Educational Studies in Mathematics (2023) 112:359–381
https://doi.org/10.1007/s10649-022-10198-6

The relation between attitudes towards mathematics and dropout from university mathematics—the mediating role of satisfaction and achievement

Sebastian Geisler[1] · Stefanie Rach[2] · Katrin Rolka[3]

Accepted: 30 October 2022 / Published online: 4 January 2023

Abstract

The transition from school to university mathematics is a challenging process for many students, which is reflected in high dropout rates during the first year at university. Using mediation analysis, we want to shed light on the role of students' attitudes towards mathematics—especially their interest in mathematics and their mathematical self-concept—for early dropout and investigate the underlying mechanisms for the relations between attitudes and dropout. Informed by frameworks of person-environment-fit and results from educational psychology, we consider satisfaction with one's studies and achievement as potential mediators, influencing the relations between attitudes and early dropout. Our results within a sample of 274 first-year students, enrolled in a pure mathematics or a teacher education program at a German university, show that interest in university mathematics and mathematical self-concept are associated with less risk to drop out. In the case of interest, this relation is mediated by students' satisfaction, and in the case of self-concept, this relation is mediated by satisfaction and achievement. Based on these results, we discuss how to support students during the transition from school to university mathematics in order to prevent early dropout.

Keywords Transition from school to university mathematics · Attitudes · Satisfaction · Achievement · Dropout · Person-environment-fit

Many students struggle during the transition from school to university mathematics. This fact is revealed by high dropout rates in many countries (e.g., Chen, 2013). In Germany,

✉ Sebastian Geisler
Sebastian.Geisler@uni-potsdam.de

Stefanie Rach
Stefanie.Rach@ovgu.de

Katrin Rolka
Katrin.Rolka@rub.de

1 University of Potsdam, Karl-Liebknecht-Str. 24-25, D-14476 Potsdam, Germany

2 Otto-Von-Guericke-University Magdeburg, Universitätsplatz 2, D-39106 Magdeburg, Germany

3 Ruhr University Bochum, D-44780 Bochum, Germany

where our study took place, up to 80% of the mathematics students give up their studies and leave university or change their subject, half of them during the first year at university (Dieter & Törner, 2012)—so called early dropout. These high numbers illustrate the individual and social relevance of this phenomenon and justify the need of knowing reasons to drop out. According to Artigue (2016), previous research concerning the transition from school to university mathematics mainly focused on cognitive variables and processes (overview in Ulriksen et al., 2010). These studies, which often use a longitudinal design and a quantitative approach, have shown that cognitive variables have an important impact on a successful transition (e.g., Halverscheid & Pustelnik, 2013; Rach & Heinze, 2017). As the variance in indicators of dropout is not totally explained by cognitive variables, these variables alone cannot explain why some students succeed during the transition while others decide to drop out (Rach & Ufer, 2020).

In order to better understand students' decisions to drop out, recent studies also considered affective variables—such as students' attitudes (e.g., Di Martino & Gregorio, 2019; Martínez-Sierra & García-González, 2016). However, many studies used students' dropout intention instead of actual dropout (e.g., Fellenberg & Hannover, 2006; Höhne & Zander, 2019; Schnettler et al., 2020) and these studies concerning dropout intention naturally provide valuable insights, but it remains uncertain to what extent these results can be transferred to actual dropout (cf. Sarcletti & Müller, 2011). Therefore, we want to extend the aforementioned studies by relating students' attitudes, in particular their interest and self-concept, with actual dropout from mathematics study programs in the first year.

To enhance our theoretical understanding of the dropout phenomenon and to deepen our understanding in which way interest and self-concept have an effect on dropout, we also want to analyse underlying mechanisms of these relations. Informed by frameworks of person-environment-fit that propose the fit between characteristics of persons and of the environment as the key for a successful transition, we use mediation analysis to better understand the mechanisms of the relations between attitudes and dropout. A clearer picture of these mechanisms might also help mathematics instructors to support students who are at risk to drop out.

In the following, we give a brief overview about frameworks of person-environment-fit before discussing characteristics of mathematics programs at university and the role of students' attitudes during the transition, mainly from educational psychology and mathematics education. This theoretical background sets the frame for our quantitative study which is based on longitudinal data from 274 first-year students enrolled in mathematics programs.

1 Frameworks of person-environment-fit

Having their origin within the theory of work adjustment (Swanson & Fouad, 1999), frameworks of person-environment-fit have been applied to the transition from school to university in general (Nagy, 2006) and in mathematics in particular (Blömeke, 2009; Rach & Heinze, 2017). According to frameworks of person-environment-fit, a sufficient fit between students' characteristics (e.g., attitudes, knowledge, needs) and the characteristics of the learning environment (e.g., demands, characteristics of the major) is necessary for a successful transition. An insufficient fit may increase the risk for dropout (Nagy, 2006).

As we want to analyse mechanisms to understand dropout in university study programs, frameworks of person-environment-fit can serve as a resource to identify possible mechanisms. We therefore follow the conceptualization of person-environment-fit by Lubinski and Benbow (2000) who proposed two different fit dimensions (Fig. 1): first, the fit between students' abilities and knowledge on the one hand and the demands of the university on the other hand, which we assume to be visible by students' *achievement*, for example achieving competences and passing exams; second, the fit between students' attitudes and needs on the one hand and the characteristics of the specific subject (major) on the other hand, which we assume to be visible in students' *satisfaction* with their study program (Lubinski & Benbow, 2000). According to Blüthmann (2012), we hereby understand satisfaction as an evaluative rating which is based on students' affective experiences and comparisons with the learning environment. Both achievement and satisfaction serve in this study as indicators for the fit between persons and environment in the sense that the extent of satisfaction and achievement indicates the extent of fit. We assume that both variables are relevant with regard to dropout because of the following reasons: in the case of low achievement, students may have to quit their studies due to restrictions of the university (e.g., in the case of finally failed exams) or decide to withdraw voluntarily; low satisfaction may result in voluntary withdrawal as well (Nagy, 2006). As students' attitudes may be related to their learning behaviour (Kolter et al., 2016) and therefore influence achievement as well, attitudes may be relevant to both fit dimensions which is an extension of the framework of person-environment-fit by Lubinski and Benbow (dotted arrow in Fig. 1).

In this study, we focus on the left-hand side of the model and restrict our analyses to persons' characteristics. To examine systematically these characteristics, we do not vary the characteristics of the environment but analyse the impact of persons' characteristics, in particular of students' attitudes, in one specific environment.

Empirical findings from studies with participants from different study programs supported the assumed relations between satisfaction and achievement as indicators of a successful fit and dropout (intention). Within the German context, Fleischer et al. (2019) reported that satisfaction is a negative predictor of dropout intention in natural science and engineering programs. Moreover, Brandstätter et al. (2006) found that students' satisfaction as well as their achievement during the first term is related negatively with actual dropout.

In this contribution, we restrict our attention to students' mathematics-related attitudes. Reasons why these attitudes have effects on study dropout are based on

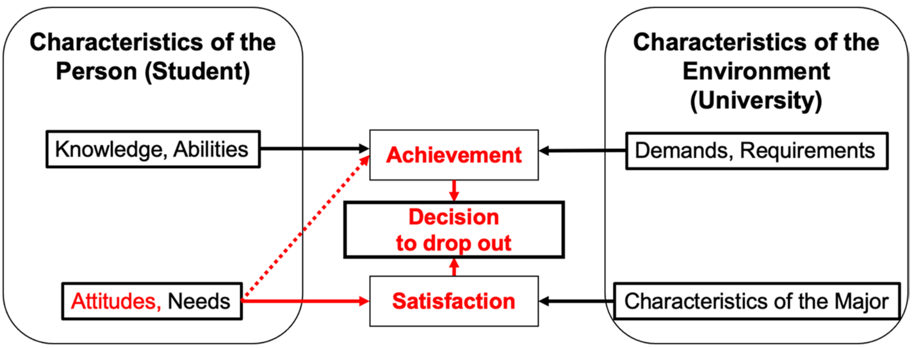

Fig. 1 Person-environment-fit during the transition from school to university; variables and relations focused in the present study are marked in red; self-developed figure inspired by Lubinski and Benbow (2000, p. 140)

theoretical assumptions which are brought together in frameworks of person-environment-fit. To our knowledge, there are no empirical studies which confirm these reasons in whole. Before we sum up theoretical and empirical results which support single assumed relations in the model, we describe characteristics of the context in which the study took place.

2 Characteristics of university mathematics

Especially with regard to study programs in pure mathematics and mathematics teacher education, a sufficient fit between students' characteristics and characteristics of the university is not obvious even amongst those students who were successful in school mathematics (cf. Di Martino & Gregorio, 2018). An insufficient fit can be explained by substantial differences between mathematical learning processes at school and at university, which involve institutional (e.g., study conditions by learning contracts) as well as subject-specific facets (e.g., demands located in typical tasks for students) and have been widely discussed (cf. Engelbrecht, 2010; Gueudet, 2008).

Advanced mathematics lectures usually have a strong focus on formal definitions and deductive proofs (Dreyfus, 1991; Engelbrecht, 2010). New concepts are often introduced via formal definitions from which properties of concepts are deductively derived and students only seldom identify properties through experimentation with (counter) examples (Rach & Heinze, 2017; Tall, 1992). Usually, proofs are presented in a finished and formal way, and the proving process remains invisible (Pinto, 2017). The aspects which are reported in many parts of the world apply for the German context as well: both lecture courses—real analysis and linear algebra—that German mathematics students usually attend during their first year at university mainly deal with proofs and formal definitions (Halverscheid & Pustelnik, 2013).

Normally, lecture courses in advanced mathematics are accompanied by homework tasks (Pritchard, 2015). These tasks typically differ from those tasks students know from school. In school, tasks that can be solved using schematic calculations are prevalent (De Guzman et al., 1998). Empirical projects like COACTIV (Cognitive Activation in the Mathematics Classroom and Professional Competence of Teachers) and TALIS (Teaching and Learning International Survey) showed that cognitively demanding tasks are only seldomly implemented in mathematics high school classrooms in Germany as well as in other countries (Jordan et al., 2008; OECD, 2020). In particular, Engelbrecht (2010, p. 143) stated that "most students' perception of being successful in mathematics in school does not involve much inquiry but mostly just the application of different methods". Comparing typical tasks at university with typical tasks in school, a clear shift to proving is reported (Vollstedt et al., 2014; Weber & Lindmeier, 2020). As these proving tasks usually cannot be solved by using only schematic calculations or algorithms and most students are unfamiliar with formal proofs when entering university (De Guzman et al., 1998), cognitive and affective problems can occur when students have to deal with proofs on their own: cognitive in the sense that they are not able to cope with homework tasks and affective in the sense that they do not dare to work on the tasks to avoid failures and that they are more interested in school mathematics, focusing on schematic calculations, compared to university mathematics, focusing on proofs.

3 Attitudes towards mathematics

As described in the last paragraph, the learning environment, and especially the learning content, change during the transition from school to university. According to frameworks of person-environment-fit, students have to adapt their attitudes towards the characteristics of the new learning environment university to be successful in this environment. Hereinafter, we restrict our attention to students' interest and self-concept because of the following reasons: Previous studies suggested that both attitudes are relevant factors during the transition from school to university mathematics (e.g., Di Martino & Gregorio, 2019; Rach & Heinze, 2017) because according to expectancy-value theories (Eccles & Wigfield, 2020), interest and self-concept influence decision making in educational settings, for example the decision to drop out. Furthermore, interest and self-concept are compatible with and explicitly addressed by frameworks of person-environment-fit (e.g., Lubinski & Benbow, 2000). In addition, both concepts can be clearly distinguished theoretically as well as empirically (Corbière et al., 2006).

3.1 Interest

Interest is considered to have an important impact on learning processes because persons engage more deeply with learning contents they are interested in (Hidi & Renninger, 2006). The person-object theory describes interest as a special relation between a person and an object (in our case: mathematics) and distinguishes between interest as a state and a trait (Krapp, 2007). Situational interest (state) is caused by external factors and refers to a specific situation or task, whereas individual interest is viewed as a rather stable disposition (trait) comprising an emotion-related (positive emotions towards the object of interest) and a value-related (subjective esteem for the objects of interest) component.

Individual interest can emerge through the recurring experience of situational interest (cf. Hidi & Renninger, 2006). Once developed, individual interest can induce the psychological state of actualized individual interest in certain learning situations (Krapp, 2007; Krapp et al., 1992). According to Krapp et al. (1992), beneficial outcomes of this state involve more attention and concentration as well as affective reactions like pleasant feelings. Given these beneficial outcomes in the learning process that are based on theoretical assumptions, individual interest should also lead to achievement and satisfaction with one's studies as indicators of the person-environment-fit.

In previous research, there is some empirical evidence that individual interest relates to achievement, study satisfaction and dropout. However, the results are rather ambiguous. Geisler and Rolka (2018) found that students who failed in their final exam in the first term at university reported less interest in mathematics than students who succeeded, but Rach and Heinze (2017) observed no relation between interest and students' achievement. Schiefele and Jacob-Ebbinghaus (2006) reported that students with more interest were also more satisfied with their study programs.

Even if it is not yet clear whether results concerning dropout intention can be transferred to actual dropout, we sum up some relevant results concerning the relation between interest and dropout intention, because quantitative studies concerning actual dropout from mathematics are scarce. Individual interest is closely negatively connected to dropout intention in STEM (science, technology, engineering, mathematics) subjects (Fellenberg & Hannover, 2006) and in mathematics in particular (Blömeke, 2009). Furthermore, mathematics students who did not attend the final exams at the end of the first term reported less interest in mathematics at the beginning of the first term than those who participated in the exams (Geisler & Rolka, 2018). This result underlines the role interest probably plays for early dropout in mathematics, as students who do not attend the exams are at risk to drop out (Baars & Arnold, 2014).

The inconsistent results concerning the role of interest during the transition—especially regarding achievement—might be explained by the fact that the mentioned studies used general measurements of interest in mathematics. When students estimated their interest concerning mathematics, it remained unclear which character of mathematics, mathematics in school or in university (see Section 3), they referred to. Thus, Ufer et al. (2017) argued that it is essential to differentiate in questionnaires between interest in school mathematics and interest in university mathematics. Indeed, Kosiol et al. (2019) showed that interest in school mathematics was negatively associated with students' satisfaction while interest in university mathematics was positively associated with satisfaction. A possible explanation might be that individual interest in school mathematics does not lead to actualized individual interest in learning situations involving university mathematics and therefore does also not contribute to the person-environment-fit. However, no empirical relations between students' achievement and the two interest facets have been found in their study.

3.2 Mathematical self-concept

Mathematical self-concept can be understood as students' mental image concerning their knowledge and abilities in the domain of mathematics (cf. Gourgey, 1982; Marsh et al., 2019; Trautwein et al., 2006). Hierarchical models of self-concept describe mathematical self-concept as one facet of students' academic self-concept which comprises affective as well as cognitive evaluations and is merely based on past experiences of success and failure as well as the attribution thereof (e.g., Bong & Skaalvik, 2003). Furthermore, frames of reference (e.g., comparisons with other students, evaluation by others) influence students' self-concept.

With regard to possible effects, self-concept is considered to influence achievement-related outcomes (Bong & Skaalvik, 2003). In the school context, previous studies have reported evidence for a positive bidirectional relation between mathematical self-concept and achievement (e.g., Chen et al., 2013; Trautwein et al., 2006). A reason discussed in the literature for the influence of self-concept on achievement is that students with a higher mathematical self-concept are more likely to engage in demanding mathematical tasks and show more persistence when working on these tasks (cf. Rach et al., 2019). Indeed, in the school context, Cai et al. (2018) reported that the relation between self-concept and mathematics achievement was mediated by students' engagement with the tasks. Due to students' unfamiliarity with proving, the tasks in university can be considered very demanding. For dealing successfully with such tasks, a high self-concept could be even more important. Following this theoretical argumentation, high mathematical self-concept can lead to more achievement as an indicator for the person-environment-fit.

However, empirical results concerning the role of self-concept in the transition from school to university draw a less clear picture. With regard to engineering students, Liston and O'Donoghue (2009) reported a weak correlation between mathematical self-concept and achievement. Rach and Heinze (2017) found no influence of mathematics and teacher education students' mathematical self-concept on their achievement during the first term. In contrast to that, Hailikari et al. (2008) studied effects of mathematical self-beliefs—which are closely connected to self-concept (Eccles & Wigfield, 2020)—on students' achievement and reported indirect effects which were mediated by students' prior knowledge. Geisler and Rolka (2018) reported lower mathematical self-concept at the beginning of the first term amongst students who failed the mathematics final exams compared to those students who passed the exams. Studies relating self-concept and satisfaction are scarce. Bernholt et al. (2018) reported a positive impact of teacher education students' academic self-concept on their satisfaction with their major. Given the sample which consists of students from very different study programs and the measurement (academic instead of mathematical self-concept) used by Bernholt et al. (2018), it remains uncertain whether these results can be transferred to the relation between mathematical self-concept and satisfaction in a mathematics program.

Qualitative research has suggested a relation between mathematical self-concept and early dropout (e.g., Bampili et al., 2017; Di Martino & Gregorio, 2018, 2019). Di Martino and Gregorio (2018) described the phenomenon that students, who had been high achievers in school, reported low mathematical self-concept in the study entry phase. In this study, it is unclear if students start their study with a low self-concept or if students' self-concept declines in the first weeks of study. Rach and Heinze (2017) found that students with low mathematical self-concept at the beginning of term were more likely not to attend the exams (see also Geisler & Rolka, 2018)—which is a resilient predictor of early dropout according to Baars and Arnold (2014).

Given the inconsistent results concerning the relation between students' self-concept and achievement and the aforementioned differences between school and university mathematics, it has been discussed whether differentiating between self-concept regarding school mathematics and self-concept regarding university mathematics may enable more insights (Rach et al., 2019). For the study at hand, we have decided to use a general measure of mathematical self-concept as a differentiated instrument was not available at the time of data collection. We consider this decision as appropriate because self-concept is hierarchically organized (Marsh et al., 2019), school and university mathematics are both part of the domain mathematics and we expected that students would rate their abilities concerning school and university mathematics as rather similar. Thus, the differentiation between self-concept regarding school and university mathematics seems to be less clear than differentiating between interest in school and in university mathematics. Indeed, empirical results with a newly developed instrument, which differentiates between self-concept concerning school and self-concept concerning university mathematics, indicated a strong relation between general mathematical self-concept and self-concept for university mathematics (Rach et al., 2021).

4 The current study

The overarching aim of this study is to extend our knowledge of the dropout process by analysing and confirming the underlying mechanisms of relations between students' attitudes towards mathematics and actual dropout. Based on the already discussed theoretical mechanisms, informed by frameworks of person-environment-fit and previous empirical studies, we propose a path model (Fig. 2) that describes the assumed relations between students' interest facets or self-concept and early dropout as well as the underlying mechanisms. This path model takes into account total effects (overall relations between attitudes and dropout without differentiating between different mechanisms), indirect effects

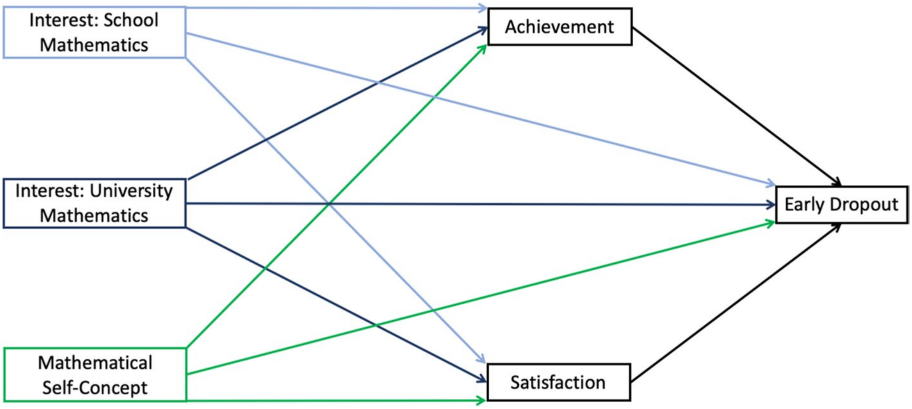

Fig. 2 Assumed path model for the relation between students' attitudes towards mathematics and early dropout

(relations between attitudes and dropout that are mediated by satisfaction or achievement) and direct effects (relations between attitudes and dropout while the mediators are controlled) (for a detailed explanation see Hayes, 2018). The specific research questions and related hypotheses are presented in the following.

4.1 Relations between attitudes towards mathematics and early dropout (total effects)

With regard to interest, we distinguished between interest in school and university mathematics (see Ufer et al., 2017). As self-concept concerning school mathematics and self-concept concerning university mathematics cannot be clearly distinguished empirically (Rach et al., 2019), we decided to measure general mathematical self-concept to answer the following question:

1) In which way do students' interest in school and university mathematics as well as mathematical self-concept predict early dropout from university mathematics?

Based on the aforementioned arguments (see Sections 4.1 and 4.2), we assume that students' interest in university mathematics is related to less risk for early dropout (H 1.1). As many demands of school mathematics do not play a prominent role in university mathematics, we have no specific hypothesis concerning interest in school mathematics. Besides, we expect that a higher mathematical self-concept decreases the risk for early dropout (H 1.2).

4.2 Mechanisms underlying the relation between attitudes and early dropout (direct and indirect effects)

We want to further understand the mechanisms underlying this relation. According to frameworks of person-environment-fit, the fit between students' characteristics and characteristics of the university is visible by high achievement and satisfaction (Lubinski & Benbow, 2000; Swanson & Fouad, 1999). Achievement and satisfaction are assumed to be related with less risk to drop out (Brandstätter et al., 2006). Therefore, we use achievement and satisfaction as two (potential) mediators for the relations between attitudes and early dropout (see Fig. 2):

2) In which way do students' interest and self-concept predict achievement and satisfaction? Are students' achievement and satisfaction predictors of early dropout?

In the case of interest in university mathematics, previous studies (Section 4.1) found only relations with satisfaction but not with achievement. Therefore, we assume a positive relation between interest and satisfaction and no significant relation with achievement (H 2.1). Due to the fact that school mathematics is not the learning content in university, we have no specific hypothesis concerning interest in school mathematics. As theoretical considerations as well as empirical results have suggested relations of self-concept with achievement as well as with satisfaction (see Section 4.2), we expect a positive relation between self-concept and satisfaction and achievement (H 2.2). We assume that satisfaction and achievement are related to decreasing risk for early dropout (H 2.3).

3) Are the relations between students' attitudes towards mathematics and early dropout mediated by students' achievement or satisfaction (direct and indirect effects)?

Based on the aforementioned assumptions of person-environment-fit, we expect that both indicators of a successful fit—achievement and satisfaction—mediate the relations between students' attitudes and early dropout (H 3.1). Concretely, we assume satisfaction to be a stronger mediator than achievement (H 3.2) because attitudes probably relate stronger to satisfaction than to achievement (see Section 2).

However, we have no specific hypothesis as to whether satisfaction and achievement will explain the whole relations between attitudes and early dropout or if there will still be a significant direct relation of attitudes on early dropout when achievement and satisfaction are controlled (direct effects).

5 Methods

5.1 Context and participants

Our sample consists of two cohorts of first-year students enrolled in a mathematics teacher education program (for upper secondary education) or a pure mathematics program at a large public university in Germany. Students from both mathematics programs attended exactly the same two mathematics lecture courses during the first year: real analysis and linear algebra. Both lecture courses had a strong focus on formal definitions and proofs. In addition, students in pure mathematics had some courses in a minor subject, whereas students in the teacher education program had courses in a second subject. There were no specific required mathematics courses for students in the pure mathematics program or for students in the teacher education program during the first year. The mathematics programs at this university were not selective, but students had to decide on their major upon enrolment. Changing major meant to quit the actual program and to reenrol in another program.

In our study, 286 students voluntarily participated and 274 (62 in the math program, 212 in the teacher education program) of them gave permission to check whether they would drop out during their first year at university. From these students, 135 were male while 138 were female—one student did not indicate the gender. At the time of enrolment, the students were between 17 and 33 years old (*M* (age) = 19 years; *SD* (age) = 2.4 years).

5.2 Design and instruments

In order to answer the research questions, a quantitative study with a longitudinal design and three measurement points was conducted. Students filled in a first questionnaire in the first weeks of the term (T1) during the lecture courses real analysis and linear algebra. The questionnaire captured students' interest in school as well as university mathematics and their mathematical self-concept (see Table 1 for an overview). The interest scales differentiate between interest in school and interest in university mathematics and include items that address the emotion-related component of interest (e.g., *The kind of mathematics that is done at university is fun for me*) as well as the value-related component of interest (e.g., *The kind of mathematics that I learned at university belongs to the most important things to me*) (Ufer et al., 2017). The mathematical self-concept scale was adapted from the PaLea-project (Kauper et al., 2012) and focuses on students' self-concept regarding their studies of mathematics (e.g., *I am very good in my study subject mathematics*). An exploratory factor analysis confirmed the intended structure of the interest and self-concept scales: both screeplot and Kaiser criterion suggested three factors (interest in university mathematics, interest in school mathematics, mathematical self-concept) with main loadings bigger than 0.5 and crossloadings smaller than 0.4. The three scales showed satisfactory to good reliabilities (see Table 1). Furthermore, demographical data like gender, age and self-reported school qualification grade (the German equivalent to grade point average) were captured by the first questionnaire.

A second questionnaire, capturing students' satisfaction, was handed out 8 weeks later (T2) in the middle of the term (see Table 1). The scale was taken from Schiefele and Jacob-Ebbinghaus (2006) and focuses on students' satisfaction with their mathematics study program overall and the content of the program in particular. Students estimated all items for attitudes and satisfaction on a 5-point Likert scale where 1 indicated *totally disagree* and 5 *totally agree*.

Only 23% of the students in our sample, who finally dropped out of the mathematics program, attended the final exams at the end of the first term—thus, some might have dropped out prior to the exam. Therefore, we decided not to use the exam marks as an indicator for students' achievement in the first term because we had only little information on the exam marks of students who are considered dropout students in our study.[1] Instead, we used students' homework sheets in real analysis to assess their achievement during the term. Students were allowed to work on these sheets alone or in pairs, forming the pairs on their own. Working on tasks was voluntarily, but students could receive extra points for the final exam if they handed in correct task solutions. Participation on the tasks was high—over 92% of all students and 85% of the students who later dropped

[1] By dropout students, we mean those students in our sample that dropped out from their mathematics program in the first year.

Table 1 Measurement instruments of constructs with timing, number of items, reliability (Cronbach's α) and sample items

Construct (timing)	Source	# Items	α	Sample item
Interest, school (T1)	Ufer et al. (2017)	5	0.77	In school, mathematics was very important for me
Interest, university (T1)	Ufer et al. (2017)	5	0.88	The kind of mathematics that is done at university is fun for me
Self-concept (T1)	Kauper et al. (2012)	4	0.84	I am very good in my study subject mathematics
Satisfaction (T2)	Schiefele and Jacob-Ebbinghaus (2006)	4	0.84	All in all, I am satisfied with my studies of mathematics

Note: $N_1 = 274$ for attitude variables at T1, $N_2 = 181$ for satisfaction at T2. Ratings on a 5-point Likert scale between *1* (*totally disagree*) and *5* (*totally agree*)

out of the program in our sample handed in homework sheets. Handed in solutions were corrected and graded by tutors. These tutors were PhD students or experienced Masters students who also taught the sections that accompanied the real analysis lectures. Tutors used a grading guide provided by the lecturer in order to ensure fair and comparable grading. The grading guide included expected solutions and detailed rules for granting points to the solutions. For our analysis, we considered those homework sheets handed in during 3 consecutive weeks around T2 (the week prior to T2 and the following 2 weeks). As the achievable points of the tasks differed from week to week, we standardized the points students received.

In order to determine whether students dropped out during the first year or continued their studies, we checked whether they were still enrolled in a mathematics program at this university at the beginning of the second year (T3). Dropout was defined as changing the study program or leaving the university.

5.3 Data analysis

In order to answer the research questions, we examined the assumed path model (Fig. 2) using Mplus. Mplus allows to calculate all total, direct and indirect effects simultaneously within one model (Muthén & Muthén, 1998–2017) and therefore offers the possibility to test our hypotheses within one single analysis. As the dependent variable dropout is dichotomous, we used a maximum likelihood estimator with robust standard errors using numerical Monte Carlo integration (Muthén & Muthén, 1998–2017). In order to test inference for indirect effects, bootstrap confidence intervals (based on 10,000 bootstrap samples) were used (Hayes, 2018). As previous studies reported that prior achievement in school was an important predictor of study success (e.g., Brandstätter et al., 2006; Schneider & Preckel, 2017) and was also correlated to academic self-beliefs (Hailikari et al., 2008), we controlled for students' self-reported school qualification grade (1≙very good, 4≙sufficient) as an indicator for prior achievement during the whole analysis. By doing so, we wanted to ensure that the relation between self-concept and dropout (as well as between self-concept and satisfaction and achievement) is not overestimated.

In both questionnaires (T1 and T2), 175 students took part. We used a MANOVA (in order to prevent accumulation of the alpha error compared to single *t*-tests) with the dependant variables “interest in university mathematics”, “interest in school mathematics” and “mathematical self-concept” to screen for differences between students who participated only at T1 and those who filled out both questionnaires. The MANOVA reveals a significant main effect: $F(4, 263) = 7.26$, $p < 0.001$, $\eta^2 = 0.10$. In particular, students who filled out both questionnaires report more interest in school ($F(1, 266) = 6.69$, $p < 0.01$, $\eta^2 = 0.03$) and university mathematics ($F(1, 266) = 13.22$, $p < 0.001$, $\eta^2 = 0.05$) as well as a higher mathematical self-concept ($F(1, 266) = 18.12$, $p < 0.001$, $\eta^2 = 0.06$) and better school qualification grade ($F(1, 266) = 11.58$, $p < 0.001$, $\eta^2 = 0.04$). This indicates that the subsample with full data is positively selected. Therefore, we applied the full information maximum likelihood algorithm (as implemented in Mplus) to estimate the path coefficients for the full sample.

6 Results

Overall, 100 students in our sample (36%) dropped out during or directly after the first year in a mathematics program. Table 2 summarizes descriptive statistics of the attitude variables as well as the self-reported school qualification grade, which served as an indicator for prior achievement. Students who dropped out already started their studies with less interest in school and less interest in university mathematics as well as a lower mathematical self-concept and less prior achievement than those students who continued the mathematics programs after the first year. All differences between the two groups of students are statistically significant ($p < 0.05$).

Table 2 Means and standard deviations of the attitude variables and the self-reported school qualification grade

	Total ($N = 274$)		Dropout ($n_1 = 100$)		No Dropout ($n_2 = 174$)	
	M	*SD*	*M*	*SD*	*M*	*SD*
Interest, school mathematics	3.55	0.46	3.43	0.64	3.63	0.69
Interest, university mathematics	2.99	0.71	2.67	0.80	3.17	0.82
Mathematical self-concept	2.82	0.50	2.54	0.63	2.96	0.71
Self-reported school qualification grade	2.19	0.63	2.32	0.61	2.12	0.63

Note: Ratings on a 5-point Likert scale between *1* (*totally disagree*) and *5* (*totally agree*); self-reported school qualification grade between *1* (*very good*) and *4* (*sufficient*)

6.1 Relations between attitudes towards mathematics and early dropout (total effects)

In order to analyse the overall relations between attitudes and early dropout (RQ 1), we tested the total effects of interest in school and in university mathematics as well as mathematical self-concept on early dropout (see Table 3, first column). No significant total effect of interest in school mathematics could be found ($B = -0.24$, $\exp(B) = 0.79$, $p > 0.40$). In contrast, increasing interest in university mathematics was related to decreasing risk for early dropout. However, the total effect of interest in university mathematics was only marginally significant ($B = -0.50$, $\exp(B) = 0.61$, $p < 0.10$) which is only a weak support for H 1.1. Contrary to that, H 1.2 could be confirmed: mathematical self-concept was negatively related with early dropout ($B = -0.72$, $\exp(B) = 0.49$, $p < 0.05$). We controlled for students' self-reported school qualification grade (as an indicator for prior achievement) during the whole analysis and only a marginal significant total effect of the self-reported school qualification grade was observed ($B = 0.48$, $\exp(B) = 1.62$, $p < 0.10$).

The path coefficients in Table 3 are in a log-odds metric, so a negative path coefficient indicates a negative relation and a positive coefficient indicates a positive relation. For $B = -0.72$, a resulting $\exp(B) = 0.49$—like in the case of mathematical self-concept—indicates that the proportion of the probability to drop out and the probability to continue ones mathematics program (P(dropout = 1)/P(dropout = 0)) decreases by 51% as the self-concept increases by one point on the Likert scale.

6.2 Mechanisms underlying the relation between attitudes and early dropout (direct and indirect effects)

While the total effects discussed in the previous section represent the overall relations between students' attitudes and early dropout, research questions 2 and 3 are concerned with the underlying mechanisms of these relations. We therefore deconstructed the total effects into direct effects (effects of attitudes on early dropout when the mediators *achievement* and *satisfaction* are controlled) and indirect effects (effects of attitudes on early

Table 3 Overview of all total, direct and indirect effects on dropout estimated in the path model

	Total effects	Direct effects	Indirect effects via achievement		Indirect effects via satisfaction	
	B	*B*	*B*	95% CI	*B*	95% CI
Interest, school	−0.24	−0.24	−0.03	[−0.23, 0.16]	0.03	[−0.10, 0.25]
Interest, university	−0.50^{t}	0	−0.10	[−0.31, 0.08]	−0.40*	[−0.79, −0.02]
Self-concept	−0.72*	−0.10	−0.29**	[−0.59, −0.08]	−0.33*	[−0.75, −0.03]
Achievement	-	-0.95***	-	-	-	-
Satisfaction	-	-0.86*	-	-	-	-

Note: $N = 274$; $^{t}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$; path coefficients controlled for self-reported school qualification grade; inference of indirect effects tested via bootstrap confidence intervals based on 10,000 bootstrap samples; all path coefficients are presented in a log-odds metric dropout via *achievement* and *satisfaction*). The total effects are the sums of the related direct and indirect effects whereas the indirect effects are calculated as the product of the path coefficient from the predictor (e.g., self-concept) to the mediator (achievement or satisfaction) and the path coefficient from the mediator to the outcome (early dropout) (Hayes, 2018).

Hypothesis H 2.3 could be confirmed because both potential mediators—achievement ($B = -0.95$, $\exp(B) = 0.39$, $p < 0.001$) and satisfaction ($B = -0.86$, $\exp(B) = 0.42$, $p < 0.05$)—were related to dropout (see Fig. 3 and Table 3). In the following, we describe the relations between students' attitudes towards mathematics and achievement or satisfaction (RQ 2) as well as the direct and indirect effects of students' attitudes on early dropout (RQ 3) ordered by the attitude variables.

With regard to interest in school mathematics, we found neither significant effects on achievement ($B = 0.03$, $p > 0.70$) and on satisfaction ($B = -0.03$, $p > 0.60$) nor a significant direct effect on early dropout ($B = -0.24$, $\exp(B) = 0.79$, $p > 0.30$). Likewise, the indirect effects of interest in school mathematics via achievement ($B = -0.03$, $\exp(B) = 0.97$, 95% CI = [−0.23, 0.16]) and via satisfaction ($B = 0.03$, $\exp(B) = 1.03$, 95% CI = [−0.10, 0.25]) were not significant. All in all, we found no relation between interest in school mathematics and early dropout (see Table 3 and Fig. 3).

As expected, (H 2.1), interest in university mathematics was positively associated with satisfaction ($B = 0.46$, $p < 0.001$) but no significant relation with achievement could be confirmed ($B = 0.11$, $p > 0.20$). Likewise, a negative indirect effect on early dropout via satisfaction could be detected ($B = -0.40$, 95% CI = [−0.79, −0.02], $\exp(B) = 0.67$), whereas the indirect effect via achievement was not significant ($B = -0.10$, 95% CI = [−0.31, 0.08], $\exp(B) = 0.90$). Furthermore, no direct effect on early dropout was found in our sample ($B = 0$, $\exp(B) = 1$, $p = 1$).

Regarding mathematical self-concept, positive relations with achievement ($B = 0.30$, $p < 0.01$) as well as satisfaction ($B = 0.38$, $p < 0.001$) could be confirmed (H 2.2). Achievement and satisfaction both served as mediators of the relation between self-concept and

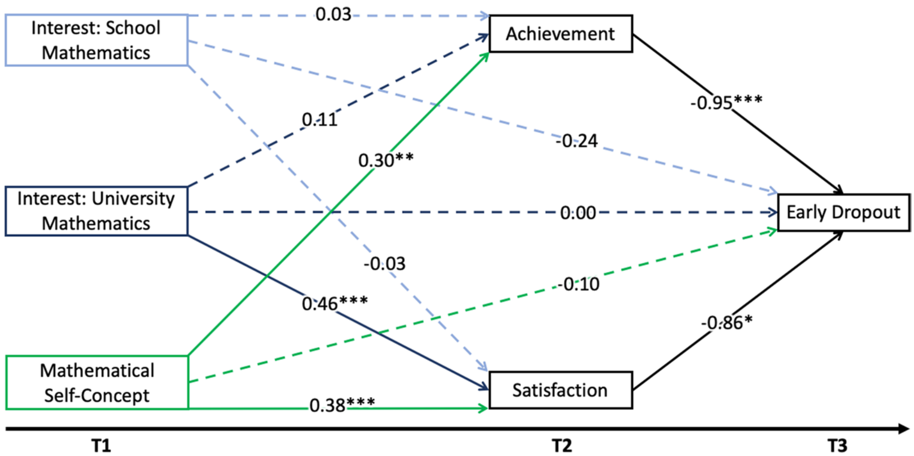

Fig. 3 Path model for the effects of students' attitudes towards mathematics on early dropout. *Note:* $N = 274$; $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$; path coefficients controlled for self-reported school qualification grade; not significant paths ($p > 0.05$) are presented as dashed lines; effects on early dropout are presented in log-odds metric. $R^2_{\text{Satisfaction}} = 0.52$, $R^2_{\text{Achievement}} = 0.27$, $R^2_{\text{Dropout}} = 0.40$

early dropout leading to significant indirect effects ($B = -0.29$, 95% CI = [−0.59, −0.08], exp(B) = 0.75 and $B = -0.33$, 95% CI = [−0.75, −0.03], exp(B) = 0.72). Similar to interest, no significant direct effect on early dropout was revealed ($B = -0.10$, exp(B) = 0.90, $p > 0.70$).

Summarizing, the relation between interest in university mathematics and early dropout was only mediated by satisfaction and the relation between self-concept and early dropout was mediated by achievement and satisfaction. Thus, our hypothesis that achievement and satisfaction will mediate the relation between attitudes and early dropout (H 3.1) but satisfaction will be the stronger mediator (H 3.2) could be confirmed only partially.

All in all, the tested model (see Fig. 3) is suitable to explain nearly 40% of the variance in dropout, 52% of the variance in satisfaction and 27% in achievement.[2]

7 Discussion

In order to understand the high dropout rates in university mathematics programs in Germany (Dieter & Törner, 2012), we wanted to extend existing results concerning the role of attitudes, firstly by focussing actual dropout. This approach goes beyond existing research using indicators like exam attendance or dropout intention that come with uncertainty concerning the actual dropout (cf. Brandstätter et al., 2006; Sarcletti & Müller, 2011). Secondly, we deepen our understanding in which way attitudes predict early dropout by identifying mediators of this relation. To be able to compare our results with existing results in the field, we measured students' attitudes by well-known instruments, for example Schiefele and Jacob-Ebbinghaus (2006) and Ufer et al. (2017), which are based on prominent theories like person-object theory and expectancy-value theory. In the following, we discuss the results of our study ordered by research questions.

7.1 Relations between attitudes towards mathematics and early dropout

All in all, students' attitudes were related with early dropout. When controlling for all attitude variables and prior achievement, interest in university mathematics was suitable to predict early dropout in mathematics, whereas interest in school mathematics could not predict dropout. High interest in school mathematics is probably a reason why students choose a mathematics study program (Ufer et al., 2017) but this interest facet does not predict staying in the program. Thus, choosing a study program and staying in this program seem to be two phenomena which are influenced by different students' characteristics.

That interest in school and in university mathematics play different roles in the first term is not too surprising because mathematics at school and at university differ substantially as discussed in Section 3. Thus, interest in school mathematics might not lead to actualized individual interest in learning situations at university because these involve different characteristics compared to school. Therefore, different levels of interest in school mathematics do not lead to different psychological states in a learning situation at university

[2] Within an alternative model without prior achievement as a control variable, only the explained variance of students' achievement was smaller ($R^2_{\text{Achievement}} = .13$).

(cf. Krapp et al., 1992). However, more specific research linking individual interest and actualized individual interest in the field of transition is needed to confirm this hypothesis. The presented results underline the necessity to distinguish between interest in school and in university mathematics (cf. Ufer et al., 2017). It remains an open question with which expectations of the learning environment students started their studies. Daskalogianni and Simpson (2002) as well as Liebendörfer and Hochmuth (2013) have argued that unfulfilled expectations might result in low interest in university mathematics, which seems problematic, as interest in university mathematics is related with less dropout. Thus, a hypothesis derived from this study is that students decide to enrol in a mathematics program because of high interest in school mathematics (see Table 2) but decide to quit the program after the first year because of low interest in university mathematics.

Mathematical self-concept was a good predictor of early dropout in this study. This result goes beyond the works of Rach and Heinze (2017) and Geisler and Rolka (2018) who reported relations between students' mathematical self-concept and participation in the final exams. A reason for this strong relation between self-concept and early dropout could be that students with a high self-concept dare to work on the demanding mathematical tasks and show high persistence during this work (cf. Rach et al., 2019). As there is a bidirectional relation between self-concept and achievement (Wu et al., 2021), achievement in the first weeks may also have an effect on self-concept. As we wanted to explain in this study why self-concept at the beginning of the study program has an effect on early dropout, we focused on one of the two directions between self-concept and achievement. In further studies, the other direction could bring new insights into the interplay between self-concept and achievement in the first year of university.

As argued in Section 4.2, we did not differentiate self-concept into self-concept concerning school mathematics and self-concept concerning university mathematics. However, combining two results of our study—the importance of self-concept for dropout and the value of differentiating interest in school and university mathematics—the idea of splitting self-concept into two facets could be valuable for analysing the role of attitudes in the transition from school to university mathematics. Given the result that interest in university mathematics is more relevant regarding dropout than interest in school mathematics, a stronger prediction of early dropout by self-concept regarding university mathematics seems possible. However, as self-concept is structured hierarchically (e.g., Bong & Skaalvik, 2003) and the few empirical results available to date showed a strong correlation between general mathematical self-concept and self-concept regarding university mathematics (Rach et al., 2021), it is also possible that self-concept concerning school mathematics and self-concept concerning university mathematics both are similarly relevant with regard to early dropout. Thus, it is an open question up to now if it is worthwhile to split up self-concept in two facets.

7.2 Mechanisms underlying the relation between attitudes and early dropout

Regarding the mechanism underlying the relation between attitudes and dropout, empirically represented in mediation effects, we could confirm assumptions proposed by research using frameworks of person-environment-fit (Lubinski & Benbow, 2000; Nagy, 2006; Swanson & Fouad, 1999) and triggered by empirical results in mathematics education and educational psychology (e.g., Fellenberg & Hannover, 2006; Ufer et al., 2017). First, achievement and satisfaction are both clearly related to early dropout in mathematics, supporting the assumption that both are suitable indicators for the fit in the sense of person-environment-fit frameworks (Lubinski & Benbow, 2000). Second, interest in university mathematics was a predictor of satisfaction and self-concept was a predictor of achievement as well as of satisfaction. Thus, higher interest in university mathematics and higher self-concept contribute to a better person-environment-fit, whereas low interest and low self-concept can be a hindrance for the fit. For both interest in university mathematics and mathematical self-concept, no significant direct effects on early dropout were found when integrating the mediators (achievement and satisfaction) into the model. This underlines the strong mediating role of achievement and satisfaction for early dropout and helps to explain in which way attitudes affect early dropout.

In detail, two mechanisms explained the relation between attitudes and dropout from mathematics programs in our study: (1) mathematical self-concept was positively related to higher achievement, which in turn affected a lower risk for early dropout; and (2) interest in university mathematics and mathematical self-concept led to higher satisfaction and higher satisfaction was related to lower risk for early dropout.

We now present similarities and differences between our results and the existing literature. Concerning the first mechanism—attitudes predict achievement, which predicts dropout—the context of our study has to be taken into account when comparing the results of our study to other studies. Regarding the relation of self-concept and achievement in mathematics programs, previous studies reported divergent results, probably because previous studies often used exam results as an indicator for achievement (Geisler & Rolka, 2018; Hailikari et al., 2008; Liston & O'Donoghue, 2009; Rach & Heinze, 2017). By using points in homework sheets which students could voluntarily hand in to earn extra points for the final exam, we measured achievement during the first term instead of at the end of the term. Concerning the framework of person-environment-fit by Lubinski and Benbow (2000), we enlarged this idea by relating attitudes, in particular self-concept, not only to satisfaction but also to achievement.

Concerning the second mechanism—attitudes predicts satisfaction, which predicts dropout—this study pointed out that both attitudes, interest in university mathematics and mathematical self-concept, predicted satisfaction, whereas previous research (e.g., Kosiol et al., 2019; Schiefele & Jacob-Ebbinghaus, 2006) concentrated on interest to predict satisfaction. The relation between satisfaction and dropout intention, which is known from the literature (Fleischer et al., 2019), was extended to the relation between satisfaction and actual dropout. By analysing these mechanisms, we shed light on the question in which way interest and self-concept have an effect on learning processes in the first term so that students decide to drop out or stay in the study program.

7.3 Limitations

One limitation of our study lies in the sample. We administrated the questionnaires measuring attitudes and satisfaction during lectures. Students who did not regularly attend lectures were probably not captured. It seems plausible that this group of students contains a lot of students that are at risk to drop out. Thus, our sample might be positively selected and reported effects of interest in university mathematics and mathematical self-concept may even be underestimated. Of course, a small number of students in our sample might have quit their studies of mathematics at the university where our study took place in order to enrol in a mathematics program at another university.

A further limitation lies in the used instruments. Especially, the instrument measuring interest in university mathematics reflects upon the mathematics students encounter in their program. In programs that focus less on formal definitions and proofs, other results might occur. Therefore, it is not clear whether our results can be transferred to other mathematics-demanding study programs (like programs for elementary teachers or engineers).

Moreover, our data concerning the attitudes relies on self-reports that can be biased. For example, some students could rate their interest higher due to effects like social desirability. However, since students' attitudes are latent and not directly observable variables, self-reports are a common approach and can hardly be bypassed. As students were allowed to work on their homework sheets alone or in pairs, the validity of the sheets for measuring students' achievement can be questioned. However, an advantage of considering three consecutive sheets instead of a single test is that the measurement was not based by students' performance at one single time. Furthermore, the homework tasks represented the actual demands students were faced with during the term.

7.4 Implications

Besides the theoretical implications of our results presented above, we want to propose possible practical implications to support students during the transition to university. These didactical measures, which are of course focused on the learning environment to improve students' characteristics, are inspired by our results and by works of other researchers.

As low interest in university mathematics at the very beginning of the study program plays a substantial role for study success, support measures for this interest facet should be provided before the term starts. Rach and Engelmann (2018) used workshops to inform upper secondary students about the characteristics and demands of university mathematics to enhance interest in university mathematics and foster realistic expectations about a mathematics study program. Of course, these workshops may on the one hand affect students with low interest in university mathematics to decide not to enrol in such a program but, on the other hand, other students who get to know university mathematics for the first time in the workshops may enjoy this form of mathematics and decide to enrol in a mathematics program. Thus, informing students about mathematics at university may enable students to perform a more appropriate study choice which offers a stronger person-environment-fit and therefore a smaller risk to drop out.

With regard to mathematical self-concept, the validated mechanism—self-concept predicts achievement, which predicts dropout—seems to be central. During the transition, many students struggle with mathematics tasks for the first time and show only little achievement in the homework sheets (Liebendörfer & Hochmuth, 2017). The assumption is that students, who start their study with a low self-concept, do not dare to work on the demanding homework sheets and therefore show only little achievement. Thus, it may be an arguable idea to design homework sheets partially less demanding than they are at the moment in Germany. Especially, well-balanced homework sheets with less demanding and demanding mathematical tasks at the same time would encourage students with less self-concept to work on the tasks while the learning goals of the first term courses could also be achieved (Blömeke, 2016).

7.5 Conclusion and outlook

All in all, we found evidence that students' attitudes towards mathematics, in particular their interest in university mathematics and their mathematical self-concept, played an important role for predicting early dropout, and that satisfaction and achievement mediated these relations. Thus, the fact that interest and self-concept lead to high study satisfaction and partially to mathematics achievement in the first term illustrates that both attitudes contribute to the person-environment-fit and thus explains how both attitudes influence early dropout. In order to understand the mechanisms behind decisions to drop out in more depth, methods of experience sampling that involve frequent data collections (cf. Akkerman & Bakker, 2019) could be applied. In particular, specific situations as antecedents of the interplay of attitudes and effects on satisfaction and achievement could be analysed in more detail.

Furthermore, we focused on students' characteristics (namely their attitudes) and did not collect data on the actual characteristics of the mathematics courses in which students participated. According to frameworks of person-environment-fit (Lubinski & Benbow, 2000; Swanson & Fouad, 1999), the interplay between students' characteristics and characteristics of the environment determines whether the transition to university mathematics is successful. Characteristics of lecture courses could be captured via structured observations (cf. Rach et al., 2016). Further studies could consider both students' attitudes and actual characteristics of lecture courses using multi-level analysis to gain more detailed insights in the aforementioned interplay (cf. Sarcletti & Müller, 2011). With this study, we give fruitful insight into students' attitudes in a university program which could be a starting point for such analyses.

Funding Open Access funding enabled and organized by Projekt DEAL.

Data availability The datasets generated during or analysed during the current study are available from the corresponding author on reasonable request.

Declarations

Conflict of interest The authors declare no competing interests.

References

Akkerman, S. F., & Bakker, A. (2019). Persons pursuing multiple objects of interest in multiple contexts. *European Journal of Psychology of Education, 34*(1), 1–24. https://doi.org/10.1007/s10212-018-0400-2

Artigue, M. (2016). Mathematics education research at university level: Achievements and challenges. In E. Nardi, C. Winslow, & T. Hausberger (Eds.), *Proc. 1st Conf. of INDRUM* (pp. 11–27). INDRUM.

Baars, G. J. A., & Arnold, I. J. M. (2014). Early identification and characterization of students who drop out in the first year at university. *Journal of College Student Retention: Research, Theory & Practice, 16*(1), 95–109. https://doi.org/10.2190/CS.16.1.e

Bampili, A.-C., Zachariades, T., & Sakonidis, C. (2017). The transition from high school to university mathematics: A multidimensional process. In T. Dooley & G. Gueudet (Eds.), *Proceedings of the Tenth Congress of the European Society for Research in Mathematics Education* (pp. 1985–1992). DCU Institute of Education & ERME.

Bernholt, A., Hagenauer, G., Lohbeck, A., Gläser-Zikuda, M., Wolf, N., Moschner, B., Lüschen, I., Klaß, S., & Dunker, N. (2018). Bedingungsfaktoren der Studienzufriedenheit von Lehramtsstudierenden. [Conditions of study-satisfaction among pre-service teachers]. *Journal for Educational Research Online, 10*(1), 24–51. https://doi.org/10.25656/01:15412

Blömeke, S. (2016). Der Übergang von der Schule in die Hochschule: Empirische Erkenntnisse zu mathematikbezogenen Studiengängen [The transition from school to university: Empirical results concerning mathematics demanding study programs]. In A. Hoppenbrock, R. Biehler, R. Hochmuth, & H.-G. Rück (Eds.), *Lehren und Lernen von Mathematik in der Studieneingangsphase* (pp. 3–13). Springer.

Blömeke, S. (2009). Ausbildungs- und Berufserfolg im Lehramtsstudium im Vergleich zum Diplom-Studium – Zur prognostischen Validität kognitiver und psycho-motivationaler Auswahlkriterien. [Vocational and career success in teacher education programs in comparison to diploma programs.] *Zeitschrift Für Erziehungswissenschaft, 12*(1), 82–110. https://doi.org/10.1007/s11618-008-0044-0

Blüthmann, I. (2012). Individuelle und studienbezogene Einflussfaktoren auf die Zufriedenheit von Bachelorstudierenden [Individual and study-related influences on bachelor students' satisfaction]. *Zeitschrift Für Erziehungswissenschaften, 15*(2), 273–303. https://doi.org/10.1007/s11618-012-0270-3

Bong, M., & Skaalvik, E. M. (2003). Academic self-concept and self-efficacy: How different are they really? *Educational Psychology Review, 15*(1), 1–40. https://doi.org/10.1023/A:1021302408382

Brandstätter, H., Grillich, L., & Farthofer, A. (2006). Prognose des Studienabbruchs. [Prediction of dropout.] *Zeitschrift für Entwicklungspsychologie und Pädagogische Psychologie, 38*(3), 121–131. https://doi.org/10.1026/0049-8637.38.3.121

Cai, D., Viljaranta, J., & Georgiou, G. K. (2018). Direct and indirect effects of self-concept of ability on math skills. *Learning and Individual Differences, 61*, 51–58. https://doi.org/10.1016/j.lindif.2017.11.009

Chen, S.-K., Yeh, Y.-C., Hwang, F.-M., & Lin, S. S. J. (2013). The relationship between academic self-concept and achievement: A multicohort–multioccasion study. *Learning and Individual Differences, 23*, 172–178. https://doi.org/10.1016/j.lindif.2012.07.021

Chen, X. (2013). *STEM attrition: College students' paths into and out of STEM fields*. Washington, DC: National Centre for Education Statistics, U.S. Department of Education. Retrieved from https://nces.ed.gov/pubs2014/2014001rev.pdf

Corbière, M., Fraccaroli, F., Mbekou, V., & Perron, J. (2006). Academic self-concept and academic interest measurement: A multi-sample European study. *European Journal of Psychology of Education, XX, I*(1), 3–15. https://doi.org/10.1007/BF03173566

Daskalogianni, K., & Simpson, A. (2002). "Cooling-Off": The phenomenon of a problematic transition from school to university. In *2nd International Conference on the Teaching of Mathematics (at the Undergraduate Level)* (pp. 103–110). Crete.

De Guzman, M., Hodgson, B. R., Robert, A., & Villani, V. (1998). Difficulties in the passage from secondary to tertiary education. In *Documenta Mathematica - Extra Volume ICM 1998 III* (pp. 747–762).

Di Martino, P., & Gregorio, F. (2018). The first-time phenomenon: Successful students' mathematical crisis in secondary-tertiary transition. In E. Bergqvist, M. Österholm, C. Granberg, & L. Sumpter (Eds.), *Proceedings of the 42nd Conference of the International Group for the Psychology of Mathematics Education* (Vol. 2, pp. 339–346). PME.

Di Martino, P., & Gregorio, F. (2019). The mathematical crisis in secondary-tertiary transition. *International Journal of Science and Mathematics Education, 17*(4), 825–843. https://doi.org/10.1007/s10763-018-9894-y

Dieter, M., & Törner, G. (2012). Vier von fünf geben auf. [Four out of five are giving up.] *Forschung und Lehre, 19*(10) 826–827.

Dreyfus, T. (1991). Advanced mathematical thinking processes. In D. Tall (Ed.), *Advanced Mathematical Thinking* (pp. 25–41). Kluwer.

Eccles, J. S., & Wigfield, A. (2020). From expectancy-value theory to situated expectancy-value theory: A developmental, social cognitive, and sociocultural perspective on motivation. *Contemporary Educational Psychology, 61*, 101859. https://doi.org/10.1016/j.cedpsych.2020.101859

Engelbrecht, J. (2010). Adding structure to the transition process to advanced mathematical activity. *International Journal of Mathematical Education in Science and Technology, 41*(2), 143–154. https://doi.org/10.1080/00207390903391890

Fellenberg, F., & Hannover, B. (2006). Kaum begonnen, schon zerronnen? Psychologische Ursachenfaktoren für die Neigung von Studienanfängern, das Studium abzubrechen oder das Fach zu wechseln. [Psychological reasons for first-year students intention to drop out or change subject.] *Empirische Pädagogik, 20*(4), 381–399.

Fleischer, J., Leutner, D., Brand, M., Fischer, H., Lang, M., Schmiemann, P. & Sumfleth, E. (2019). Vorhersage des Studienabbruchs in naturwissenschaftlich-technischen Studiengängen. [Dropout-prediction in science study programs.] *Zeitschrift für Erziehungswissenschaft, 22*(5), 1077–1097. https://doi.org/10.1007/s11618-019-00909-w

Geisler, S., & Rolka, K. (2018). Affective variables in the transition from school to university mathematics. In V. Durand-Guerrier, R. Hochmuth, S. Goodchild, & N.M Hogstad (Eds.), *Proceedings of the Second Conference of the International Network for Didactic Research in University Mathematics* (pp. 528–537). University of Agder and INDRUM.

Gourgey, A. F. (1982). *Development of a scale for the measurement of self-concept in mathematics.* Retrieved from https://files.eric.ed.gov/fulltext/ED223702.pdf.

Gueudet, G. (2008). Investigating the secondary–tertiary transition. *Educational Studies in Mathematics, 67*, 237–254. https://doi.org/10.1007/s10649-007-9100-6

Hailikari, T., Nevgi, A., & Komulainen, E. (2008). Academic self-beliefs and prior know- ledge as predictors of student achievement in mathematics: A structural model. *Educa- Tional Psychology, 28*(1), 59–71. https://doi.org/10.1080/01443410701413753

Halverscheid, S., & Pustelnik, K. (2013). Studying math at the university: Is dropout predictable? In A. M. Lindmeier & A. Heinze (Eds.), *Proceedings of the 37th Conference of the International Group for the Psychology of Mathematics Education.* (Vol. 2, pp. 417–424). PME.

Hayes, A. F. (2018). *Introduction to mediation, moderation and conditional process analysis - a regression-based approach* (2nd ed.). The Guildford Press.

Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist, 41*(2), 111–127. https://doi.org/10.1207/s15326985ep4102_4

Höhne, E., & Zander, L. (2019). Belonging uncertainty as predictor of dropout intentions among first-semester students of the computer sciences. *Zeitschrift Für Erziehungswissenschaft, 22*(5), 1099–1119. https://doi.org/10.1007/s11618-019-00907-y

Jordan, A., Krauss, S., Löwen, K., Blum, W., Neubrand, M., Brunner, M., & Baumert, J. (2008). Aufgaben im COACTIV-Projekt: Zeugnisse des kognitiven Aktivierungspoten- tials im deutschen Mathematikunterricht [Tasks in the COACTIV-project: Evidence of the potential for cognitive cctivation in German mathematics classes]. *Journal Für Mathematikdidaktik, 29*(2), 83–107. https://doi.org/10.1007/BF03339055

Kauper, T., Retelsdorf, J., Bauer, J., Rösler, L., Möller, J., & Prenzel, M. (2012). *PaLea - Panel zum Lehramtsstudium: Skalendokumentation und Häufigkeitsauszählungen des BMBF-Projektes.* [PaLea – panel of teacher education: Documentation of the scales used in the BMBF-project.] Retrieved from http://www.palea.uni-kiel.de/wp-content/uploads/2012/04/PaLea%20Skalendokumentation%204_%20Welle.pdf.

Kolter, J., Liebendörfer, M., & Schukajlow, S. (2016). Mathe – nein danke? Interesse, Beliefs und Lernstrategien im Mathematikstudium bei Grundschullehramtsstudierenden mit Pflichtfach. [Math – no thanks? Interest, beliefs and learning strategies of elementary pre-service teachers] In A. Hoppenbrock, R. Biehler, R. Hochmuth & H.-G. Rück (Eds.), *Lehren und Lernen von Mathematik in der Studieneingangsphase Konzepte und Studien zur Hochschuldidaktik und Lehrerbildung Mathematik* (pp. 567–583). Springer.

Kosiol, T., Rach, S., & Ufer, S. (2019). (Which) mathematics interest is important for a successful transition to a university study program? *International Journal of Science and Mathematics Education, 17*(7), 1359–1380. https://doi.org/10.1007/s10763-018-9925-8

Krapp, A. (2007). An educational-psychological conceptualisation of interest. *International Journal for Educational and Vocational Guidance, 7*(1), 5–21. https://doi.org/10.1007/s10775-007-9113-9

Krapp, A., Hidi, S., & Renninger, K. A. (1992). Interest, learning and development. In K. A. Renninger, S. Hidi, & A. Krapp (Eds.), *The role of interest in learning and development* (pp. 3–25). Erlbaum.

Liebendörfer, M., & Hochmuth, R. (2013). Interest in mathematics and the first steps at the university. In *Proceedings of the 8th Conference of the European Society for Research in Mathematics Education* (pp. 2386–2395). Middle East Technical University.

Liebendörfer, M., & Hochmuth, R. (2017). Perceived competence and incompetence in the first year of mathematics studies: Forms and situations. In R. Göller, R. Biehler, R. Hochmuth, & H.-G. Rück

(Eds.), *Didactics of Mathematics in Higher Education as a Scientific Discipline – Conference Proceedings* (pp. 286–293). Universitätsbibliothek Kassel.

Liston, M., & O'Donoghue, J. (2009). Factors influencing the transition to university service mathematics: Part 1 a quantitative study. *Teaching Mathematics and Its Applications, 28*(2), 77–87. https://doi.org/10.1093/teamat/hrp006

Lubinski, D., & Benbow, C. (2000). States of excellence. *American Psychologist, 55*(1), 137–150. https://doi.org/10.1037/0003-066X.55.1.137

Marsh, H. W., Pekrun, R., Parker, P. D., Murayama, K., Guo, J., Dicke, T., & Arens, A. K. (2019). The murky distinction between self-concept and self-efficacy – Beware of lurking jingle-jangle fallacies. *Journal of Educational Psychology, 111*(2), 331–353. https://doi.org/10.1037/edu0000281

Martínez-Sierra, G., & García-González, M. D. S. (2016). Undergraduate mathematics students' emotional experiences in linear algebra courses. *Educational Studies in Mathematics, 91*(1), 87–106. https://doi.org/10.1007/s10649-015-9634-y

Muthén, L. K., & Muthén, B. O. (1998–2017). *Mplus user's guide* (8th ed.). Muthén & Muthén.

Nagy, G. (2006). Berufliche Interessen, kognitive und fachgebundene Kompetenzen: Ihre Bedeutung für die Studienfachwahl und die Bewährung im Studium. [Career interest, cognitive and subject specific competences: On their relevance for course choices and study success] (Doctoral dissertation). Freie Universität Berlin. Retrieved from http://www.diss.fu-berlin.de/diss/receive/FUDISS_thesis_000000002714.

OECD (2020). *Global teaching insights: A video study of teaching*. OECD Publishers. Retrieved from https://doi.org/10.1787/20d6f36b-en

Pinto, A. (2017). Why different mathematics instructors teach students different lessons about mathematics in lectures. In R. Göller, R. Biehler, R. Hochmuth, & H.-G. Rück (Eds.), *Didactics of Mathematics in Higher Education as a Scientific Discipline – Conference Proceedings* (pp. 236–240). Universitätsbibliothek Kassel.

Pritchard, D. (2015). Lectures and transition: From bottles to bonfires? In A. C. Croft, M. J. Grove, J. Kyle, & D. A. Lawson (Eds.), *Transitions in Undergraduate Mathematics Education* (pp. 57–69). University of Birmingham.

Rach, S., & Heinze, A. (2017). The transition from school to university in mathematics: Which influence do school-related variables have? *International Journal of Science and Mathematics Education., 15*(7), 1343–1363. https://doi.org/10.1007/s10763-016-9744-8

Rach, S., & Ufer, S. (2020). Which prior mathematical knowledge is necessary for study success in the university study entrance phase? Results on a new model of knowledge levels based on a reanalysis of data from existing studies. *International Journal of Research in Undergraduate Mathematics Education, 6*, 375–403. https://doi.org/10.1007/s40753-020-00112-x

Rach, S., Siebert, U., & Heinze, A. (2016). Operationalisierung und empirische Erprobung von Qualitätskriterien für mathematische Lehrveranstaltungen in der Studieneingangsphase [Development and testing of quality criteria for mathematics lectures]. In A. Hoppenbrock, R. Biehler, R. Hochmuth, & H.-G. Rück (Eds.), *Lehren und Lernen von Mathematik in der Studieneingangsphase Konzepte und Studien zur Hochschuldidaktik und Lehrerbildung Mathematik* (pp. 567–583). Springer.

Rach, S., & Engelmann, L. (2018). Students' expectations concerning studying mathematics at university. In E. Bergqvist, M. Österholm, C. Granberg & L. Sumpter (Eds.), *Proceedings of the 42nd Conference of the International Group for the Psychology of Mathematics Education* (Vol. 5, p. 141). PME.

Rach, S., Ufer, S. & Kosiol, T. (2019). Self-concept in university mathematics courses. In U. T. Jankvist, M. Van den Heuvel-Panhuizen & M. Veldhuis (Eds.), *Proceedings of the Eleventh Congress of the European Society for Research in Mathematics Education* (pp. 1509–1516). Freudenthal Group & Freudenthal Institute, Utrecht University and ERME.

Rach, S., Ufer, S. & Kosiol, T. (2021). Die Rolle des Selbstkonzepts im Mathematikstudium – Wie fit fühlen sich Studierende in Mathematik? [The role of self-concept when studying mathematics – how fit do students feel in mathematics?] *Zeitschrift für Erziehungswissenschaft 24*, 1549–1571. https://doi.org/10.1007/s11618-021-01058-9

Sarcletti, A., & Müller, S. (2011). Zum Stand der Studienabbruchforschung. Theoretische Perspektiven, zentrale Ergebnisse und methodische Anforderungen an künftige Studien. [State of the art in research concerning dropout. Theoretical perspectives, central results and methodological demands for future studies.] *Zeitschrift Für Bildungsforschung, 1*, 235–248. https://doi.org/10.1007/s35834-011-0020-2

Schiefele, U., & Jacob-Ebbinghaus, L. (2006). Lernermerkmale und Lehrqualität als Bedingungen der Studienzufriedenheit. [Learners‘ characteristics and teaching quality as predictors of satisfaction.] *Zeitschrift Für Pädagogische Psychologie, 20*(3), 199–212. https://doi.org/10.1024/1010-0652.20.3.199

Schneider, M., & Preckel, F. (2017). Variables associated with achievement in higher education: A systematic review of meta-analyses. *Psychological Bulletin, 143*(6), 565–600. https://doi.org/10.1037/bul0000098

Schnettler, T., Bobe, J., Scheunemann, A., Fries, S. & Grunschel, C. (2020). Is it still worth it? Applying expectancy-value theory to investigate the intraindividual motivational process of forming intentions to drop out from university. *Motivation and Emotion*. https://doi.org/10.1007/s11031-020-09822-w.

Swanson, J. L., & Fouad, N. A. (1999). Applying theories of person-environment fit to the transition from school to work. *The Career Development Quarterly Jun, 47*(June), 337–347. https://doi.org/10.1002/j.2161-0045.1999.tb00742.x

Tall, D. (1992). The transition to advanced mathematical thinking: Functions, limits, infinity and proof. In D. A. Grouws (Ed.), *Handbook of Research on Mathematics Teaching and Learning* (pp. 495–511). Macmillan.

Trautwein, U., Lüdtke, O., Köller, O., & Baumert, J. (2006). Self-esteem, academic self-concept, and achievement: How the learning environment moderates the dynamics of self-concept. *Journal of Personality and Social Psychology, 90*(2), 334–349. https://doi.org/10.1037/0022-3514.90.2.334

Ufer, S., Rach, S., & Kosiol, T. (2017). Interest in mathematics = interest in mathematics? What general measures of interest reflect when the object of interest changes. *ZDM-Mathematics Education, 49*(3), 397–409. https://doi.org/10.1007/s11858-016-0828-2

Ulriksen, L., Madsen, L., & Holmegaard, H. T. (2010). What do we know about explanations for drop out/opt out among young people from STM higher education programs? *Studies in Science Education, 46*(2), 209–244. https://doi.org/10.1080/03057267.2010.504549

Vollstedt, M., Heinze, A., Gojdka, K., & Rach, S. (2014). Framework for examining the transformation of mathematics and mathematics learning in the transition from school to university. In S. Rezat, M. Hattermann, & A. Peter-Koop (Eds.), *Transformation – A fundamental idea of mathematics education* (pp. 29–50). Springer.

Weber, B.-J. & Lindmeier, A. (2020). Viel Beweisen, kaum Rechnen? Gestaltungsmerkmale mathematischer Übungsaufgaben im Studium. [A lot of Proofing, barely calculating? Characteristics of mathematics tasks at university.] *Mathematische Semesterberichte, 39* (2), 223–245. https://doi.org/10.1007/s00591-020-00274-4

Wu, H., Guo, Y., Yang, Y., Zhao, L., & Guo, C. (2021). A meta-analysis of the longitudinal relationship between academic self-concept and academic achievement. *Educational Psychology Review, 33*, 1749–1778. https://doi.org/10.1007/s10648-021-09600-1