Who benefits from modelling tasks combined with experiments? Effects of students' affective traits and learning situations on situational interest and feeling of competence

Quem beneficia das tarefas de modelação combinadas com experiências? Efeitos das características afetivas dos alunos e das situações de aprendizagem no interesse situacional e no sentimento de competência

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Abstract. Modelling is a key mathematical competence. However, previous research has found inconsistent results concerning students' motivation regarding modelling. One frequently discussed approach to foster students' motivation is to combine modelling tasks with scientific experiments. In this contribution, we analyse which students benefit from such tasks – in the sense of beneficial affective states like situational interest and feelings of competence – by taking into account different learning situations related to modelling tasks with and without experiment as well as students' affective traits, namely individual interest and mathematical self-concept. Our results with 82 students indicate that students' affective states do depend on both, the specific learning situation and their affective traits. Especially in the case of situational interest, an interaction of learning situation and individual interest exists: students with low individual interest in mathematics report most situational interest in conducting experiments but not in modelling their experimental data, while students with high individual interest are most interested in modelling without experiments. We discuss theoretical and practical implications of these results.
Keywords: modelling; experiments; interest; feeling of competence; affect; exponential function.

Resumo. A modelação é uma competência matemática fundamental. No entanto, investigações anteriores encontraram resultados inconsistentes relativamente à motivação dos alunos para a modelação. Uma abordagem frequentemente discutida para promover a motivação dos alunos é

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combinar tarefas de modelação com experiências científicas. Nesta contribuição, analisamos quais os alunos que beneficiam de tais tarefas - no sentido de estados afetivos benéficos como o interesse situacional e sentimentos de competência - tendo em conta diferentes situações de aprendizagem relacionadas com tarefas de modelação com e sem experimentação, bem como as características afetivas dos alunos, como o interesse individual e o autoconceito matemático. Os nossos resultados indicam que os estados afetivos dos alunos dependem tanto da situação de aprendizagem específica como das suas características afetivas. Em particular, no caso do interesse situacional, existe uma interação entre a situação de aprendizagem e o interesse individual: os alunos com baixo interesse individual pela matemática relatam maior interesse situacional na realização de experiências, mas não na modelação dos seus dados experimentais, enquanto os alunos com elevado interesse individual estão mais interessados na modelação sem experiências. Discutimos as implicações teóricas e práticas destes resultados.
Palavras-chave: modelação; experiências; interesse; sentimento de competência; afeto; função exponencial.

Introduction

It is well-known that modelling is a mathematical key competence and is relevant for a modern society (Niss, 1994). Likewise, national standards around the world (e.g., KMK, 2012; National Governors Association Center for Best Practices and Council of Chief State School Officers, 2010) as well as the PISA framework (OECD, 2017) stress the role of modelling in mathematics classes especially in secondary education. At the same time, mathematical modelling is challenging for students, in the sense to conduct modelling processes, and for teachers, in the sense to offer adequate modelling tasks to students. Beneath cognitive hurdles in the modelling process, previous studies also point to affective challenges in modelling processes. For example, students of grade nine and ten reported less interest concerning modelling tasks than concerning intra-mathematical tasks (Krug & Schukajlow, 2013). Furthermore, students' felt less capable solving modelling tasks (Krawitz & Schukajlow, 2018). As these variables play an important role in students' successful learning processes and in choosing a course or a career in STEM (science, technique, engineering, mathematics, van Tuijl et al., 2016), fostering students' interest and feelings of competence in modelling processes is an important aim.

Besides using different contexts (Schulze Elfringhoff & Schukajlow, 2021), combining modelling with (scientific) experiments can be an approach to foster interest and feeling of competence for modelling (Ludwig & Oldenburg, 2007). The assumption is that students perceive the relevance of the modelling process for themselves when they conduct this modelling process with self-measured data. In addition, the modelling process is more connected to students' real life. An important feature of these experiments is that they are hands-on experiments which need only few additional materials in classroom. This feature is important because the experiments combined with mathematical tasks should be easily implemented in mathematics lessons (cf. Zell, 2010). By this combination, a natural link between mathematics and nature sciences is established.

The purpose of this paper is twofold: First, this study gives the chance to better understand the affective variables interest and self-concept according to modelling processes. In particular, we analyse individual interest and situational interest in three different learning situations to contribute to the question in which way individual interest as a trait is related to situational interest as a state and the similar question concerning the relation of self-concept (trait) and feeling of competence (state). By answering this question in the setting of modelling, we get a better insight in which way students' interests and students' perceptions of their competences are rather object- or more situation-specific. Second, this study enables a more nuanced insight whether experiments are really suitable to foster students' interest in modelling and their feeling of competence during modelling processes. Until now, it is unclear if a high situational interest when conducting experiments maintain during the whole modelling process. Bringing together these two perspectives, we want to shed more light on which students benefit from the combination of modelling activities and experimentation in particular.

In the following, we first describe the theoretical frameworks for interest, self-concept, and modelling on which our study is based. Furthermore, we give an overview of recent research concerning students' affective variables regarding modelling as well as experimentation in mathematics lessons.

Theoretical background

We focus on students' variables which influence students' choices and the success of mathematical learning processes. The variables, which were analysed in prior studies, are diverse from more cognitive-characterised variables, such as prior knowledge or strategy use (e.g., Rellensmann et al, 2021), to more affective-characterised variables, such as perceptions of one's own competence or interest in mathematics (e.g., Krawitz & Schukajlow, 2018). In the present contribution, we concentrate on the more affective-characterised variables because they probably play an important role in mathematical learning processes and the development of affective-characterised variables is a learning aim on itself. In the following, we present the main ideas of two theoretical frameworks which conceptualize interest and feeling of competence.

Conceptualisation of interest and feeling of competence in the P-O-theory of interest and in the basic needs theory

It is frequently assumed that interest is a relevant factor for successful learning processes (not only in mathematics) because more interest goes along with more concentration, attention, and effort in the process (Krapp, 2007). In his P-O-theory of interest, Krapp (2007) defines interest as a special relation between a person and an (abstract) object. This relation comprises feeling- and value-related valences. Thus, persons experience positive emotions like joy when engaging with the object of interest and the object has a subjective high esteem for them. Moreover, the P-O-theory distinguish between interest as a state (situational interest) and interest as a trait (individual interest) (see also Hidi & Renninger, 2006).

Situational interest is a motivational state that leads to higher attention and concentration in a learning situation. This state is mainly dependent on the interestingness of a certain learning situation and is thus fluctuating and unstable within one person. Contrary, individual interest is considered to be a rather stable disposition within one person that was developed over a longer time period. Both kinds of interest are closely related (Figure 1). Persons who have developed an individual interest can show similar behaviour in a situation that falls in the area of their individual interest as persons who experience situational interest. In this case, the individual interest has induced the motivational state of a so-called actualized individual interest which is empirically difficult to distinguish from an emerging situational interest.

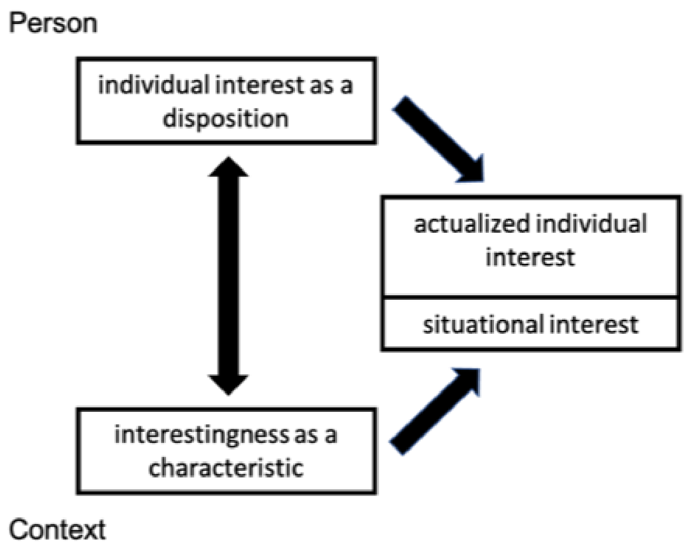

Figure 1. Relations between individual interest (trait), actualized individual interest, and situational interest (state) (following Krapp, 2007, p. 9)

Moreover, situational interest plays an important role in the development of individual interest. If persons recurrently experience situational interest in similar situations, this can lead to the development of individual interest (Hidi & Renninger, 2006). This process is mediated by fulfilment of the three basic needs: competence, autonomy, and social relatedness (Krapp, 2005; Schukajlow & Krug, 2014a). In this contribution, we concentrate on the feeling of competence because it seems to be important for interest development in different mathematical learning situations (Schulze Elfringhoff & Schukajlow, 2021).

Following Deci and Ryan (2000), feeling of competence as a basic need is relevant because persons have the need to feel successful and effective in their behaviour. Past feelings of competence stimulate the development of a high academic self-concept and high self-concept is surely a predictor of feeling of competence – a similar reciprocal relationship like situational, individual, and actualized interest. We follow Bong and Skaalvik (2003) who define self-concept as a persons' perception of his or her own abilities (in a certain domain like mathematics).

Given the reciprocal relationship between situational, individual, and actualized individual interest, fostering students' situational interest is of particular interest especially for persons who have not yet developed a well-established individual interest. Besides, the same is true for persons who have not yet developed a well-established self-concept and which can profit from situations in which they feel competence.

Modelling processes and tasks

In this contribution, the objects of interest and the situations, in which feeling of competence occur, are in the area of mathematical modelling. Mathematical modelling describes the entire process of translating a real situation or a real problem into a mathematical model that can be analysed using mathematical methods and afterwards the received mathematical results are translated back into reality. Most conceptualisations describe this process idealized as circular (e.g., Galbraith et al., 2013). We follow the framework of Blum and Leiss (2007) who propose a detailed modelling cycle with seven steps (Figure 2).

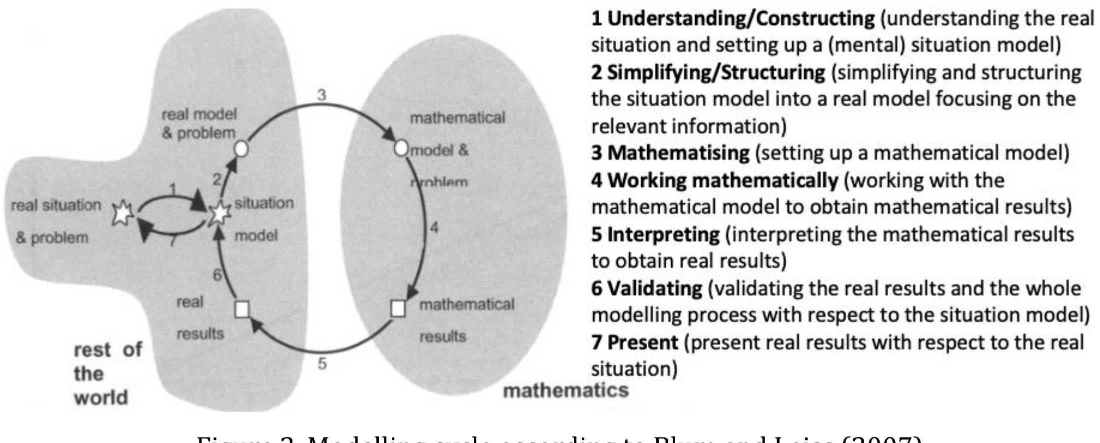

Figure 2. Modelling cycle according to Blum and Leiss (2007)

First, the real situation has to be understood, leading to the so-called situation model. The situation model is a mental representation of the real situation. As the situation model sometimes contains irrelevant information, a separation of relevant from irrelevant information is necessary. In other cases, relevant information is missing and has to be estimated or investigated. The result of this structuring process is a real model that can be translated into a mathematical model. Using intra-mathematical methods, mathematical results can be derived from the mathematical model. These mathematical results have to be interpreted in order to translate them back to real results. During the whole modelling process, decisions have to be taken that can lead to models that do not describe the real situation in an adequate or helpful way and lead to results that are not relevant or sensible with regard to the real situation. Thus, the validation of one's results, the used mathematical model as well as the whole process is necessary.

The extensive and complex transition stages between the real situation and the mathematical model distinguish real modelling tasks from other mathematics tasks like dressed-up word problems or tasks without real world connection. So called dressed-up word problems are related to a real-world context. However, this context is rather irrelevant for solving the task and can be substituted easily by another context or even completely deleted. Thus, the real and sometimes the mathematical model are accessible directly from the task, cutting of important steps of the modelling process (Krawitz & Schukajlow, 2018).

Engel (2011) distinguishes theoretical and data-driven modelling. In the first case, theoretical knowledge about the situation is used to set up and specify a mathematical model. In the latter case, data concerning the real situation is collected and the model is set up based on this data. Both, using one's existing knowledge about a phenomenon or collecting data can be successful even for the same situation. The modelling tasks used in the study reported here follow a data-driven approach.

Interest and feeling of competence regarding modelling tasks

Di Martino (2019) describes a complex relationship between modelling and motivational constructs such as interest. On the one hand, modelling is thought to foster students' motivation because real world applications can grasp students' interest and illustrate the usefulness of mathematics. On the other hand, students' motivation influences their modelling performance. Empirical results support that interest in modelling tasks is related to students' performance in these tasks (Schukajlow & Krug, 2014b). Thus, fostering interest in modelling is a sensible learning aim because a high interest is useful in learning processes and is related to students' competences in modelling. Because of the first aspect, which Di Martino (2019) mentioned, fostering interest in modelling should not be very difficult. However, previous studies reported inconsistent results concerning the relationship of motivation and mathematical modelling in general as well as especially interest and mathematical modelling. Hereby, two types of studies have to be distinguished: studies that investigate whether modelling is suitable to foster students' interest in mathematics and studies that analyse students' interest in modelling itself.

Studies of the first type usually focus on the effects of interventions on rather stable motivational constructs like individual interest. In these interventions, students work on mathematical modelling tasks. Bednorz et al. (2021) provide information about a modelling intervention that led to a decrease of students' interest in mathematics. In contrast, Parhizgar and Liljedahl (2019) report positive effects of a modelling intervention for students who were not experienced with modelling before. After the intervention, students showed more positive affective variables towards mathematics in general as well as a higher engagement in modelling tasks than before. Though, their engagement in intra-mathematical tasks and dressed-up word problems increased, too. Thus, it is not clear if the intervention has specific effects on engagement in modelling tasks or if the students are more engaged in solving problems at all. Schukajlow and Krug (2014a) used an intervention in which students were prompted to search for multiple solutions for modelling problems. This intervention led to a higher interest in mathematics and the effect was mediated by students' feeling of competence during the intervention. This study shows that interest in mathematics and feeling of competence are interrelated when working on modelling problems.

Studies of the second type usually include more situated motivational variables and compare different kinds of tasks. Schukajlow et al. (2012) found no differences concerning students' interest, value, and enjoyment between modelling tasks, dressed-up word problems, and intra-mathematical tasks. Moreover, students were similar confident to be able to solve the three kinds of tasks. In contrast, Krug and Schukajlow (2013) found that students were less interested in modelling tasks than in intra-mathematical tasks and dressed-up word problems. In line with this result, Krawitz and Schukajlow (2018) found that students valued modelling tasks less than other tasks and were less confident to be able to solve them. Summing up, the studies show that in contrast to the theoretical-based expectations, students do not show more interest in modelling tasks than in other mathematical tasks. Thus, students' interest in mathematics cannot be easily increased by involving modelling tasks in the learning process. Given, that modelling is a key mathematical competence (e.g., KMK, 2012; OECD, 2017), students' lack of interest and feeling of competence seems problematic.

Recent studies took into account different characteristics of modelling tasks such as the mathematical content and the real-world context to explain students' interest. With regard to the mathematical content, Krawitz and Schukajlow (2018) report that students value modelling problems that belong to the area of linear functions higher than those covering the Pythagorean theorem. Furthermore, emotions related to the real-world-context as well as students' feeling of competence influenced situational interest in modelling problems (Schulze Elfringhoff & Schukajlow, 2021).

Interest and feeling of competence regarding experimentation and regarding combining modelling with experimentation

One often discussed approach to foster students' interest in mathematics in general and for modelling in particular is to combine experiments with modelling tasks. In these kinds of tasks, students first conduct an experiment and thereby gather data that are used in a subsequent modelling process. According to Halverscheid (2008, p. 226), modelling and experiments are naturally linked because experiments "represent the 'rest of the world', for which models are built". Conducting an experiment represents the first two steps in the modelling cycle (see Figure 2, cf. Geisler, accepted). If the instruction for the experiment is given to students, these two steps are much easier to perform than in regular modelling tasks. After working mathematically (steps 3-4), the students transfer their mathematically generated results in the rest of the world and connect it to the conducted experiment. Ludwig and Oldenburg (2007) go even further and argue that combining modelling with experimentation is valuable because experiments tie the whole modelling process to students' real-life experiences. Thus, experiments and modelling tasks fit well together.

Studies from nature science lessons have repeatedly shown that experiments can foster students' interest in nature science (e.g., Guderian & Priemer, 2008; Ochsen et al., 2021). Moreover, there is some evidence that students are also interested in experiments in mathematics lessons. Ganter (2013) reported that students' interest in working on experiments concerning functional thinking increased whereas the interest of the control groups without experiments or with demonstration of the experiments was not fostered. Moreover, students' mathematical self-efficacy increased when working on experiments.

In a study by Beumann (2016), students reported a high situational interest as well as feelings of competence regarding modelling tasks with experiments from different domains such as geometry and stochastics. Moreover, modelling tasks with experiments are experienced as especially credible (Carreira & Baioa, 2018). However, Beumann (2016) as well as Carreira and Baioa (2018) used no control group in their studies. To analyse whether modelling tasks with experiments are indeed more interesting for students than traditional modelling tasks, Geisler and Rach (in press) compared students' situational interest in both kinds of tasks. Students reported more situational interest concerning modelling with experiments than concerning traditional modelling tasks. As students reported their situational interest after working on the whole task, it is an open question if the interest is also attributed to the modelling part after experimenting or only to the conduction of the experiments.

The current study

Research questions

In this study, we analyse students' affective variables in three different learning situations: *i) conduction of experiments*, subsequent *ii) modelling with one's own experimental data* and traditional *iii) modelling with given data* – the first two situations together constitute modelling combined with experimentation and the last situation is modelling without experimentation. The purpose of the current study is twofold: first, we want to contribute to the question in which way individual interest as a trait is related to situational interest as a state and the similar question concerning the relation of self-concept (trait) and feeling of competence (state). By answering this question in the setting of modelling, we get a better insight in which way students' interests and students' perceptions of their competences are rather object- or more situation-specific. Second, we want to analyse if combining modelling tasks with experimentation leads to higher situational interest and feelings of competence. Until now, it is unclear if a high situational interest in the experimental part of the task (learning situation i), which was observed in previous studies (e. g., Ganter, 2013), impacts students' perceptions of the subsequent modelling part of the task (learning situation ii) as well.

Moreover, we are interested in which way individual interest in mathematics and mathematical self-concept have an impact on the relation between situational interest, feeling of competence, and the aforementioned learning situation. These possible relations can inform us which students benefit more from combining modelling with experimentation. In particular, we want to answer the following research questions (see also Figure 3):

Relations between students' situational interest, feeling of competence, and students' traits

1. In which way are students' situational interest and feeling of competence in the aforementioned learning situations related to students' individual interest in mathematics and experiments as well as mathematical self-concept?

   According to Krapp (2007), students' interest in a learning situation can be triggered by the situation itself or induced by their individual interest. Because of the latter aspect, we expect that students' individual interest in experiments will be positively related to their situational interest concerning *conduction of experiments* (H1) whereas the individual interest in mathematics goes along with situational interest in *modelling with experimental data* and *modelling without experiments* (H2). Furthermore, students' mathematical self-concept will be positively related to feelings of competence regarding *modelling with experimentation* and *modelling without experimentation* (H3). We do not have clear hypotheses concerning the other relations.

Differences in students' situational interest and feeling of competence

2. Are there differences in students' situational interest and feeling of competence between the aforementioned learning situations?

   Based on the results of previous studies, we expect that students will report higher situational interest and feelings of competence regarding *modelling with experimental data* than regarding *modelling without experiments* (H4). We do not have clear hypotheses concerning conducting experiments.

3. Are differences in the situational interest and feelings of competence in the aforementioned learning situations depended on students' individual interest in mathematics, individual interest in experimentation or mathematical self-concept?

   This last question is rather explorative and seeks to analyse which students benefit from which learning situation. Likewise, no special hypotheses have been formulated.

This study is part of a larger project. Other results will be published in Geisler and Rach (in press).

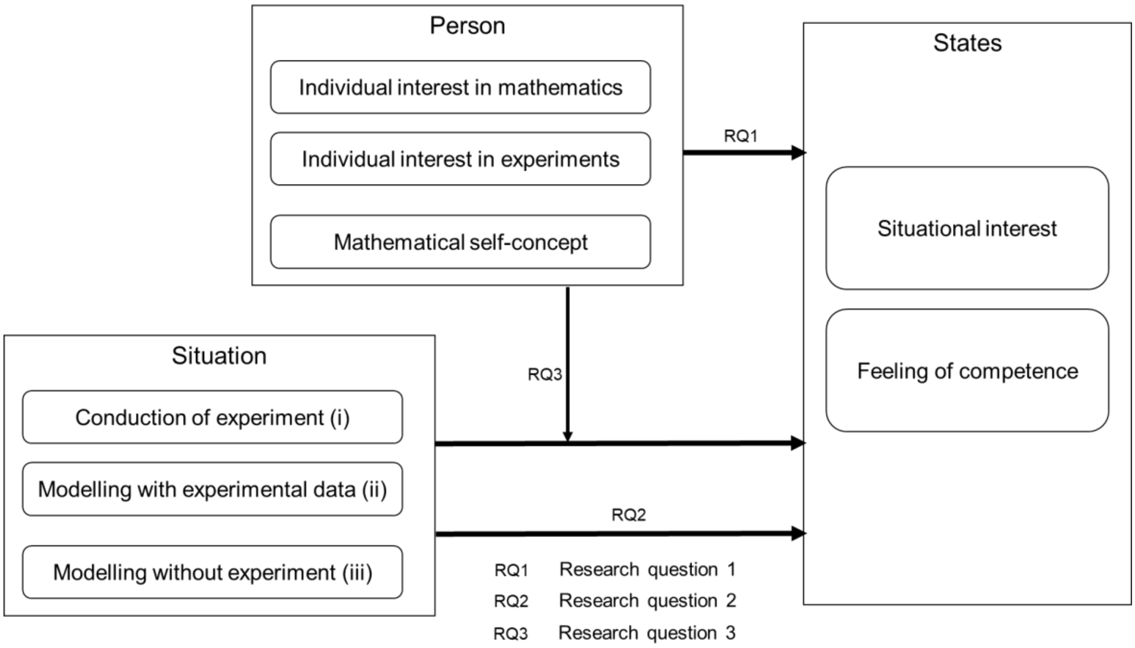

Figure 3. Visualisation of research questions

Methods

Sample

In the study, 82 tenth grade students (M(age)=16, 51% girls) from three German grammar schools (Gymnasium) voluntarily participated. All students worked on one modelling task combined with experimentation (learning situations i) and ii)) and on one modelling task without experimentation (learning situation iii). These tasks and the concrete design of the study are described in more detail in the following sections. The tasks involved working with exponential functions. Students were familiar with exponential functions and their typical characteristics from prior lessons. However, exponential functions were not the actual topic of the mathematics course at the time the study took place.

Used modelling tasks

Two modelling tasks ("cold coffee" and "stale beer") have been used in the study. The contexts of the tasks are from everyday life (see Habig et al., 2018; Schulze Elfringhoff & Schukajlow, 2021) and are well-known for students. Most of the students were able to model the situation mathematically with exponential functions. For both modelling tasks, a version with experiment and a version without experiment exist. Both versions of the modelling tasks begin with a short description of the context and an overall goal of the task. The following example illustrates the context of the "cold coffee" task:

> After brewing, coffee needs some time to cool off in order to be conveniently drinkable. The desired drinking temperature differs from person to person. Model the temperature decrease and evaluate at which time the coffee can be delightfully drunken.

In the version with experiments, students are asked to state a hypothesis concerning the decrease of temperature and to perform an experiment to gather data afterwards:

> Set up a hypothesis how the temperature of the tea changes with the time.

An experiment description is offered in the task. In contrast, in the version without experiment, a table with data was given to the students. In both versions, students are asked to set up a function describing the data.

> Determine a function which describe the decrease of temperature and represent this function with GeoGebra.

Students were provided with GeoGebra applets to support their modelling process (https://www.geogebra.org/m/vvxvdzpj; https://www.geogebra.org/m/kbqnd7rf). Afterwards they should reflect whether the function fits well to the data and if the fit between data and function can be increased:

> Compare the function with the data and answer two questions:
>
> 1. Does the function fit to the data?
>
> 2. (In which way) can you improve your model?

Noticeable is that the experiments for both modelling tasks are hands-on experiments which do not need much additional material or time and can be conducted in regular mathematics classroom. For conducting the Cold-Coffee experiment, a kettle, a beaker, a thermometer, a ruler, and water are needed. For conducting the Stale-Beer-experiment, a measuring cylinder, a ruler, a timer, and (alcohol-free) bear are needed.

Design and Instruments

The study took place during a regular 90 minutes lesson. At the beginning of the lesson, students filled out a questionnaire concerning their individual interest in mathematics (8 items, e.g., "I like mathematics.") and in experimentation (3 items, e.g., "I like to do experiments in my free time as well.") as well as their mathematical self-concept (4 items, e.g., "I am good in mathematics."). All items were answered on a six-point likert scale (1 = totally disagree, 6 = totally agree). Furthermore, demographic data were collected.

All students worked on one modelling task without experiment (learning situation iii) and one modelling task with experiment (learning situations i) and ii)). The order of the two contexts (Cold Coffee and Stale Beer) as well as the two conditions (with experiment and without experiment) were systematically varied, resulting in two*two=four subgroups, as can be seen in Figure 4. For every context and condition, the students worked in pairs on the tasks and every student wrote the solution on his or her work sheet. For practical issues, classes were split and randomly assigned to two version which leads to 20 to 21 students per version. After each learning situation, students answered a short questionnaire concerning their situational interest (4 items, e.g., "I liked conducting this experiment") and feeling of competence (3 items, e.g., "I had the feeling that I could analyse the data on my own"). The formulation of the items uses the same structure in the three learning situations and the items differ only between the learning situations i) and ii) and between i) and iii) with regard to the specific learning situation. All items were answered on a six-point likert scale (1 = totally disagree, 6 = totally agree). Table 1 gives an overview of the used instruments.

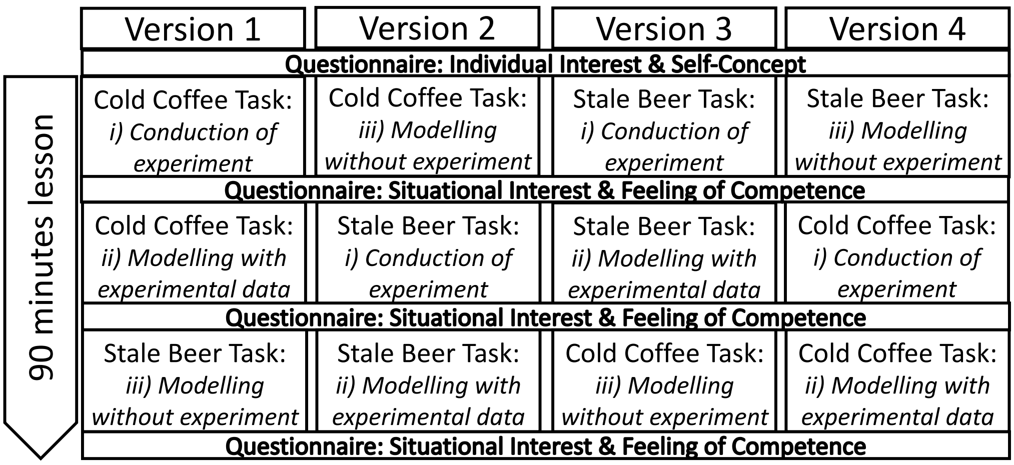

Figure 4. Design of the study

Table 1. Overview of used instruments

Variable	Source	# Items	α	Example Item
Individual Interest Mathematics	Rakoczy et al., 2005	8	.92	I like mathematics.
Individual Interest Experiments	Ganter, 2013	3	.67	I like to do experiments in my free time as well.
Mathematical Self-Concept	Arens et al., 2011	4	.94	I am good in mathematics.
Situational Interest	Adapted from Willems (2011)	4	.85 - .89	I liked conducting this experiment.
Feeling of Competence	Adapted from Willems (2011)	3	.77 - .91	I had the feeling that I could analyse the data on my own.

Analysis strategy

We used quantitative analysis methods to answer the research questions and conduct the analyses in SPSS 27. To answer question 1, correlations between different affective variables were calculated. To answer question 2, we applied repeated measures Analyses of Variance (ANOVAs) with the dependent variables "situational interest" and "feeling of competence" and the three-level factor "learning situation". To answer question 3, we split the sample in three groups according to their individual interest in mathematics, in experiments or their mathematical self-concept: high, medium, and low. We added these grouping variables to the mentioned ANOVAs.

Results

The descriptive data concerning the different scales can be found in Table 2. As assumed, students report medium to high situational interest and feelings of competence in conducting the experiment.

Relations between students' situational interest, feeling of competence, and students' traits

To answer research question 1), we used correlation analyses. The results can be found in Table 2. As expected, students' individual interest in experiments is positively related to their situational interest in conducting experiments (situation i) with a middle effect size (H1). The individual interest in mathematics goes along with more situational interest in both modelling situations (ii and iii) with a middle to high effect size, confirming our hypothesis (H2). Moreover, students' mathematical self-concept is positively related on a middle to high level to the feeling of competence when modelling one's own mathematical data (ii) and when modeling without experiments (iii). Therefore, our data also support H3.

Table 2. Descriptive results and correlations (significant correlations are printed in bold)

		M (SD)	IM	IE	SM	SIi	SIii	SIiii	FCi	FCii
Trait	Individual Interest Mathematics (IM)	3.38 (1.22)	-							
	Individual Interest Experiments (IE)	3.25 (1.13)	-.03	-						
	Self-Concept Mathematics (SM)	3.40 (1.51)	**.77****	-.21	-					
Situational Interest	Situational Interest Conduction of Experiments (SIi)	3.78 (1.14)	.11	**.31****	.02	-				
	Situational Interest Modelling with experimental Data (SIii)	3.46 (1.24)	**.38****	.20	**.30***	**.52****	-			
	Situational Interest Modelling without Experiment (SIiii)	3.73 (1.26)	**.44***	.22	**.30***	**.43****	**.74****	-		
Feeling of competence	Feeling of Competence Conduction of Experiments (FCi)	5.17 (0.98)	.20	-.04	.14	.13	.22	.10	-	
	Feeling of Competence Modelling with experimental Data (FCii)	4.05 (1.58)	**.32****	-.02	**.37****	-.13	**.40***	**.26***	**.46****	-
	Feeling of Competence Modelling without Experiment (FCiii)	4.12 (1.46)	**.44****	-.05	**.39****	**.25***	**.57****	**.57***	.17	**.42****

N = 82, answers between *1 = totally disagree* and *6 = totally agree*, **p* < .05 ***p* < .01

The data also give hints that mathematical self-concept is not related to student's feeling of competence or situational interest in conducting experiments (i) but is positive correlated with situational interest in both modelling situations (ii and iii). As the corresponding trait variables and state variables are related from medium to high to each other, students' affective states are not only situation specific but depend to a considerable degree on the corresponding object, the specific affective trait.

Differences in students' situational interest and feeling of competence

To answer research question 2 and to identify general differences in students' situational interest and feeling of competence, repeated measures ANOVAs were applied. The Huynh-Feldt correction was used in the case of situational interest because the assumption of sphericity was violated by the data. Students reported similar high situational interest in conducting experiments (learning situation i) and modelling without experiments (learning situation iii). Surprisingly, students report slightly less situational interest in modelling with their own experimental data (learning situation ii) but the difference between the learning situations is not significant (Huynh-Feldt $F(1.74, 102.53) = 2.19$, $p > .10$, $\eta^2 = .04$). Students felt similarly competent in both modelling situations but reported clearly more feeling of competence when conducting experiments ($F(2, 118) = 20.05$, $p < .001$, $\eta^2 = .25$).

Answering research question 3, mixed ANOVAs with students' individual interest in mathematics and experiments or mathematical self-concept as between factors were used. Therefore, students were split in three groups according to their trait affect. To analyze the situational interest data, students were first split according to their individual interest in mathematics resulting in the following three groups: low individual interest ($1.0 <$ mean value ≤ 2.5), middle individual interest ($2.5 <$ mean value < 4.5), and high individual interest ($4.5 \leq$ mean value < 6.0). The mixed ANOVA revealed a significant interaction between individual interest in mathematics and learning situation (Huynh-Feldt $F(3.53, 89.70) = 2.19$, $p < .001$, $\eta^2 = .16$) while the main effects of individual interest in mathematics ($F(2, 56) = 2.79$, $p > .05$, $\eta^2 = .09$) and learning situation (Huynh-Feldt $F(1.76, 89.70) = 3.15$, $p > .05$, $\eta^2 = .05$) are not significant. As can be seen in Figure 5, the different groups of students with different interest in mathematics do not differ concerning their situational interest in conducting experiments (i) but there are clear differences in their situational interest in both modelling situations (ii and iii). Students with high individual interest in mathematics report the lowest situational interest in conducting experiments (i) and clearly more interest in modelling with experimental data (ii). They show the most situational interest in modelling without experiments (iii). In contrast, students with low individual interest in mathematics are most interested in conducting experiments (i) and report less situational interest in both modelling situations.

Second, students were split according to their individual interest in experiments, in a similar way. No significant interaction between individual interest in experiments and the learning situations could be found using a mixed ANOVA (Huynh-Feldt $F(3.29, 92.22) = 0.71$, $p > .50$, $\eta^2 = .03$). While there was also no significant main effect of the learning situation (Huynh-Feldt $F(1.65, 92.22) = 3.08$, $p > .05$, $\eta^2 = .05$), a clearly significant main effect of the individual interest in experiments was detected ($F(2, 56) = 5.20$, $p < .01$, $\eta^2 = .16$). Indeed, Figure 6 shows that students with high and medium individual interest in experiments report clearly more situational interest for conducting experiments (i) than students with low individual interest in experiments. However, this last group of students also reports the least situational interest for the subsequent modelling with their experimental data (ii) as well as the modelling without experiments (iii).

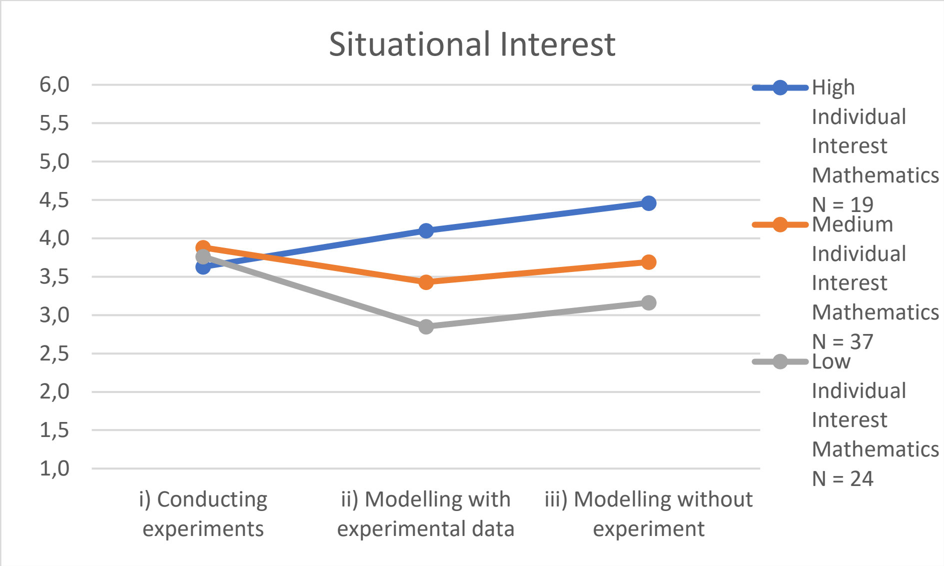

Figure 5. Situational interest patterns of student groups with different individual interest in mathematics patterns (ratings from *1 = totally disagree* to *6 = totally agree*)

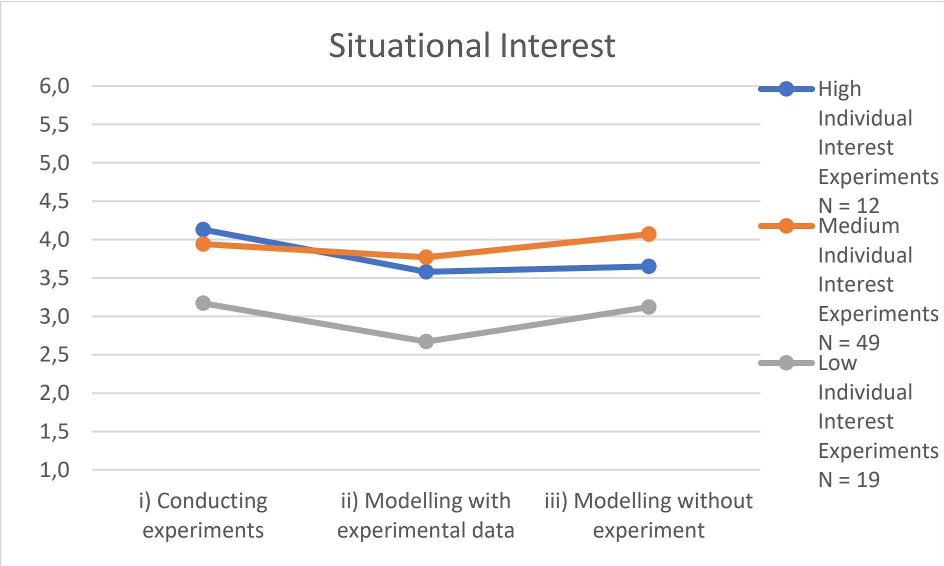

Figure 6. Situational interest patterns of student groups with different individual interest in experiments patterns (ratings from *1 = totally disagree* to *6 = totally agree*)

In a similar way, students were grouped according to their mathematical self-concept to analyze the feelings of competence, resulting in three groups: low self-concept (1.0 < mean value ≤2.5), middle self-concept (2.5 < mean value < 4.5), and high self-concept (4.5 ≤ mean value ≤6.0). The mixed ANOVA revealed no significant interaction between self-concept and learning situation ($F(4, 112) = 1.11$, $p > .10$, $\eta^2 = .04$) while the main effects of learning situation ($F(1, 112) = 19.50$, $p < .001$, $\eta^2 = .26$) and self-concept ($F(2, 96) = 4.62$, $p < .05$, $\eta^2 = .14$) are both significant. Indeed, Figure 7 shows similar patterns of feeling of competence in all three groups. Students in all groups report the highest feelings of competence when conducting experiments (i). Moreover, the differences between the groups are only small in this situation. Students with high mathematical self-concept report similar high feelings of competence in both modelling situations (ii and iii) while students with low self-concept seem to report even lower feelings of competence when modelling with their own experimental data (ii) than when modelling without experiments (iii).

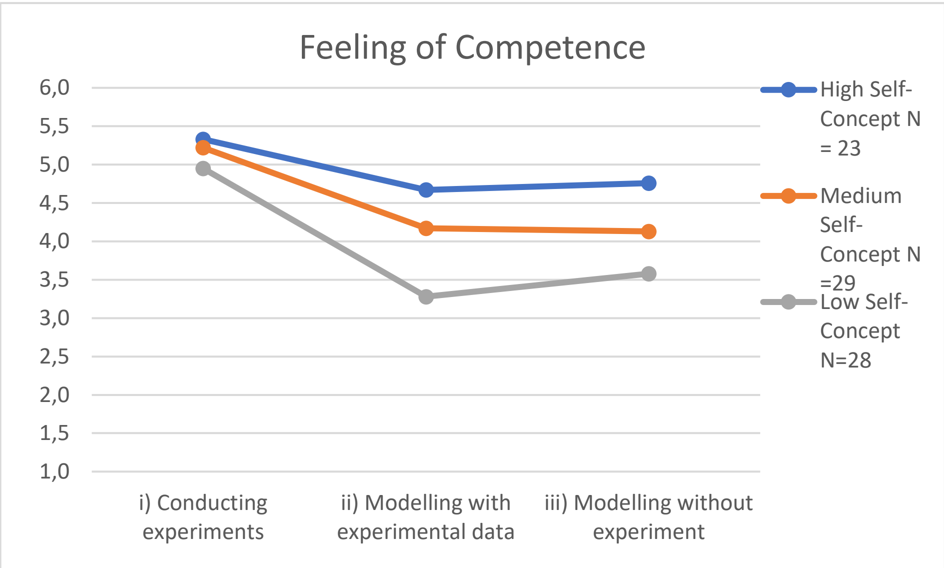

Figure 7. Feeling of competence patterns of student groups with different mathematical self-concept (ratings from *1 = totally disagree* to *6 = totally agree*)

Discussion

Summary

The purpose of this study was to enable a more nuanced insight in students' situational interest and feeling of competence. First, we want to analyze whether interest and perceptions of one's competences are rather object specific and thus mainly related to students' affective traits or more situation specific and thus mainly related to the characteristics of the learning situation. Second, we want to investigate whether conducting hands-on experiments influences students' situational interest and feeling of competence for the modelling part of a modelling tasks. Moreover, we bring these two aspects together by analyzing in which way individual interest in mathematics as well as in experiments and mathematical self-concept (traits) influence the relation between the different learning situations and students' situational interest or feeling of competence (states).

Concerning the first aspect, we found substantial correlations between individual interest in mathematics and situational interest in both modelling situations. Moreover, individual interest in experiments was only positive related with situational interest in conducting experiments. Contrary to that, individual interest in mathematics does not seem to be related to situational interest in conducting the experiment. Mathematical self-concept is related to feelings of competence in both modelling situations whereas it does not seem to be related to feelings of competence when conducting the experiment. These results strengthened the theoretical framework of Krapp (2007): the results indicate that interest is specific to certain objects and that individual interest as a trait becomes visible in learning situations as the state of actualized interest (cf. Figure 1). Moreover, students' mathematical self-concept as a trait affects the state feeling of competence in mathematical learning situations. Thus, the affective variables concerning experiments do not relate to the affective variables concerning mathematics which point to the assumption that students distinguish between the objects experiments and mathematics when rating their interest and self-concept. One reason could be that these two objects seldom appear together in mathematics classroom, because experiments are only seldom used in mathematics.

Concerning the second aspect, we analyze differences of situational interest and feeling of competence according to the three learning situations. The idea for expecting a higher situational interest in modelling tasks with experiments than in modelling tasks without experiments is based on previous research that has reported positive affective variables regarding modelling with experiments among students (e.g., Beumann, 2016; Carreira & Baioa, 2018). In our own previous research, we even found hints that students are more interested in modelling with experiments than in "traditional" modelling tasks without experiments (Geisler and Rach, in press). However, in the study at hand, we cannot confirm these results in general. In the whole sample, students seem to be more interested in modelling without experiments (iii) than in modelling with their own experimental data (ii). These results might be explained when taking into account students' feeling of competence in the learning situations. Students reported high feelings of competence when conducting the experiments but considerably less feelings of competence during both modelling situations. According to Schulze-Elfringhoff and Schukajlow (2021), students' situational interest in modelling depends on their feelings of competence and modelling with experimental data could be more challenging because students have to deal with measurement errors. However, as in the whole sample students do not report significantly less feelings of competence for the modelling with their own experimental data compared to modelling without experiments, students' feelings of competence cannot alone explain the whole differences in the situational interest. Another explanation can be found when having in mind that students seldom validate their modelling process (Blum & Leiss, 2007). For validating the modelling process, considering all steps of the modelling process is necessary (Czocher, 2018) so that students have to include the experiment when validating the process. If the students would include the experiment in their considerations, it is likely that situational interest which occur when conducting the experiment is transferred to the mathematical part of the modelling process because these two parts of the modelling process are interconnected. As we cannot support the hypothesis that students' interest in modelling with their own experimental data is higher than their interest in modelling without experiments, such a transfer of interest is not supported by the data and thus, the students do not seem to use experiments to validate their modelling process.

Combining these two aspects, we divided the students in three profiles which are characterized by the level of individual interest in mathematics or mathematical self-concept: low, middle, and high. Students with a high interest in mathematics reported a substantial higher interest in the modelling situations than in conducting experiments. Thus, we assume that their individual interest in mathematics induced actualized individual interest during the modelling activity. However, when conducting experiments, individual interest in mathematics seems not to have a clear effect on students' states. Moreover, the learning situation seems not to induce a high situational interest as well.

Students who showed low interest in mathematics reported most situational interest in conducting experiments (i) but less situational interest in both modelling situations (ii and iii), in particular in the modelling situation with their own experimental data. It seems that experiments induce situational interest for these students but the interest is not maintained during the subsequent modelling process. One reason for the result concerning students with low interest in mathematics is that after being attracted by the experiments, students' expectations could be frustrated because the subsequent modelling is again "just mathematics". Moreover, as aforementioned modelling with experimental data is more challenging due to measurement error and alike. So, students could be less confident to solve the task which could negatively impact their situational interest (cf. Schulze Elfringhoff & Schukajlow, 2021). This assumption is supported by the results concerning students' feelings of competence in the different learning situations. The result of the corresponding analysis is not significant but the descriptive data gives hints that students with a low mathematical self-concept show lower feeling of competence when modelling with their own experimental data comparing to modelling with given data.

Limitations and strength

Limitations of our study lie in the general design as well as in the used modelling tasks. We did not use a classical control-group design. Instead, all students worked on one modelling task with and one without experiment. We varied condition and context systematically to avoid effects of the order. Moreover, since it was only a short intervention in a 90 minutes lesson and we did not use a post-test, we have no information on the development of students' individual interest and self-concept after the intervention. Another limitation is that situational interest and actualized individual interest have different origins but manifest themselves in the same behavior. Thus, empirically both constructs are not easy to distinguish and it is not always clear whether one measures the one or the other.

The tasks used in this study both covered the topic of exponential function. Thus, it is possible that modelling tasks from other mathematical domains or other kinds of experiments, e. g., simulations in the field of stochastic, or contexts, e. g., not everyday relatedness but concerning special phenomena (see Habig et al., 2018), lead to different results. Thus, more research on different experiments in different mathematical domains is necessary.

However, a clear strength of our study is that we did not only compare modelling with and without experiments but differentiated also between the conduction of the experiments and the subsequent modelling with one's own experimental data. Moreover, we linked students' situational interest and feeling of competence to other student characteristics which enabled a more detailed analysis which students profit from which modelling tasks.

Implications and outlook

Given the fact that many students are less interested in modelling tasks than in other mathematical tasks (e.g., Krawitz & Schukajlow, 2018) and that modelling is an essential mathematical competence, fostering students' interest for modelling is an important educational aim. In our study, especially students with a low interest in mathematics were interested in conducting the experiments and felt clearly more competent than in the modelling situations. Therefore, using experiments could be a way to grasp low interested students' attention in mathematics lessons. Because the results indicate that students perceive experiments and mathematics as two separate objects, it is important that experiments are more included in mathematics classrooms. Then, students perceive the experiment as a natural part of the modelling tasks which has to be checked when reflecting the whole process, thus more validating activities may occur.

However, it is still an open question how the situational interest in conducting the experiment can be maintained during the whole subsequent modelling process as well. Because situational interest seems closely related to feeling of competence (see also Schulze Elfringhoff & Schukajlow, 2021), a possible way to keep the grasped interest high would be more competence support during the subsequent modelling process. In a follow-up study, we test whether written instructions that support students in critical phases of the modelling process can help to maintain their initial situational interest. Moreover, we will analyze whether different experiments have different effects on students' situational interest for the subsequent modelling activities.

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