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Teachers' and students' perspectives on modeling projects
La perspectiva de los profesores y estudiantes en los proyectos de modelización

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Abstract

Mathematical modeling can be promoted in regular lessons as well as in project form. Both options have advantages and disadvantages and provide different challenges, but also opportunities for students and teachers. Since 2001, teachers in Hamburg have the opportunity to participate with their students in modeling projects organized by members of the University of Hamburg. In this paper, the perspective of teachers, some of whom have been participating in modeling activities for more than five years, on the opportunities, but also on the difficulties of participation are presented. In addition, the views of over 200 students regarding their participation in the modeling days are outlined.

El modelado matemático puede promoverse tanto en las lecciones regulares como en forma de proyectos. Ambas opciones tienen ventajas y desventajas y ofrecen diferentes desafíos, pero también oportunidades para los estudiantes y los maestros. Desde 2001, los profesores de Hamburgo tienen la oportunidad de participar con sus alumnos en jornadas de modelación organizadas por los profesores de la Universidad de Hamburgo. En este documento se presenta la perspectiva de los profesores, algunos de los cuales han participado en actividades de modelado durante más de cinco años, sobre las oportunidades, pero también sobre las dificultades de la participación. Además, se esbozan las opiniones de más de 200 estudiantes con respecto a su participación en los días de modelación.

Keywords: Modeling projects, modeling days, modeling competencies, teacher's perspective, student's perspective
Palabras clave: Proyectos de modelado, días de modelado, competencias de modelado, perspectiva del profesor, perspectiva del estudiante

1. Introduction[1]

Modeling projects have been conducted in Hamburg for years. Teachers are grateful to participate, but so far there has been little research regarding the output of modeling projects or even the experiences of participating students and teachers[2]. Working on mathematical modeling problems is a challenge for students, but also for teachers (Niss & Blum, 2020). The latter, for example, are not only faced with the challenge of finding suitable problems, but also of supervising their students in such a way that they are not only able to solve the problem, but also to develop their modeling competencies at the same time. With respect to regular classes, motivations and obstacles from the teacher's point of view have already been summarized by Schmidt (2011) and Niss & Blum (2020). More complex problems, which take more than one or a few double lessons to solve and which are therefore worked on in project form, pose other obstacles. However, they can have other effects on the learning process of students as in this way they have the opportunity to work on a mathematical problem continuously and without disruption.

Since 2001, teachers in Hamburg have had the opportunity to participate with their students in modeling days or weeks organized by members of the University of Hamburg. The persons responsible as well as the specific format have changed in recent years, not least because of regular feedback from participating teachers as well as changing school conditions. The format presented in this paper has been taking place in its basic form for six years.

In this paper, after a brief summary of the process of the Hamburg Modeling Days as well as three exemplary modeling problems, the teachers' perspectives on the opportunities and difficulties of participating in the Hamburg Modeling Days are presented. As a supplement, the students' views on participation in the Hamburg Modeling Days will also be presented and both views will then be summarized in conclusion.

2. Hamburg Modeling Days

For almost 20 years, the University of Hamburg has offered modeling projects for school students in Hamburg, although the responsibility for implementation has changed over time. From the beginning, the implementation was linked to the training of prospective teachers. The supervision of students working on the modeling problems was carried out by the teachers of the students together with prospective teachers of the teaching profession mathematics, who could apply and subsequently reflect on their knowledge acquired in the context of subject-specific and subject-specific didactic seminars beforehand.

The current format has been in place for six years and is aimed at grade 9 and 10 students who work in small groups on a complex modeling problem during a two-day work period, usually from 8am to 3pm. The goals of the modeling days are to foster modeling competencies of the participating students and to foster teachers' and prospective teachers' competencies for teaching mathematical modeling. Thus, as preparation for the supervision activity, the prospective teachers, but also the practicing teachers in the context of an advanced training course, are asked to first think through and work on the modeling problem they will be supervising themselves. This allows to anticipate central problems in the processing and to prepare support that correspond to the principle of minimal help Aebli (1997), so that the students are supported

[1] Parts of this article (Sections1.1,1.2 and 1.4.1) can be found in more detail in German in Vorhölter & Alwast (2021). The structure and concept of the Hamburg Modeling Days, which evaluation are in the focus of this paper, are described in more detail in Vorhölter & Freiwald (in this issue).

[2] Several groups of people are involved in the Hamburg Modeling Days: Students in grades 9 and 10 work on modeling problems and are supervised by student teachers, hereafter referred to as prospective teachers, and the students' mathematics teachers, hereafter referred to as practicing teachers.

without pushing them too much in a certain direction or prescribing too much to them.
Students should be able to experience during working on a modeling problem that they are able to find answers to complex questions on their own. Therefore, it is taken care that the students can perceive the posed question as relevant for themselves personally or for society (see chapter 3). During the Hamburg Modeling Days, they work as independently as possible. Depending on the task, this also includes researching information or data by themselves in various ways and visualizing data or simulating models. Therefore, some equipment like computers or laptops, as well as printing facilities and internet access, is usually essential; furthermore, students should be allowed to leave the school premises for certain periods of time for some tasks.
Each year, students are presented with three modeling problems, from which they may choose one task to work on throughout the two days. Following the choice, the students are divided into groups. The specific distribution takes place after consultation with the teachers, but it is specified that ultimately between 12 and 15 students should work on the same modeling problem in one room, and this group should be divided again into small groups.
After the students have worked on the problem, they present their results on posters, to which—also depending on the concrete circumstances in the schools—the remaining teaching staff, parents or fellow students from other grades can be invited.

3. Exemplary short description of used modeling problems

As mentioned above, every year, three modeling problems are posed to the students to choose from. Care is taken to ensure that the problems have different mathematical content and are different in terms of their subject context. The problems are briefly presented together with the respective challenges before the starting of the modeling days. This is to ensure that the students choose a task of interest for themselves and that they feel competent to work on. In the year from which the student assessments (chapter 4.2) were taken, the problems used are briefly presented below.

3.1. CO_2-saving

As one of many cities, the Free and Hanseatic City of Hamburg has been offering the "StadtRad" as part of its public transport system for several years. This bike rental system is operated on behalf of the city by DB Rent, a subsidiary of Deutsche Bahn. After registering once, users can rent and return a bicycle at more than 220 stations. The duration of the ride determines the amount of the rental fee. The city of Hamburg is funding the project with 2 million euros per year, so that with this support the emission of pollutants and CO_2 of the public transport and thus of the whole city is reduced. The aim of this modeling problem is to question the benefit of promoting a public funding measure to reduce CO_2- emissions.
In the problem description, students are informed that there are some critical voices about this type of investment. This results in critically questioning the actual benefits of this system. As supposed employees of a consulting company, the groups are to decide whether the amount of subsidies is justified or whether the money could be better used elsewhere for the same aim. For this purpose, students have to consider different measures and evaluate them with regard to CO_2- reduction. Typically, the students choose as alternative measures, for example, the procurement of buses with alternative drive systems or the planting of more trees in the city.

3.2. HYROX™

HYROX (www.hyrox.com) is a contest consisting of several disciplines. A running distance of 800 meters is always alternated with a strength endurance exercise. The final ranking in the competition is provided by the total time from the start time to the time the participants cross the finish line. The aim of this task is to evaluate the fairness of the rules of a new type of fitness competition. The question to be answered by the students within the framework of this modeling problem thus relates to the expressed criticism of the scoring of the competition.
As part of the problem, students were told that there is a concern that some types of athletes are favored in this form of competition. The students are asked to determine in which discipline a participant would have to be particularly good in order to achieve a good place as easily as possible. In addition, they are asked to develop alternative suggestions for conducting the competition. The goal should be to make the competition fairer for everyone (as claimed by the organizers). In addition to this general information, the groups received a spreadsheet with the disciplines (runs and power-exercises), respective times of 100 former participants, and their ranking achieved.
In order to complete this task, students usually determine statistical values such as the mean value of different disciplines, divide the disciplines according to muscle groups and then compare the corresponding sport residuals. For the development of alternative evaluations or disciplines, they deal in particular with the concept of fairness.

3.3. Cable-Camera®

Cable cameras has become more and more popular in recent years, among other things due to major sporting events. The use of such a camera allows large-area and recordings as well as the fast and targeted tracking of certain objects (e.g. at soccer). Game situations can be tracked even more precisely and the technical development of the camera allows the precise recording of ball movements. In the problem description, the students receive information about the installation of the camera in the stadium. The camera is attached to steel cables mounted on rollers at the respective corners of the stadium and controlled by extending or shortening these cables.
The task for the groups is to develop a system for controlling the camera. The aim is to find out how the camera can be moved to any specific point in the stadium and what needs to be taken into account when controlling the camera. As the modeling days only last for 2 days and students of grade 9 work on the task, during the Hamburg modelling days students usually cannot work on the entire question as described in Günster, Pöhner, Wörler and Siller (2021), for example. They usually limit themselves to a subproblem consisting of the determination of distances and coordinates in three-dimensional space, whereby many start in the two-dimensional surface.

4. Teachers' and students' perspective on modeling days

Although modeling projects like the Hamburg Modeling Days are conducted at several universities in Germany, it has not yet been verified whether the goals of teaching modeling competencies of students and modeling teaching competencies of (prospective) teachers are achieved through this form, nor has the perspective of teachers and students been systematically surveyed. The implementation of the Hamburg Modeling Days is regularly evaluated informally with the participating students, prospective teachers, and teachers. The following presentation of such a survey is intended to provide a first insight into the perceptions of the target groups involved.

4.1. Teachers' view of opportunities and difficulties

In the following, the reflections of five teachers from three schools who have participated in the past years are presented on the opportunities of modeling days as well as on difficulties associated with them. The teachers who speak here are both those who have regularly participated in modeling days for more than four years and those who have participated in modeling days for the first time and were also not very familiar with mathematical modeling beforehand. In the following presentation we stick as far as possible to the literal statements of the teachers, in line with the statement of one teacher who said that she was most likely to be convinced of new concepts when colleagues passed on direct experiences.

All quotes were taken from conversations with the teachers involved. For better readability, the statements were translated by the authors, and teachers' language has been smoothed. The points presented below relate on the one hand to organizational aspects, but also to content-related aspects concerning the competence development and motivation of the students.

The aspect of **organization** represents an essential aspect, which in particular includes challenges in the preparation and implementation of the modeling days. On the one hand, this includes the **willingness of the teaching staff** to skip lessons in all other subjects on two school days in favor of mathematics. However, the teachers also mention numerous arguments that help to convince the staff, as will become clear below. Another difficult point in the preparation is to organize the necessary **technology**, whereby the teachers mean the equipment with sufficient computers or laptops and printers. Because not having the technology "slows the kiddies down in the creativity they might otherwise have had in researching."

The **provision of rooms** could also become a problem - if it is not planned early enough and the person responsible for the room planning is also involved. The reason for this is that, if possible, the students should work in a fixed room within the two days, and because of the form of work, two rooms should be available per class if possible.

The teachers agree that the organization that has to be done in advance is a challenge. Normally, they are not allocated any time for this, for example in the form of relief hours, but have to carry out this work in addition to their regular working hours.

In addition to the organizational effort that has to be made in advance, there is also the **preparation of the content** of the modeling days: The teachers all agree on the importance of dealing with the modeling problems themselves in order to be able to deal with the students' problems adequately. However, they also mention that due to the repeated use of the modeling problems after some years, the familiarization with the concrete problem is no longer as time-consuming during the repeated supervision of the problem, and overall the familiarization and engagement with the problems is shorter in order to grasp the essence of the problems.

Another organizational aspect that must be considered in advance is the criteria according to which the **students are divided into groups**. This is because, in the experience of the teachers, the division into groups has a great influence on "whether content or side conversations"take place, in other words, on the group's ability to work. It is often expressed that teachers have purposefully pursued different strategies here. For example, some have deliberately formed class-homogeneous groups, others have deliberately formed cross-class groups.

As a final point on the organizational level, the teachers mention the **timing** and **duration** of the modeling days. With regard to the timing, they point out that it should be chosen in such a way that it does not unnecessarily interrupt the learning and working processes of mathematics and other subject lessons. With regard to the length of time, there was previously a fear at some schools that this would not be used sensibly, but rather that "two times six lessons would be wasted time". The teachers, who have already gained experience with modeling days over a longer period of time, therefore see the 2-day duration as an optimal compromise: On the one hand, there is enough time to deal with a (mathematical) problem in depth and, on the other hand, the regular teaching routine is not affected too much and even students whose attitude towards mathematics lessons is rather negative are willing to participate.

In addition to organizational obstacles, which can usually be overcome in advance through the efforts of dedicated teachers, there are some **content-related aspects** that should be taken into account during the modeling days. As already described, the intended goal of conducting modeling days with students is primarily to promote the process-related mathematical competence of mathematical modeling. Students should learn to solve real and authentic problems using mathematical methods they have mastered. In doing so, they should also recognize the role mathematics plays in today's world and that they are capable of understanding and solving complex problems on their own. The modeling problems we use make it possible to deal with them at different levels and with different emphases, which means that the results produced by the students can be at very **different levels**, which was initially viewed with concern by some teachers. However, ƨou have to be willing to accept that this occurs [...], so that there are some working at a simple level and others presenting a very complex solution."The danger that not only the level is different, but that some students work on the problem only superficially, cannot be denied. The teachers refer the superficiality of the solutions to the unwillingness of the students to reflect on their own solutions and to improve them if necessary. However, one teacher states, I think that's kind of normal, that's what's expected, I think, and another states, "the results, I have to say, turn out to be very solid."

Another teacher, who has already had several years of experience with modeling days at her school, notes that this motivation to revise one's own solution has changed significantly over the years in which the students have learned about the concept of modeling days from their classmates, since the students in previous years were much more quickly satisfied with edits and were more difficult to motivate, "also to reflect again on their own results and see what you can improve." One teacher clearly sees the responsibility of the supervisors and their understanding and conviction as a condition for high-quality results. According to the teachers, the depth of the work depends to a large extent on how the students are motivated and supported during the work. For just as it was experienced that students had to be animated in order to achieve acceptable results, the teachers alsocreport cases in which "the kiddies clearly went beyond the standard and where the kids were enthusiastic about it" and that there were "on the other [side] of course also very high-performing groups [that] then tried again and again and again to get even more precise." Explicitly, one teacher reports about of a student with whom she noticed "he has ideas, and that's great." Other teachers also report that individual students go far beyond what can be expected of them based on grade level and who then pull the other group members along.

The teachers not only describe the benefits and difficulties related to the individual learning processes of the students, but also classify the acquisition of competencies during this time in the effects that the modeling days have on **mathematics teaching after this time**. In particular, it became clear in the interviews that the teachers use the modeling days as a starting point to prepare the students for the oral exams at the end of grade 10, which are obligatory in Hamburg, and also for the mathematics lessons in the upper school. The advantage of the modeling days is that students are given time to deal with factual situations in peace and quiet and to practice translation processes between mathematics and factual contexts several times. However, the experience gained during the modeling days had to be referred to again and again and the strategies and perspectives developed there had to be kept alive in order to continue to be useful. The modeling days would therefore offer a good introduction to the processing of reality-related, complex tasks, whereby the strategies and solution approaches used during this processing would have to be deepened by further, less complex tasks in order to become

effective in the following performance reviews.
Overall, the teachers perceive difficulties, but at the same time many opportunities, which, in their view, not only promote the students' modeling competencies. Rather, participation in the modeling days can have an impact on the entire subsequent mathematics lessons and promote further social competencies. In summary, the statements presented represent the views of five teachers and are therefore by no means generalizable. Furthermore, the teachers' views should be compared with those of the participating students.

4.2. Students' view of the modeling days

Feedback is also regularly obtained from the participating students. The following statements are based on feedback from a total of 211 students, of which 57 % were female and 36 % were male (6.2 % did not provide gender information). The students came from three different high schools, with 61 students from School A participating in the survey, 100 from School B, and 50 from School C. Therefore, when interpreting the results, it should be noted that almost all students participated in the survey only at School B, while only about half participated at Schools A and C. Overall, it can be stated that, in line with expectations, the boys generally indicated a greater interest in mathematical topics than the girls. In advance, about 40 % of the participating students were looking forward to the modeling days, while about 20 % were skeptical about the project days. In the following, the students' statements on the group work, the tasks, as well as their attitude towards the modeling days as a whole are presented.
As already described, the students were asked to work on one of the three modeling problems in chapter 3 in groups, whereby they were free to choose the task in the first step, but the groups were then subsequently divided up by the teachers. At the request of the teachers, care was taken at School B to ensure that, as a rule, the students in a small group came from one class, whereas at School A and C, groups were deliberately formed across classes. Performance-heterogeneous and gender-heterogeneous groups were formed at all schools.

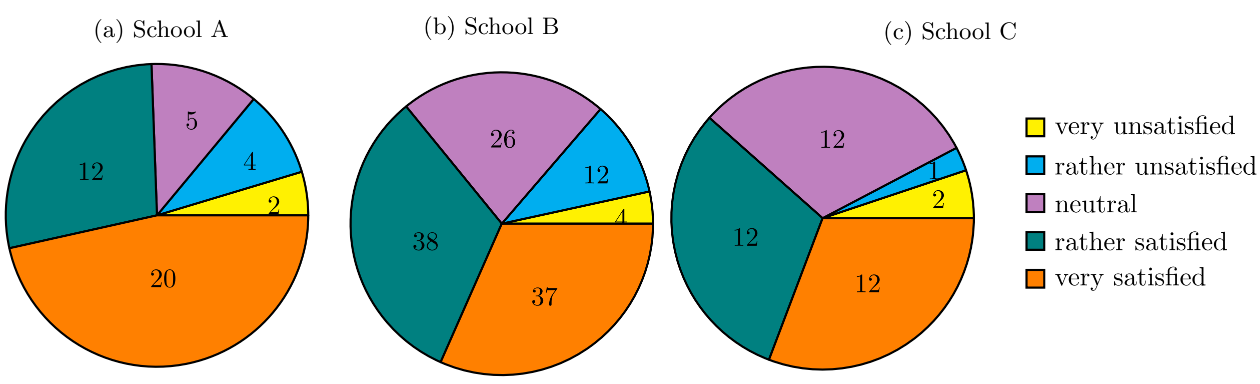
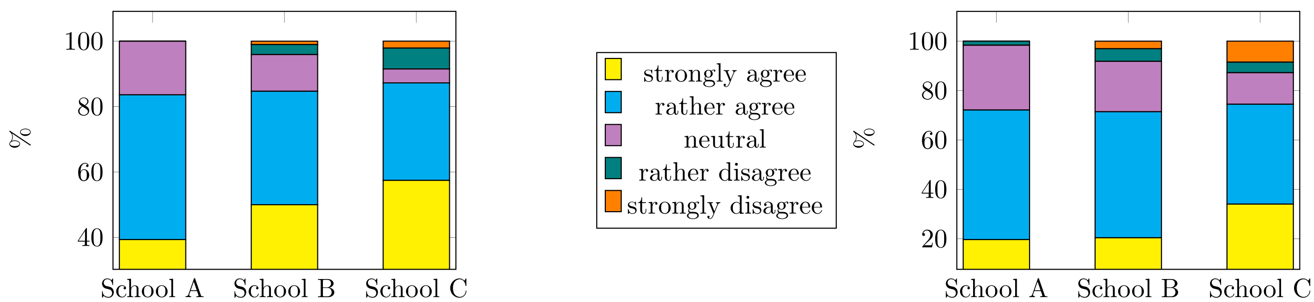


Figure 1 – Satisfaction with group composition, devided by schools

The evaluation showed that more than 75 % of the students positively conotated working in groups. With regard to the satisfaction with the group arrangement, a more differentiated picture emerges. While at school A less than 50 % of the students stated that they were satisfied with the composition of the groups, at School C about 65 % were rather or completely satisfied with the group composition, at School B even more than 75 %. At the same time, it should be noted that the proportion of students who were (rather) dissatisfied with the group composition was highest at School C with just under 20 %, and lowest at School B with about 10 % (cf. Figure

1). Overall, therefore, it can be concluded that the students who were allowed to work in in-class small groups were the most satisfied with the composition of the groups, while the students in which groups were formed within the grade were less satisfied. However, it is also clear that at each school, students were both satisfied and dissatisfied. A difference in satisfaction with the group composition with respect to gender or the chosen task could not be found.
However, the students' statements on satisfaction with the group composition do not allow any prediction regarding the tone of interaction in the groups and the perceived productivity (cf. Figure 2): While in school A the students report both a friendly working atmosphere and a rather positive productivity, there are students in the other two schools who report a less friendly interaction and a less productive work process. At the same time, it should be noted that there were no gender differences in the perception of productivity, but boys were more likely to report an unfriendly tone in the groups compared to girls. At the same time, it can be noted that in the group of students who worked on the Cable-Camera-problem, only about 65 % reported a productive working atmosphere, while in the other two tasks the proportion of students with a positive attitude was 75 %.



(a) friendly tone of conversation in the small group

(b) Productivity of group work

Figure 2 – Evaluation of the group work by the students, divided by schools

As shown, the students were presented in advance with three available modeling problems from which they had to choose one. Fig. 3. shows the distribution of the students among the tasks, separated by gender as well as by school. It can be seen that overall most students chose the CO_2-saving-problem (118 students), the other two tasks were chosen almost equally often (Cable-Camera 43, Hyrox 39).
With regard to the different schools, however, a more differentiated picture emerges: Apparently, in percentage terms, the Cable-Camera-problem was chosen significantly more often at School B than at the other schools, while the Hyrox-problem was chosen significantly more often at School C. At the same time, it can be seen that while almost the same number of boys chose the Cable-Camera- and CO_2-saving-problems, the girls chose the CO_2-saving-problem task by far more often. At the same time, it can be seen that while almost equal numbers of boys chose the Cable-Camera and CO_2-saving-problem, the CO_2-saving-problem was by far the most frequently chosen by girls.
We can only make assumptions for the reasons for this: First, when the tasks were presented, it was pointed out that large amounts of data had to be processed to complete the Hyrox-problem, which required the use of a spreadsheet. Experience at the modeling days with the students who chose this task indicates that few students had knowledge of calculating statistical characteristics using spreadsheets, so it can be surmised that many students did not choose this task in the first place due to a lack of knowledge. The CO_2-saving-problem has as a characteristic that it is a context that represents for many students a subject area that is also important in their free time (the modeling days took place before the restrictions due to the Corona pande-

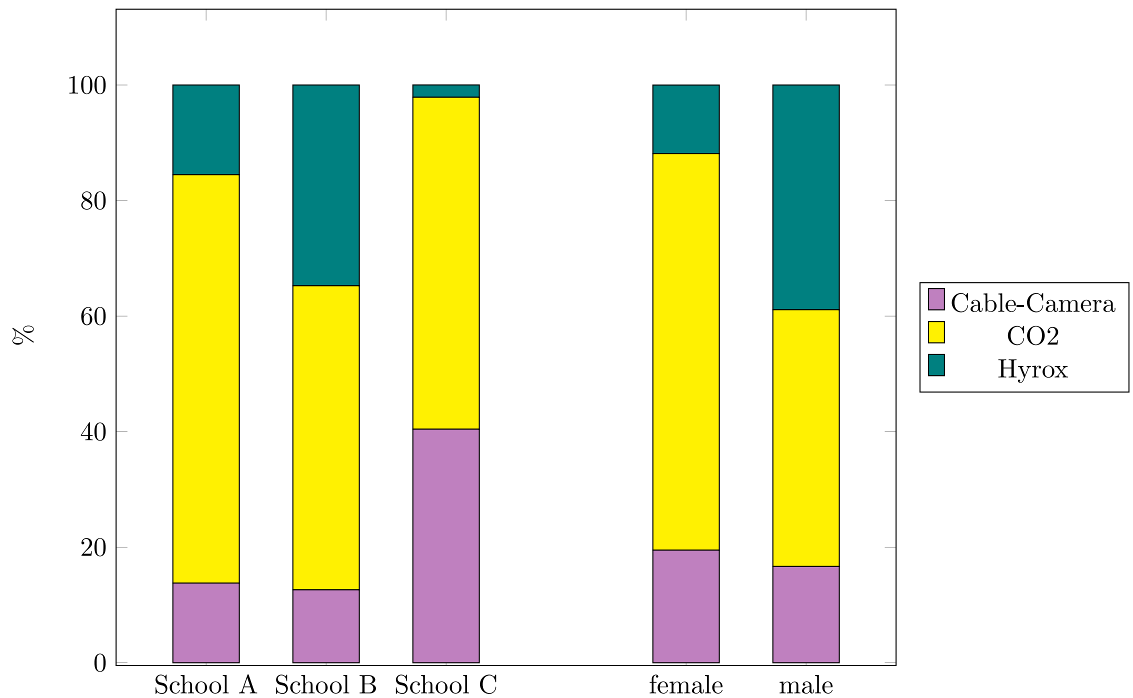
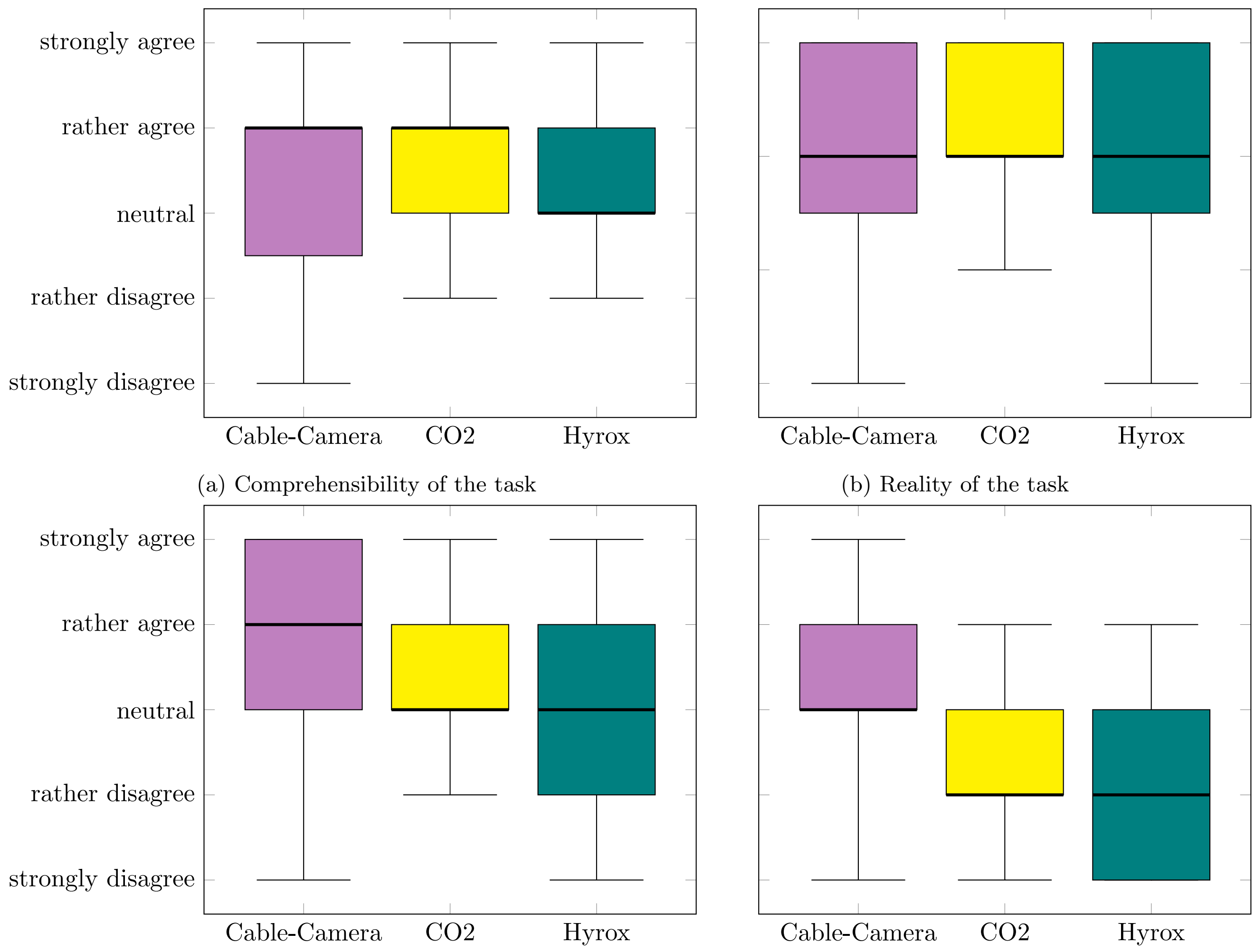


Figure 3 – Problem selection by students, divided by schools and gender

mic, when Friday-for-future demonstrations were still regularly held on Fridays). Since it is well established in the literature that female students are more likely to be engaged and enthusiastic about social issues, this could be a reason for the girls' choice of problem. In addition, students were told in advance that the Cable-Camera problem was the one with the greatest potential for further mathematical inquiry.
After working on the respective modeling problem, the students were asked how understandable, realistic, interesting and challenging they found the task they had chosen. The boxplots (Figure 4) make it clear that the students generally rated the tasks as comprehensible, with the CO_2 task and the Cable-Camera task achieving higher values than the Hyrox-problems. At the same time, it must be noted that for the Cable-Camera-problem a larger variance in terms of comprehensibility can be seen than for the CO_2-saving-problem. These results may thus offer a further explanation as to why the majority of students chose the CO_2-saving-problem.
Overall, students perceived all of the modeling problems as realistic, although the CO_2-saving-problem tended to be rated slightly more realistic here than the other two tasks. This may be due to the fact that this task has a direct connection to the city in which the students live, and the discussion about measures to save as much CO_2 as possible was very current at the time the task was completed.
However, the Cable-Camera-problem was rated particularly interesting, while the Hyrox-problem was rated very differently. The evaluation regarding the challenge of the task turned out as expected in advance: The students who worked on the Cable-Camera-problem gave it a higher value in terms of demand than the students who worked on the other two tasks with regard to their task, whereby the city bike task was still rated somewhat more demanding.

Regardless of the assessed demand, however, only a few students wished for more intensive supervision (cf. Figure 5); rather, they were apparently satisfied with the intensity of supervision.



(a) Comprehensibility of the task (b) Reality of the task

(c) Interestingness of the task (d) Problem demands

Figure 4 – Evaluation of various task properties

(a) Cable-Camera-problem (b) CO_2-saving-problem (c) Hyrox-problem

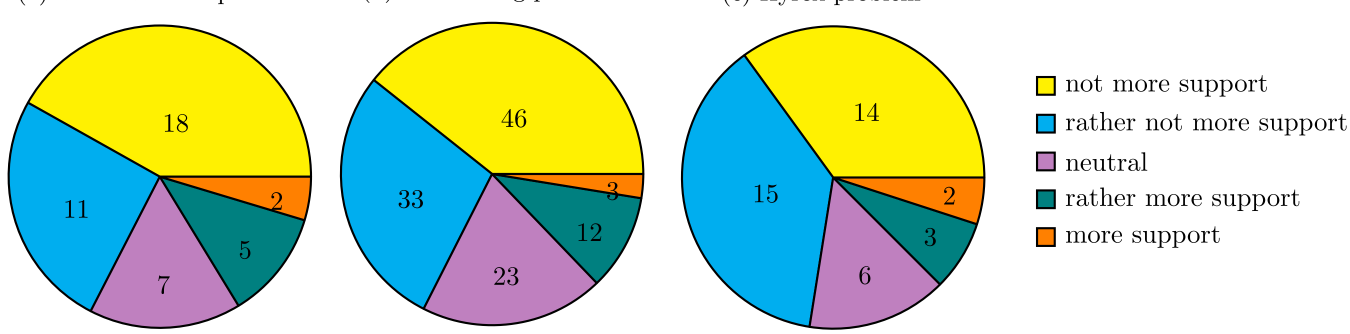


Figure 5 – Desire for more support, devided by schools.

Overall, it can be concluded that the problems were generally well received and that the freedom of choice was also well accepted. The comparison of the three tasks shows that the Cable-Camera-problem received the greatest approval from the students who had selected it in advance, while the Hyrox-problem was rated more differently by the students who had worked on it. The CO_2-saving-problem was the problem that was chosen most frequently.

Experience has shown that the students' evaluation of the entire project depends, on the one hand, on the specific task worked on and the working atmosphere in the specific small group, but also on other factors such as their general interest in mathematics and their attitude towards the modeling days in advance. A comparison of the attitudes in the run-up to the modeling days with the statement as to whether subsequent years should also carry out such a project provides an indication of the extent to which the students' attitudes toward the modeling days have changed in the course of the project implementation (cf. Tab. 1).

Table 1 – Comparison of expectations (columns) and recommendation for further modeling days (lines). The violet color indicates of in increasing positive attitude towards modeling projects, the yellow color a decreasing one.

	strongly disagree	rather disagree	neutral	rather agree	strongly agree
strongly disagree	11	1	1	3	0
rather disagree	4	6	6	6	5
neutral	1	9	21	32	18
rather agree	0	6	6	21	32
strongly agree	0	0	1	1	15

It should be emphasized that 40 % of the students tended to have a positive attitude in retrospect, while the expectations of around 14 % were not met. In the free text answers, they stated that there had been too much time available, that the tasks had not been interesting enough, and that the calculation effort had been too high. They found it positive that they could think about mathematical questions in peace and quiet, that they could research data themselves, and that they could do "mathematics in a different way".

5. Summary and Outlook

In this paper, teachers' and students' perspective on difficulties and possibilities of modeling days were presented. The aspects addressed by teachers and evaluated by students can be seen in Figure 6.

The implementation of modeling days requires a lot of engagement and time on the part of the teachers involved. Not only organizational questions such as a sufficient number of rooms and supervisors as well as the provision of technology have to be clarified, but also the development of modeling problems in particular takes time. In some cases, teachers also encounter resistance from students and staff when it is announced that two whole school days are to be blocked for working on modeling problems.[3] However, the teachers' statements presented in this article indicate that, in their eyes, the effort is worthwhile: Students not only acquire skills in applying certain mathematical procedures. They also learn to structure and work on complex problems independently and to communicate the results. At the same time, well-chosen modeling problems in the sense of natural differentiation simultaneously offer the opportunity to deepen mathematical content, and to further develop mathematical procedures independently - depending on the students' level of proficiency. The different abilities, which not only have an impact on further mathematics instruction, make it clear which learning processes can be initiated during this time, which cannot be effective in regular mathematics instruction due to the time constraints there.

[3]For ways in how teachers can be supported in this organization and at the same time make the implementation of modeling projects part of the training of prospective teachers, see Vorhölter & Freiwald (in this issue).

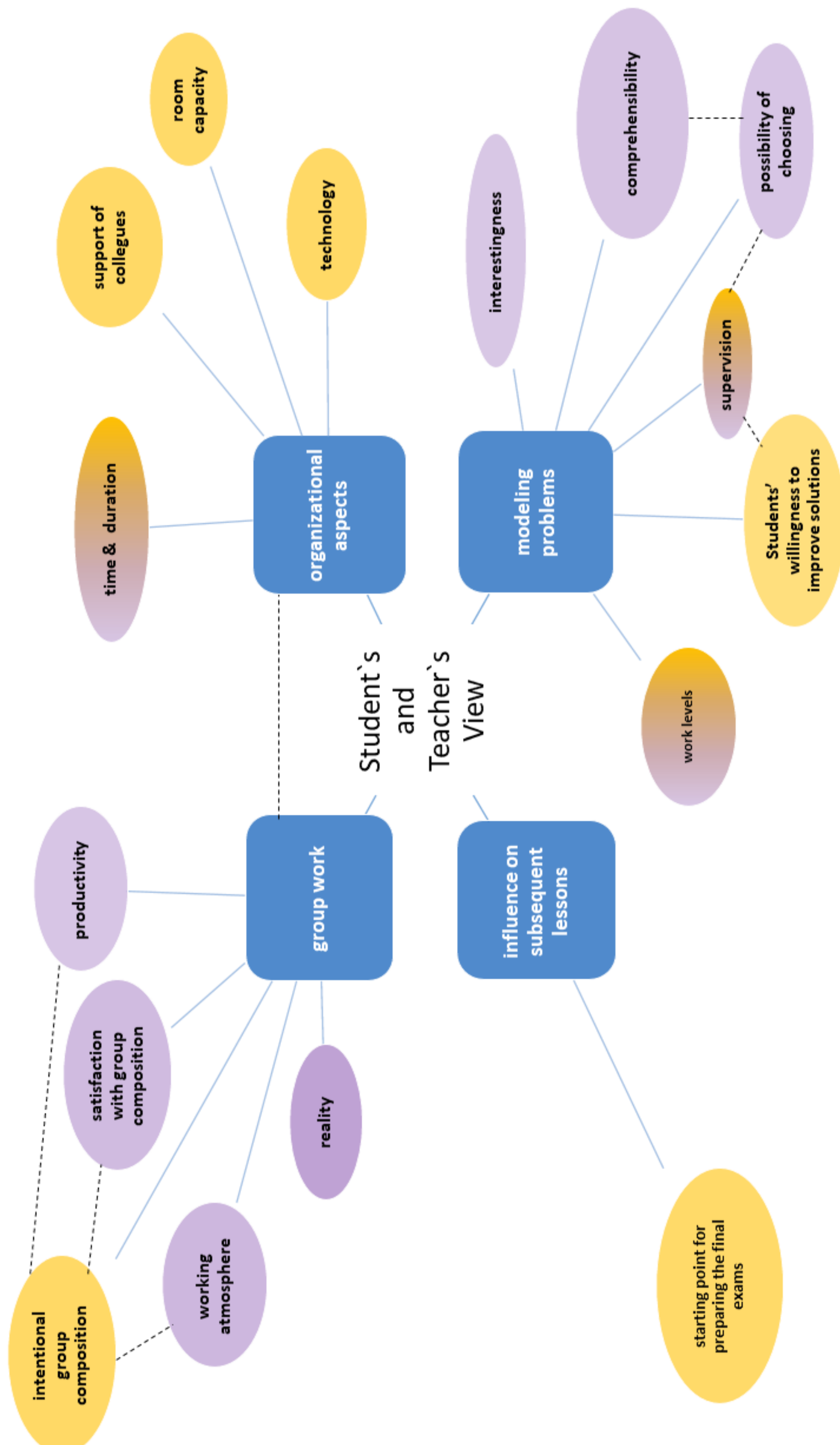


Figure 6 – Aspects mentioned by teachers (yellow) and students (purple).

For the acceptance of this challenging situation by the students, the possibility of choice regarding the problems to be worked on and the possibility of group work seem to be of decisive importance. Both aspects have an influence on the fulfillment of the Basic Needs (Ryan & Deci, 2000): The students can choose a task that is appropriate for their interests and their level of achievement and experience that they themselves are able to question mathematical representations of complex situations or even solve problems mathematically. This leads to an experience of competence and through the free choice of problems they are satisfied in their need for autonomy. Working in small groups together with adaptive help from the supervising students and teachers (cf. Vorhölter Freiwald in this volume), they can furthermore feel socially included.

Both perspectives provide evidence of the importance of such projects for students' long-term skill acquisition: teachers report mathematical and cross-cutting skills that can be used in the classroom in the long term, students report high motivation to participate in further similar projects, which will have a positive impact on skill acquisition. Structured further research that empirically proves this competence acquisition would therefore be desirable in order to convince further decision-makers of the usefulness of such projects and to be able to implement them in the long term.

References

Aebli H. (1997).
Zwölf Grundformen des Lehrens: Eine allgemeine Didaktik auf psychologischer
Grundlage Klett-Cotta (Stuttgart)

Günster St. M. and Pöhner N. and Wörler J. F. and Siller, H.St. (2021).
Mathematisches und informatisches Modellieren verbinden am Beispiel Seilkamerasystem" – im Rahmen der Würzburger Schülerprojekttage
Neue Materialien für einen realitätsbezogenen Mathematikunterricht 8. (Eds.) pp. 51–69.
Springer Spektrum (Wiesbaden)

Niss M. and Blum W. (2020).
The learning and teaching of mathematical modelling
Routledge (Abingdon, Oxon and New York, NY)

Ryan R.M. and Deci E.L. (2000).
Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being
American Psychologist 55(1) pp. 68–78 (doi:10.1037/0003-066X.55.1.68)

Schmidt B. (2011).
Modelling in the Classroom: Obstacles from the Teacher's Perspective
Trends in Teaching and Learning of Mathematical Modelling. Vol 1.
Kaiser G., Blum W., Borromeo Ferri, R. and Stillman G.A. (Eds.) pp. 641–651
Springer (Dordrecht)

Vorhölter K. and Alwast A. (2021.)
Chancen und Schwierigkeiten von Modellierungstagen aus Sicht von Lehrerinnen und Lehrern Neue Materialien für einen realitätsbezogenen Mathematikunterricht 8.
Bracke M. and Ludwig M. and Vorhölter. K. (Eds.). Springer (Wiesbaden)