3390/educsci11020038

Algani, Y. M. A., & Eshan, J. (2019). Reasons and Suggested Solutions for Low-Level Academic Achievement in Mathematics. *International E-Journal of Educational Studies*, 181–190. https://doi.org/10.31458/iejes.604884

BmBF. (n.d.). *Startchancen-Programm*. Bundesministerium für Bildung und Forschung. https://www.bmbf.de/DE/Bildung/Schule/Startchancen-Programm/startchancen-programm

Borgstedt, S., Gaber, R., & Stockmann, F. (2024). *Integrierter Gesamtbericht des SINUS-Instituts- MINT Motivation.*

Clarke, A. (2005). *Situational Analysis.* SAGE Publications, Inc. https://doi.org/10.4135/9781412985833

European Investment Bank. (2024). The EIB climate survey: *Attitudes towards climate change adaptation : 7th edition 2024.* Publications Office. https://data.europa.eu/doi/10.2867/4661519

Forsa. (2020, May 27). *Homeschooling in Corona-Zeiten Erfahrungen von Eltern und Schülern*. forsa Politik- und Sozialforschung GmbH. https://www.dak.de/dak/download/forsa-studie-2266768.pdf

Günther, A. (2024, February 27). Es trifft Kunst und Musik. *Süddeutsche Zeitung.*

Ministerium für Bildung, Wissenschaft und Kultur. (n.d.). *Lehramt an Regelschulen: Jetzt dual studieren* [Aktuelles]. Freistaat Thüringen. Retrieved March 13, 2025, from https://bildung.thueringen.de/lehrkraefte/duales-studium

OECD. (2023). *PISA 2022 Results (Volume I): The State of Learning and Equity in Education.* OECD. https://doi.org/10.1787/53f23881-en

Papanastasiou, C. (2000). Internal and external factors affecting achievement in mathematics: Some findings from TIMSS. *Studies in Educational Evaluation, 26*(1), 1–7. https://doi.org/10.1016/S0191-491X(00)00002-X

QuaMath. (2025). QuaMath - Unterrichts- und Fortbildungs-Qualität in Mathematik entwickeln. https://quamath.de/

Ramirez, G., Chang, H., Maloney, E. A., Levine, S. C., & Beilock, S. L. (2016). On the relationship between math anxiety and math achievement in early elementary school: The role of problem solving strategies. *Journal of Experimental Child Psychology, 141*, 83–100. https://doi.org/10.1016/j.jecp.2015.07.014

Robert Bosch Stiftung. (2024). Deutsches Schulbarometer: Befragung Schüler:innen. Ergebnisse von 8- bis 17-Jährigen und ihren Erziehungsberechtigten zu Wohlbefinden, Unterrichtsqualität und Hilfesuchverhalten. *Robert-Bosch-Stiftung.*

Schillinger, F. L., Vogel, S. E., Diedrich, J., & Grabner, R. H. (2018). Math anxiety, intelligence, and performance in mathematics: Insights from the German adaptation of the Abbreviated Math Anxiety Scale (AMAS-G). *Learning and Individual Differences*, *61*, 109–119. https://doi.org/10.1016/j.lindif.2017.11.014

Strübing, J. (2021). *Grounded Theory: Zur sozialtheoretischen und epistemologischen Fundierung eines pragmatistischen Forschungsstils.* Springer Fachmedien Wiesbaden. https://doi.org/10.1007/978-3-658-24425-5

Sturzbecher, D., Dusin, R., Kunze, T., Bredow, B., & Pöge, A. (2021). *Jugend in Brandenburg 2020. Auswirkungen der Corona-Pandemie [youth in Brandenburg 2020. Impact of the Corona pandemic]*. MBJS Brandenburg. https://mbjs.brandenburg.de/media_fast/6288/ifk-jugendstudie_2020_-_auswirkungen_der_corona-pandemie.pdf

Svraka, B., Lasker, J., & Ujma, P. P. (2024). Cognitive, affective and sociological predictors of school performance in mathematics. *Scientific Reports, 14*(1), 26480. https://doi.org/10.1038/s41598-024-77904-7

Tillmann, K.-J. (2015, June 19). PISA & Co. – *Eine kritische Bilanz* [Bildung]. Bundeszentrale für politische Bildung. https://www.bpb.de/themen/bildung/dossier-bildung/208550/pisa-co-eine-kritische-bilanz/

Wang, X. S., Perry, L. B., Malpique, A., & Ide, T. (2023). Factors predicting mathematics achievement in PISA: A systematic review. *Large-Scale Assessments in Education, 11*(1), 24. https://doi.org/10.1186/s40536-023-00174-8

Zwanzig Jahre Kompetenzorientierung und kein bisschen weise. (2023, December 10). Condorcet Bildungsperspektiven. https://condorcet.ch/2023/12/zwanzig-jahre-kompetenzorientierung-und-kein-bisschen-weise/

Mapping - Students

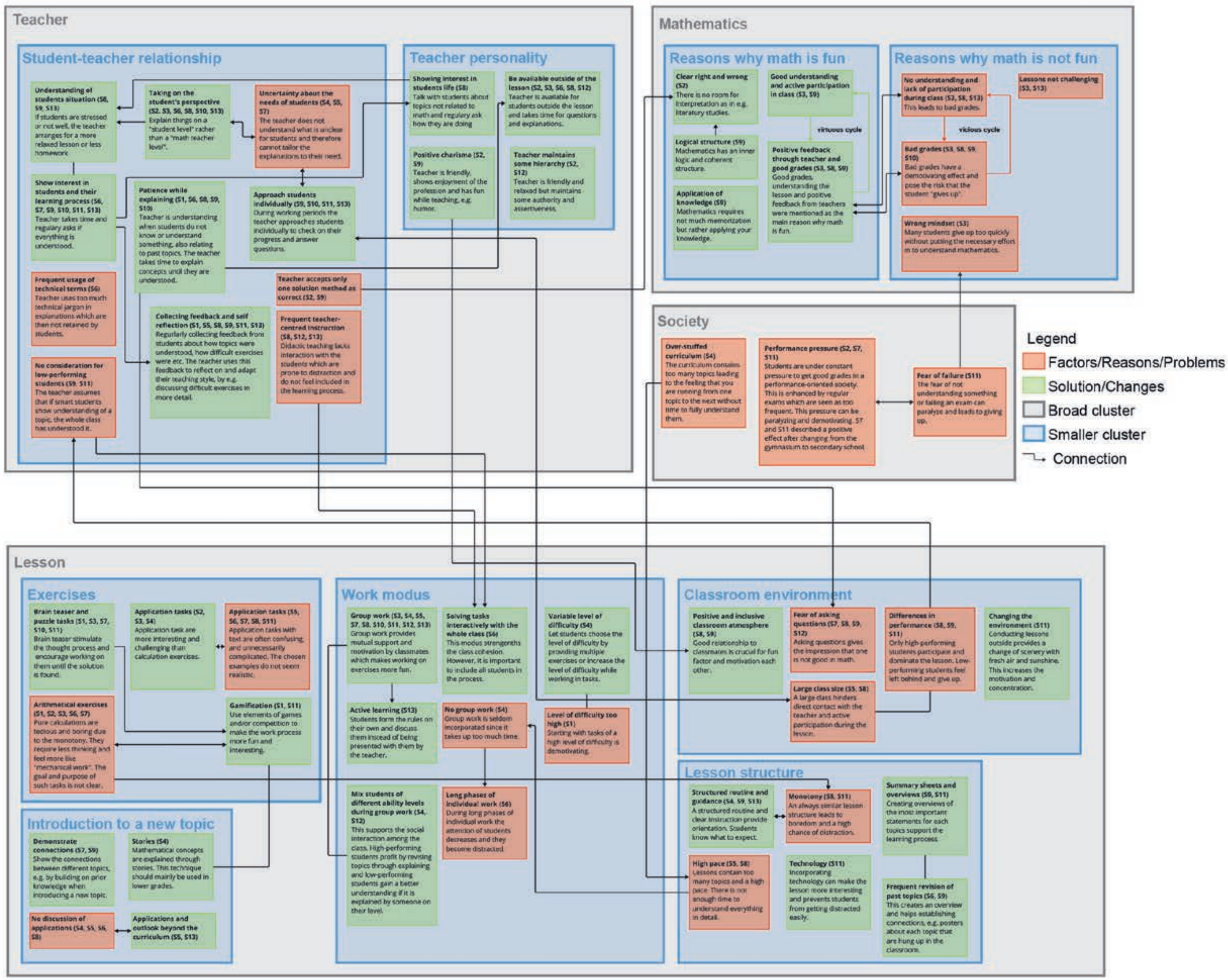


Figure 3: Mapping of factors and solutions mentioned by students

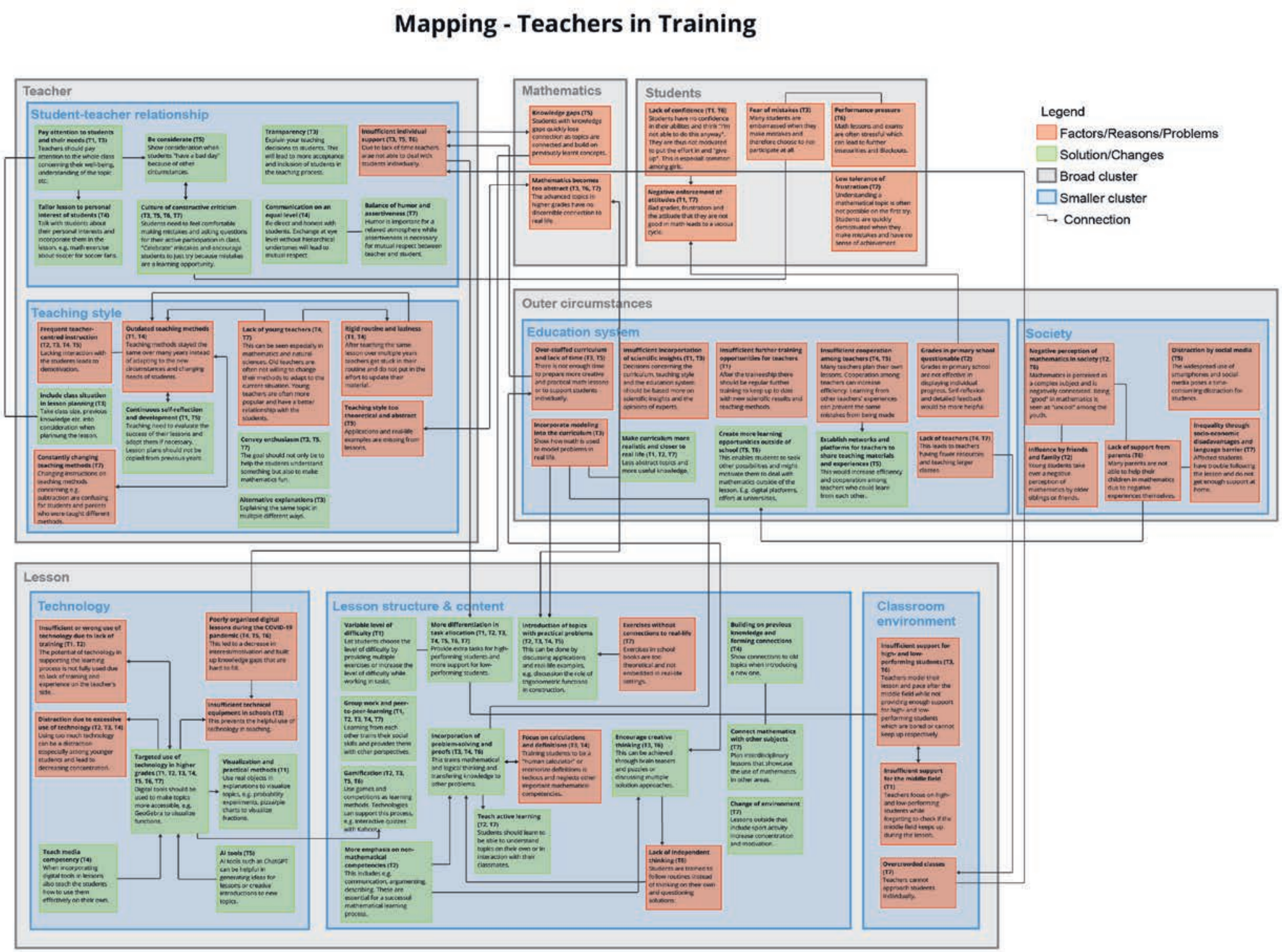


Figure 4: Mapping of factors and solutions mentioned by teachers in training.

Mapping - Scientists

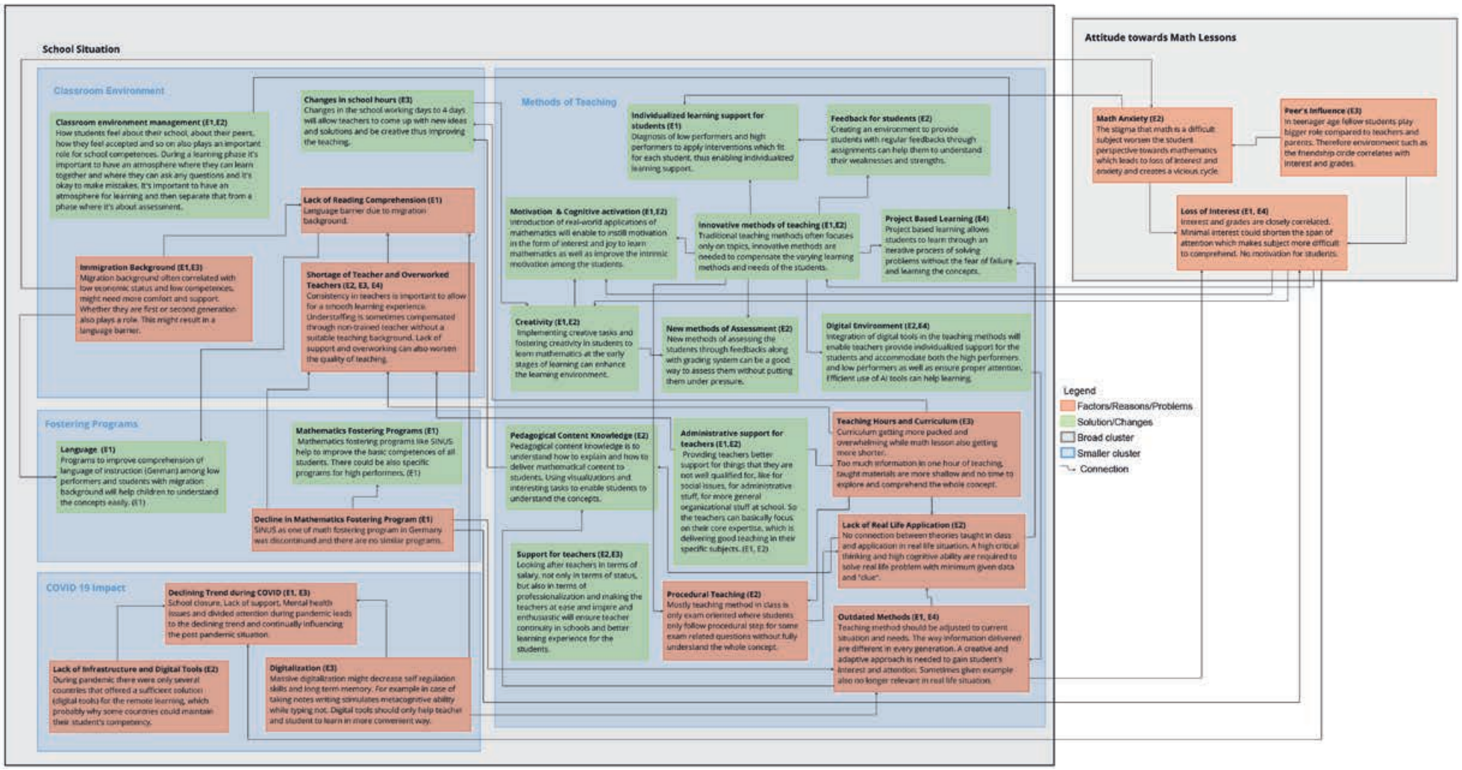


Figure 5: Mapping of factors and solutions mentioned by scientists.

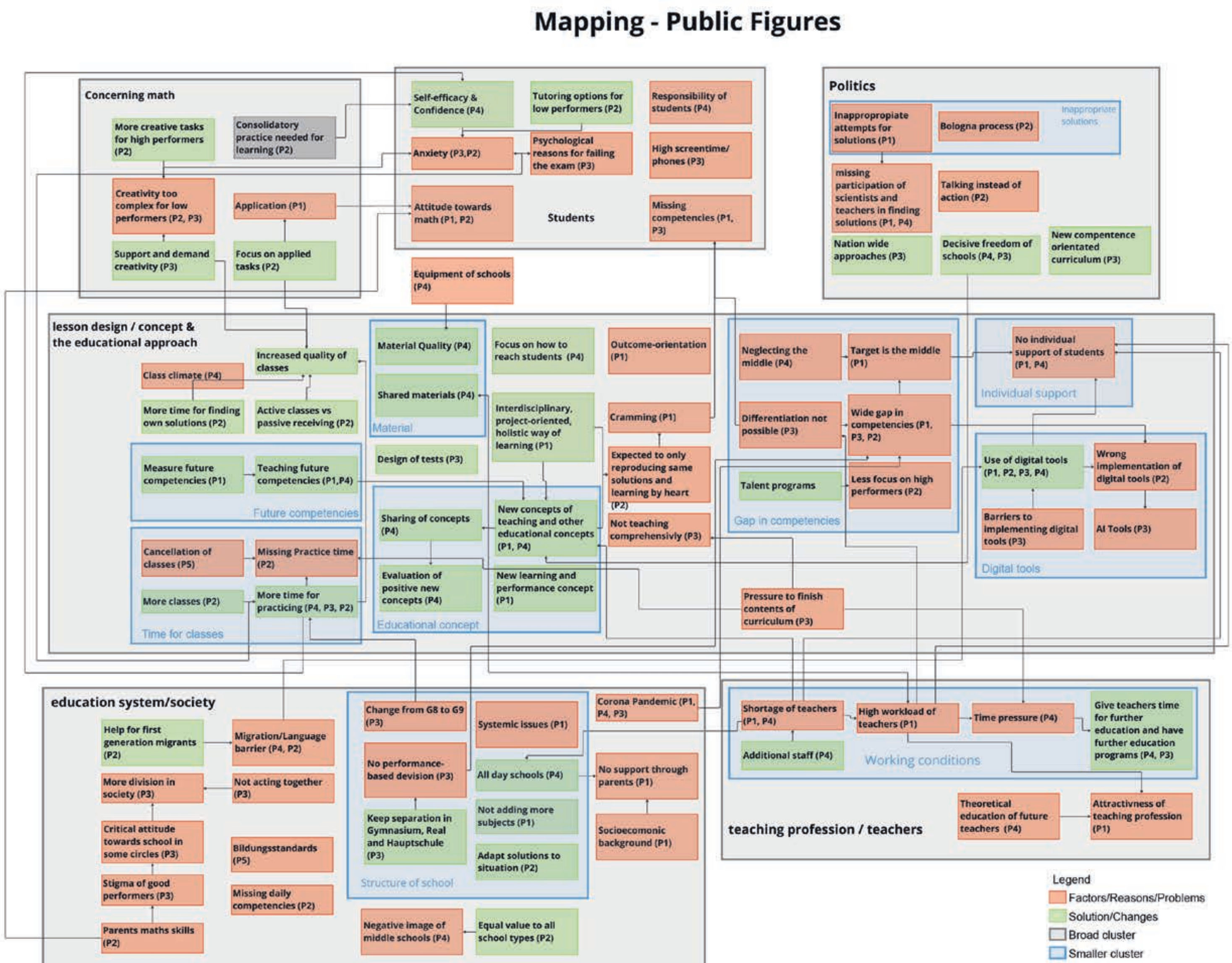
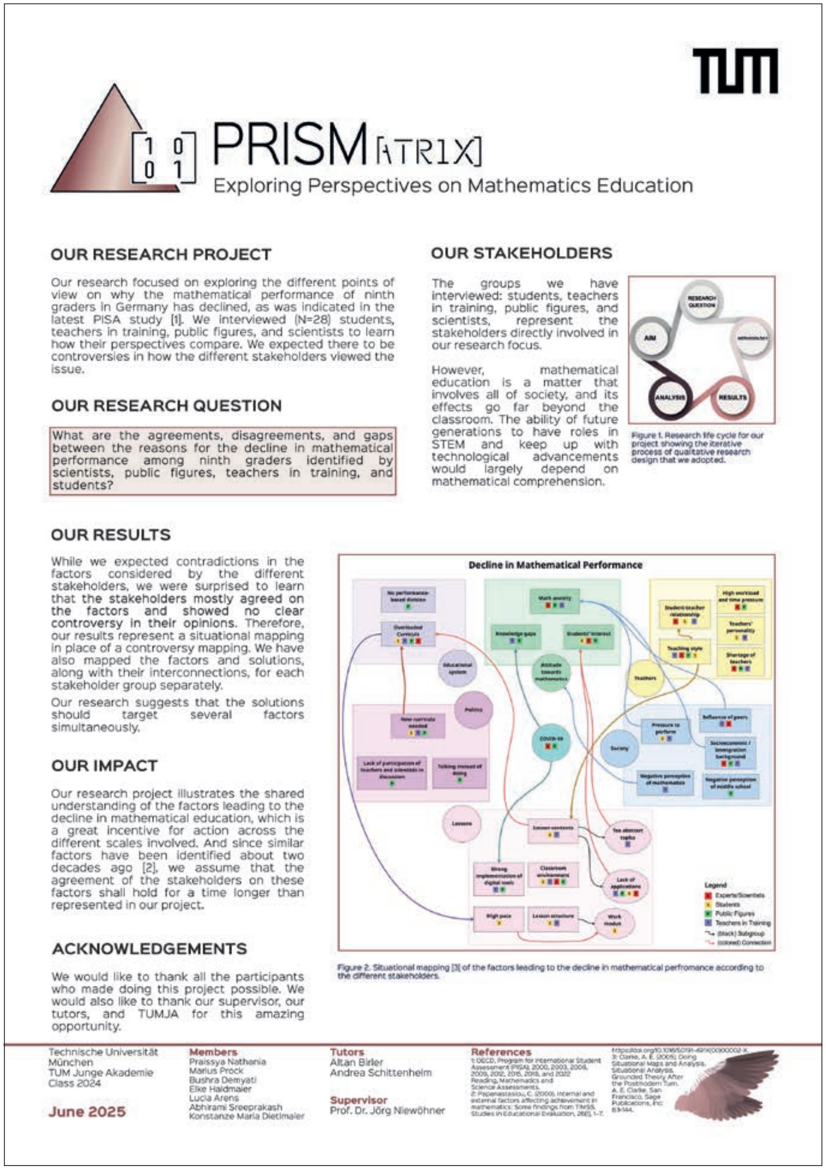


Figure 6: Mapping of factors and solutions mentioned by public figures.

Process description



Recognizing the pivotal role of lifelong learning and creativity in human life, our team initially aimed to foster creativity among working adults. In the early stages, we met to design a project around this idea. However, following the release of PISA 2022 in late 2023, which revealed a significant decline in German students' mathematics scores, we felt the urge to shift our focus and investigate the contributing factors behind this decline. We wanted to get a more personal-level view of the issue to supplement the already existing large-scale proposals for improvement. Our team aimed to identify these factors using a qualitative, exploratory approach. Over six months, we designed, conducted, and analyzed semi-structured interviews with different stakeholders. Depending on the stage of the project, our team members adapted their roles and timeframes. Based on the gathered insights, we hoped to visualize connections between problems and solutions from the perspective of different stakeholders.

In contrast to many studies focusing on the influence of different factors, we concentrated on identifying agreements, disagreements, and gaps among stakeholders. Our main challenge was recruiting interview participants. Due to legal restrictions, we were not permitted to contact public schools or interview teachers employed at state schools. Instead, we interviewed teachers in training and students through private contacts. After completing all interviews in January 2025, we finalized our coding process with the support of our supervisor and tutors. Based on the qualitative analysis, we visualized key themes and created mappings. In the final step, we compared these mappings, concluding that all stakeholders agree on the main problems in math education. ■

Self-Reflection PRISMatrix

Our interdisciplinary research team, PRISMatrix, came together in October 2023 with the shared goal of investigating the perceived causes of the mathematical decline among students in Bavaria. Our members came from varied academic backgrounds, which shaped the way we approached our project and the team dynamic as a whole.

From the beginning, we discussed what each of us is most interested in. It's certainly true to say that each member learned something new, expanded their knowledge in various areas, and got to experience aspects of research that would have otherwise been difficult to experience. Our supervisor was very helpful in guiding our process and filling any gaps in our knowledge.

The team atmosphere remained collaborative and fun even in the slower phases. We tried to meet in person as often as possible, and our meetings were always filled with stories, jokes, and, of course, lots of snacks. Our tutors were also very supportive and friendly throughout the whole process: we have quite a few inside jokes with them at this point.

The interviewing process was also new for all of us. We had the chance to conduct interviews with people of different ages, academic backgrounds, and social stations. The project is special to us because of the friendships we formed. The weekends we spent together weren't just productive - they were also very engaging! Whether it was joking around with our tutors and other scholarship holders or sharing meals after long work sessions, a sense of camaraderie developed. This was very much reflected in how we worked on the project. While PRISMatrix was a one-time collaboration, it was a meaningful and enriching experience for all of us, and one we'll carry in our future academic and professional journeys. ■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