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# Development of affect at the transition to university mathematics and its relation to dropout — identifying related learning situations and deriving possible support measures

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## Abstract

The transition from school to university mathematics is a challenging process for many students. This phenomenon is reflected by high dropout rates from mathematics programs especially during the first year at university that may be related to the development of students' mathematical interest and self-concept. Taking a learning psychological perspective, it is a relevant question if all students have similar development patterns of these variables or if students who are at risk to drop out show an unfavorable development. Moreover, for didactical issues, it is of particular relevance which factors influence this development. Within a longitudinal study, 556 first-semester students stated their interest and self-concept at the beginning and the middle of the first semester; dropout was measured at the beginning of the second year. By using regression analyses, we found that the development of students' interest and self-concept is related to dropout. It seems that interest in university mathematics and mathematical self-concept of students, who dropped out, decreased significantly in contrast to the characteristics of students who continued their studies. In an exploratory follow-up study, we identified factors which probably influenced the development of students' self-concept by asking 18 students in a first-semester mathematics course "linear algebra" about learning situations in which they experienced the emergence or the decline of self-concept. Using qualitative content analysis, we found that most of these situations occurred when students worked on mathematical homework tasks or got criterial feedback on their solutions. Based on the presented results, we discuss implications for teaching and learning of undergraduate mathematics.

**Keywords** Transition from school to university mathematics · Development of affect · Interest · Self-concept · Frame of reference

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## 1 Introduction

The transition from school to university mathematics is challenging for many students. Despite different educational systems, researchers from various countries have reported similar observations of students struggling during this phase. These observations are supported by high dropout rates from mathematics programs in many countries (e.g., USA: Chen 2013; Germany: Heublein et al., 2017). One frequently discussed reason for students' difficulties during the transition is possible differences between mathematical learning processes at school and at university (e.g., Engelbrecht, 2010; Gueudet, 2008) and students' inability to cope with these unknown requirements at university.

According to Artigue (2016), early studies in the field had a strong focus on cognitive aspects of the transition (e.g., cognitive requirements of the new learning environment and students' problems to fulfill these new requirements). However, recent research pays attention to students' affective characteristics in relation to different learning processes at school and university as well (e.g., Di Martino & Gregorio, 2019; Kosiol et al., 2019). These studies have shown that mathematics-related affects — like interest in mathematics and mathematical self-concept — are connected with students' success in mathematics study programs. Furthermore, the development of students' affect during the transition has been investigated, leading to the assumption that rather successful students probably differ from rather unsuccessful students (in terms of, e.g., failing an exam) by showing a more beneficial development of affect like stabilized interest instead of decreasing interest (e.g., Di Martino & Gregorio, 2019; Geisler & Rolka, 2021; Rach & Heinze, 2013). However, research that examines the relation between students' development of affect and dropout has still been scarce. Understanding possible links between affect development and dropout can help to better understand the phenomenon dropout itself and help to support students who are at risk to drop out.

In this contribution, we present results from two consecutive studies concerning the development of students' affect during the transition. The purpose of study 1 was to investigate in which way the development of students' interest in mathematics as well as mathematical self-concept and dropout from mathematics programs relates to each other. As students' self-concept plays a crucial role in the first semester, study 2 focused on learning situations during the transition that may affect the development of self-concept. The two studies together shed light on the role of mathematics-related affect and its development as important predictors of study success on the one hand and on possible antecedents of this development influenced by the learning environment on the other hand.

## 2 Theoretical and empirical background

In the following, we give a brief overview of significant differences between mathematical learning processes at school and university that can affect students' interest and self-concept during the transition. Hereby, we take a special focus on the German context, where our studies took place. Afterwards, we discuss the role of students' interest and self-concept during the first months at university.

### 2.1 Mathematical learning processes at school and at university

Major differences between mathematical learning processes at school and at university involve (among others) organizational as well as content-related aspects. One important organizational aspect of university mathematics programs is the lecturing format with large classes (Bergsten, 2007). Lectures in advanced mathematics are often accompanied by sections in which small groups of students work on related tasks supported by teaching assistants (usually PhD- or experienced masters-students). In Germany, students have to hand in weekly homework tasks. Sometimes, by solving these tasks correctly, students can earn extra points for the final exams, or solving tasks is mandatory in order to be allowed to participate in the exams (Weber & Lindmeier, 2020). Handed-in tasks are graded by teaching assistants.

With regard to content-related aspects, in the German context — as in many other countries — a general shift can be seen from a rather applied subject in school that aims at general literacy to a scientific and theory-driven discipline at university (e.g., Niss 1994; Rach, 2014). This general shift involves differences in the way new content is presented during lessons and lectures as well as differences in the tasks students have to solve (cf. Bergsten, 2007; de Guzmán et al., 1998; Luk, 2005; Weber & Lindmeier, 2020).

With regard to typical tasks posed in mathematics lessons at school, a dominance of schematic calculation-tasks is often discussed (e.g., de Guzmán et al., 1998; Engelbrecht, 2010). Empirical studies like COACTIV (Cognitive Activation in the Classroom, Jordan et al., 2008) and TALIS (Teaching and Learning International Survey, OECD, 2020) confirmed that most tasks in German mathematics classrooms involve routine procedures while complex problem-solving tasks are scarce. Analyzing German mathematics textbooks, Vollstedt et al. (2014, p. 47) concluded that "proofs are underemphasized at school." That is one reason why most students have only little experiences with proving when entering university (cf. de Guzmán et al., 1998).

In advanced mathematics courses at university, new concepts are usually introduced via formal definitions (Tall, 1992). The language used in many definitions is very technical and therefore hides the phenomenological roots of the concepts (Hefendehl-Hebeker, 2017). Besides, during lectures, proofs are often presented in their final form. The process of generating new theorems and of developing ideas for the proof usually remains invisible for the students (Pinto, 2017). In contrast to school, routine tasks are less prevalent at university while proof-related tasks play a bigger role (Pritchard, 2015; Thomas & Klymchuk, 2012). Weber and Lindmeier (2020) analyzed mathematics tasks from a German university and reported that nearly 70% of the tasks involve proving.

These observations concerning teaching and learning mathematics at school and at university apply for the German context as well: both lecture courses — linear algebra and real analysis — that most German freshmen attend during their first year in mathematics programs have a strong focus on formal definitions and rigorous deductive proofs (Halverscheid & Pustelnik, 2013). Observing lectures in real analysis at a German university, Rach et al. (2016) found that formal definitions are only seldom motivated and that the process of developing a proof-idea is mostly hidden in the back and not explicated to students. Usually, real analysis courses in Germany cover topics such as convergence of sequences and series, continuity, and differentiation of single- and multivariable functions while linear algebra has mostly a strong focus on vector spaces and homomorphisms as well as bilinear forms.

In order to ease the transition from school to university, most German universities offer voluntary preparatory courses (sometimes called bridging courses) prior to the official beginning of the mathematics programs. According to Greefrath et al. (2017), these courses vary in content, didactical approach, and format (online vs. in class). Most courses recall school mathematics but some courses also give first insights into the structure of the scientific discipline of mathematics.

The aforementioned differences between mathematics at school and at university are frequently recognized by students and seem to influence their affective characteristics towards mathematics (see, for example, Di Martino & Gregorio, 2019 or Hernandez-Martinez, 2016 for the international context and Geisler, 2018 or Witzke, 2015 for the German context).

## 2.2 Role of affect in the study entry phase

### 2.2.1 Conceptualization of interest and self-concept

Based on person-object theories that have been proposed for educational contexts, we conceptualize *interest* as a specific relation between an individual and an (abstract) object, for example, mathematics (Krapp, 2002). Many conceptualizations distinguish different components of mathematical interest, like an emotion-related component, usually related to joy experienced when dealing with mathematics, and a value-related component, referring to the value a person attributes to mathematics (see Di Martino & Zan, 2015; Schiefele et al., 1992). While situational interest is seen as a motivational state (Hidi & Renninger, 2006; Schiefele, 2009), individual interest describes a relatively stable personal trait which allows individuals to activate interest states in specific situations (Krapp, 2002; see also Hannula, 2011). Affective variables are also studied within expectancy-value theories of motivation (Eccles & Wigfield, 2020).

*Self-concept* and *self-efficacy* are important constructs, which describe students' views about themselves. Self-concept has its focus on a person's skills and abilities, whereas self-efficacy refers to one's beliefs to successfully perform a certain activity in the future (Marsh et al., 2019). Although self-concept and self-efficacy have different theoretical roots, the two constructs are empirically strongly related to each other (Eccles & Wigfield, 2020). However, for self-concept, there are promising frameworks which explain the adjustment of self-concept due to characteristics of the learning environment, so far mainly applied in the school context (e.g., big-fish-little-pond effect, Marsh et al., 2019). Due to these frameworks, we use in this contribution the construct self-concept to gain a global insight into students' mental image of their abilities and to understand which role this image plays in the context of a university mathematics program. We refer to mathematical self-concept as students' beliefs about their own mathematical knowledge and skills (Bong & Skaalvik, 2003). In the literature, self-concept is partially regarded as an affect and partially as a cognitive variable, since it is built on views (affect side) which refer to knowledge and skills (cognition side).

### 2.2.2 Predictors of dropout

Dropout is considered a (negative) certificate criterion of study success (e.g., Nagy, 2006; Sorge et al., 2016) and divides the group of students into two groups: students who still have the possibility to succeed in their voluntarily chosen study program at the university and students who give up their study program at that university. Dropout is related to other criteria of study success, for example, subjective criteria, such as study satisfaction, and objective criteria, such as learning achievement, or dropout intention (Sorge et al., 2016). As there are only few studies that analyze the role of interest and self-concept for actual dropout, we also refer to studies which analyze the role of affect for other criteria of study success.

Interest in mathematics is assumed to predict study success because interested learners pay more attention on the learning process (Ainley et al., 2002; Hidi & Renninger, 2006) and use more elaboration strategies leading to a deeper understanding of the learning content (Schiefele et al., 1995). This mechanism may encourage students to stay in their chosen study program. However, empirical results have shown a less clear picture for this assumed positive role of mathematics interest in a study program: whereas Rach and Heinze (2017) found no influence of students' interest in mathematics on their achievement in the first semester when controlling prior achievement and knowledge, Geisler and Rolka (2018) reported less interest among students who failed in their first exam than among those students who passed the exam. Contrary to the relation between achievement and interest, interested students indeed stated more study satisfaction (Kosiol et al., 2019; Schiefele & Jacob-Ebbinghaus, 2006). The results of Kosiol et al. (2019) point out that interest in university mathematics supports study satisfaction whereas interest in school mathematics may hinder the development of study satisfaction. For dropout intention, Schnettler et al. (2020) reported that intra-individual changes in intrinsic value (similar to interest) in a sample of law and mathematics students related to changes in dropout intention during the first semester in the sense that decreasing intrinsic value was related to increasing dropout intention.

Mathematical self-concept is assumed to relate to study success because learners with a strong self-concept engage in more demanding tasks, which results in more profound learning processes, higher achievement, and maybe satisfaction with the chosen study program. A recent meta-analysis for the longitudinal relationship between academic self-concept and academic achievement (respectively mathematical knowledge) has supported this assumption for many age groups (Wu et al., 2021) but studies in the first semester of a mathematics study program showed only weak or non-significant relations between self-concept and different criteria of study success (Hailikari et al., 2008; Liston & O'Donoghue, 2009; Rach, 2014; Rach & Heinze, 2017). Geisler and Rolka (2018) reported higher mathematical self-concept among students who passed their exams than among those students who failed and indicated that students who did not attend their exams showed a lower mathematical self-concept than students who attended the exam. Since exam attendance is a useful indicator for dropout (Baars & Arnold, 2014), it seems plausible that students' mathematical self-concept is related to dropout.

Explorative studies have claimed that a low mathematical self-concept and the decrease of self-concept in the first study year — even among students with excellent learning prerequisites — probably lead to dropout (Bampili et al., 2017; Di Martino & Gregorio, 2018). This is in line with the results of Rach et al. (2022) who analyzed the relationship between mathematical self-concept and study satisfaction and point out that students' self-concept in the middle of the first term is a stronger predictor of study satisfaction than the initial self-concept when entering university.

This short literature review indicates that in contrast to cognitive characteristics, such as prior knowledge or previous achievement (Hailikari et al., 2008; Halverscheid & Pustelnik, 2013; Rach & Heinze, 2017), the role of affective characteristics for predicting dropout is slightly unclear (see also Bengmark et al., 2017; Kosiol et al., 2019). Moreover, the studies by Schnettler et al. (2020) and Rach et al. (2022) suggest that not only affect at the beginning of a study program is relevant during the transition but also the development of affect in the first study weeks seems to be important. A theoretical chain of effects, why a decline in interest and self-concept relates to study dropout, is as follows: interest and self-concept are important predictors of study choice (interest: Jensen & Henriksen, 2015; self-concept: Moakler & Kim, 2014). If the factors why students have chosen the study program change substantially, then the choice itself may also change.

That is why we take a closer look into research analyzing the development of affect in mathematics learning processes.

### 2.2.3 Development of interest and self-concept in the learning process

There is much evidence that interest in mathematics decreases in the adolescence (Frenzel et al., 2010). However, in the university context, there are inconsistent results concerning its development: whereas Liebendörfer and Schukajlow (2017) reported no change in interest in mathematics of 92 teacher education students in a program for lower secondary schools in the first study year, Rach et al. (2018) showed a moderate decrease in interest in university mathematics (and not in school mathematics) in a sample of over 200 students in a mathematics bachelor program or a teacher education program for higher secondary schools (see also Kuklinski et al., 2018). These findings can be explained by unfulfilled expectations that do not fit to university mathematics (Daskalogianni & Simpson, 2002). If students' expectations are not fulfilled, this can lead to study dropout as the students are no longer interested in their study program and decide to leave university. According to Ufer et al. (2017), inconsistent results concerning the role of interest in mathematics during the transition can be a result of unspecific measurement in the sense that many used instruments do not distinguish between interest in school mathematics and interest in university mathematics. They pointed out that a clear distinction is necessary. Indeed, within a qualitative interview study, Liebendörfer and Hochmuth (2013) found that especially students' interest in university mathematics decreases during the first year at university.

Although theoretical conceptualizations described mathematical self-concept as a rather stable trait (Jansen et al., 2020), empirical results showed that mathematical self-concept diminishes during school (Hannula et al., 2004; Köller et al., 2006) which is also expected during the transition from school to university in mathematics. For the university context, there is empirical evidence that mathematical self-concept decreases in the first semester of a mathematics study program (Rach & Heinze, 2017). A decrease in self-concept means that students feel less confident in mathematics in the middle of the semester than at the beginning of semester and thus, they may lose hope to cope with the university requirements.

According to Bong and Skaalvik (2003), students' self-concept is influenced by prior experiences of competence and incompetence as well as the attribution thereof (cf. Liljedahl, 2005). For adjusting individual self-concept, learners use a frame of reference to evaluate their own mathematical abilities and achievement. In the internal/external frame of reference model (e.g., Marsh et al., 2015), dimensional (internal) and social (external) frames of references are subsumed: dimensional frames of references refer to performances of a person in different domains. Social frames of references occur if a student compares their own abilities with abilities which are shown by members of the peer group. As the peer group changes at the transition to university, the *big-fish-little-pond effect* (e.g., Marsh, 2005) probably plays a role in the development of self-concept at this institutional transition. Most mathematics students belonged to the group of high achievers in school mathematics and are now confronted with a new situation where they do not belong to the best in class — the frame of reference changes during the transition. In addition, for many students, it is a new experience to struggle with tasks in mathematics — Di Martino and Gregorio (2018) talked about this, calling it the *first-time-phenomenon*.

Also, temporal and criterial references can be used to adjust the individual mathematical self-concept. Using temporal references, learners compared their current performance with performances they showed some time ago (Wolff et al., 2019). For applying criterial references, self-selected or externally set requirements are needed so that a learner compares his or her performance with these requirements. Liebendörfer (2018) found that students in a university mathematics program often used criterial references to adjust their self-concept that led in most of the cases to a reduction of self-concept. If, for example, students do not experience competence when solving mathematical homework tasks or get negative feedback on their handed-in solutions, their mathematical self-concept probably declines.

This reference system gives us ideas which situational factors foster or hinder the development of mathematical self-concept. High and unfamiliar requirements in the first year are assumed to influence the development of self-concept substantially. In Germany, these requirements are often visible in the weekly mathematical homework tasks as one organizational aspect of the program, which students have to solve and hand in. As the content-related requirements for students are rather unfamiliar to them, e.g., proving a statement, they often struggle right at the beginning of the first semester.

Summarizing, empirical results on the role of interest and self-concept for dropout from mathematics programs and especially the role of the development of affects for dropout are scarce. First results by interview studies point out which factors may influence the progress of affect in the first semester.

## 3 Study 1: prediction of dropout by the development of self-concept and interest

### 3.1 Research question and hypotheses

The goal of study 1 is to provide insights on how important affective characteristics, with which students enter university, are, and how important the progress of these affective characteristics in the first semester is. Our investigation aims to provide answers to the following question:

> To what extent is dropout at the end of the first year of a university mathematics program predicted by the level of interest in school mathematics, interest in university mathematics, and mathematics self-concept at the beginning of the first year and their development during the first semester?

As school mathematics is not the learning content in the first year, we assume no influence of interest in school mathematics on dropout (hypothesis 1). As interest in university mathematics related positively to study satisfaction (Kosiol et al., 2019), we expect negative relation to dropout (hypothesis 2). In line with prior research (Geisler & Rolka, 2018), we expect that mathematical self-concept at the beginning of the first semester has a negative effect on dropout (hypothesis 3). Since affective characteristics of some students in the first semester decreased substantially (Rach et al., 2018), it is a relevant question if the individual development of the affective characteristics (intra-individual changes) has an effect on dropout, in such a way that the development is an early indicator of dropout. If students' interest and self-concept concerning the study content decrease, they are probably less motivated to go on with their study program. Based on previous research (e.g., Di Martino & Gregorio, 2018; Kosiol et al., 2019), we assume that a positive development of interest in university mathematics (increasing interest) has a negative effect on dropout (hypothesis 4), and a positive development of self-concept (increasing self-concept) in the first semester has a negative effect on dropout (hypothesis 5) as well. In contrast, we do not have a special hypothesis concerning the influence of the development of students' interest in school mathematics.

## 3.2 Sample and methods

Five hundred fifty-six first year students ($M$(Age) = 20; 48% male) from three consecutive cohorts enrolled in a mathematics bachelor program (pure mathematics) or a teacher education program (for upper secondary preservice mathematics teachers) at a large German university voluntarily participated in our study. The university is not selective. Eighty-four percent of the students indicated that the mathematics program was their first choice to study. The students attended the same lecture courses in real analysis and linear algebra during their first year. Besides, students in the mathematics bachelor program had some courses in a minor subject while preservice teachers attended additional courses in a second teaching subject. Both bachelor programs, each lasting 3 years, are rather similar concerning the mathematical courses in which students have to participate. Only at the masters level, students in the teacher education program enroll in some courses in mathematics education whereas students in the mathematics program deepen their knowledge in a specific mathematical field.

We used a longitudinal design to evaluate students' mathematics-related affects and their development. Following the approach of Ufer et al. (2017), we distinguished between interest in school and in university mathematics and we take into account items which consider the emotion-related (sample item: "The kind of mathematics that is done at university is fun for me.") and the value-related component (sample item: "The kind of mathematics that is done at university, is very important for me") of interest[1]. We decided not to distinguish self-concept concerning school and university mathematics since recent empirical results revealed high correlations between these two facets of self-concept (Rach et al., 2019). Therefore, a clear distinction between self-concept regarding school and university mathematics is less evident than in the case of interest. During the first two weeks of the semester (T1) and 6 weeks later (T2), participants reported their *interest in school and university mathematics and their self-concept in mathematics* by filling in a paper-pencil questionnaire (see Table 1) during the lecture courses "real analysis" and "linear algebra." All items were answered on a five-point likert style format[2] (1 = totally disagree, 2 = disagree, 3 = partially agree, 4 = agree, 5 = totally agree). All used scales had good reliabilities.

[1] All items of the scales "interest in school" and "interest in university mathematics" can be found here: https://static-content.springer.com/esm/art%3A10.1007%2Fs11858-016-0828-2/MediaObjects/11858_2016_828_MOESM1_ESM.pdf.

[2] We are aware that there is a long-lasting debate on how to analyze Likert scales and especially whether parametric tests can be applied (e.g., Jamieson, 2004; Norman, 2010). We follow the argumentation by Norman (2010).

**Table 1** Instruments with numbers of items, reliabilities (Cronbach's $\alpha$), and sample items

| Construct | Source | # items | $\alpha$ (T1/T2) | Sample item |
|---|---|---|---|---|
| Interest, school | Ufer et al. (2017) | 5 | 0.80/0.79 | The kind of mathematics that I learned at school, is one of the most important things for me. |
| Interest, university | Ufer et al. (2017) | 5 | 0.89/0.91 | The kind of mathematics that is done at university is fun for me. |
| Self-concept | Kauper et al. (2012) | 4 | 0.83/0.83 | I am very good in my study subject mathematics. |

Furthermore, a confirmatory factor analysis confirmed the intended factorial structure at both measurement points as well as factorial invariance[3]. At the beginning of the semester, students additionally stated demographic data (like age and gender) as well as their school qualification grades.

*Dropout* was measured at the beginning of the consecutive winter semester (beginning of year 2). We checked whether students were still enrolled in their mathematics program. All students who were not enrolled anymore (regardless whether they had changed their major or left the university entirely) were regarded as dropped out ($n=242$). The other students are non-dropout students ($n=314$).

In all analyses, continuous methods were applied despite the fact that the items on which the scales were built on had only five response categories. To answer the research question, we analyzed different logistic regression models (dependent dichotomous variable: dropout) and handled missing data via the full information maximum likelihood algorithm as implemented in Mplus (Muthén & Muthén, 1998–2015). Since previous studies confirmed that prior achievement is a strong predictor of a successful transition (Hailikari et al., 2008; Rach & Heinze, 2017), we decided to control for students' school qualification grades during the regression analyses.

### 3.3 Results

Table 2 gives an overview of all variables at all measurement points. No floor or ceiling effects occur. Relevant correlations can be found between self-concept and interest in university mathematics at the beginning of the semester (T1) as well as during the first semester (T2). Furthermore, autocorrelations between both measurement points can be found for all three affect variables.

For predicting students' dropout, we calculated logistic regression analyses with interest facets and self-concept as well as their development as predictors while constantly controlling for students' school qualification grade. Multi-collinearity was no problem for this analysis (tolerance $>0.4$; VIF[4] $<2.5$). The development of students' affect was calculated as the difference of students' affect at the middle of the first semester (T2) and their affect at the beginning of their mathematics program (T1), for example, Development

[3] The intended three factor model showed the best fit ($\chi^2(335)=1016.81$; RMSEA $=0.06$; CFI $=0.88$; SRMR $=0.09$) compared with a single factor model ($\chi^2(349)=2496.26$; RMSEA $=0.11$; CFI $=0.61$; SRMR $=0.16$) and a two-factor model where both interest-facets were combined ($\chi^2(344)=2014.88$; RMSEA $=0.09$; CFI $=0.70$; SRMR $=0.15$). A model with weak factorial invariance still showed acceptable fit ($\chi^2(346)=1060.07$; RMSEA $=0.06$; CFI $=0.87$; SRMR $=0.09$).

[4] VIF abbreviates the variance inflation factor.

**Table 2** Means, standard deviations, and correlations of all variables at T1 and T2

| | *M* | SD | *N* | IS T1 | IU T1 | SC T1 | IS T2 | IU T2 | SC T2 |
|---|---|---|---|---|---|---|---|---|---|
| Interest, school (IS) T1 | 3.51 | 0.74 | 537 | | | | | | |
| Interest, university (IU) T1 | 3.02 | 0.87 | 372 | 0.33** | | | | | |
| Self-concept (SC) T1 | 2.84 | 0.70 | 372 | 0.21** | 0.63** | | | | |
| Interest, school (IS) T2 | 3.73 | 0.71 | 267 | 0.63** | 0.16* | 0.13 | | | |
| Interest, university (IU) T2 | 3.21 | 0.88 | 267 | 0.18** | 0.81** | 0.61** | 0.06 | | |
| Self-concept (SC) T2 | 2.88 | 0.70 | 264 | 0.16** | 0.57** | 0.75** | 0.07 | 0.62** | |
| School-qualification grade | 2.71 | 0.65 | 539 | 0.13** | 0.16** | 0.20** | −0.01 | 0.15* | 0.13* |

*Note*: affect items rated from *1 = total disagreement* to *5 = total agreement*, school qualification grade from *1 = sufficient* to *4 = very good*; ** $p < .01$ (two-tailed), * $p < .05$ (two-tailed)

Self-Concept = Self-Concept (T2) − Self-Concept (T1). Therefore, positive values in the development also indicate a positive development (e.g., increasing self-concept). All predictors have been standardized.

Model 1 only consists of interest in school and university mathematics as well as students' self-concept at the beginning of their mathematics program. The results of this analysis can be found in Table 3. Model 1 explains 15% of the variance in students' dropout behavior. Students' interest in school mathematics is not predictive with regard to dropout, which supports hypothesis 1 that interest in school mathematics has no influence on dropout. In contrast, higher interest in university mathematics is related to less risk to dropout, as expected (hypothesis 2). Similarly, we can confirm hypothesis 3: students' mathematical self-concept goes along with decreasing risk to drop out.

**Table 3** Results of the regression analyses, predicting dropout

| | Model 1 | | Model 2 | |
|---|---|---|---|---|
| | *B* | Exp(*B*) | *B* | Exp(*B*) |
| Interest, school (T1) | −0.04 | 0.97 | −0.06 | 0.94 |
| Interest, university (T1) | −0.37 | 0.69* | −0.46 | 0.63** |
| Self-concept (T1) | −0.36 | 0.70* | −0.51 | 0.60** |
| Development interest, school | | | −0.09 | 0.92 |
| Development interest, university | | | −0.39 | 0.68* |
| Development self-concept | | | −0.51 | 0.60** |
| School-qualification grade | −0.26 | 0.78** | −0.27 | 0.76* |
| $R^2$ | .15 | | .27 | |

*Note*: $N = 556$ (242 regarded as dropout students, 314 as non-dropout students); * $p < .05$, ** $p < .01$. Coefficients controlled for school-qualification grade.

A model integrating students' study program (pure mathematics vs. teacher education) as a control variable showed the same results for the effects of interest and self-concept and revealed that the study program does not predict dropout.

In model 2, the development of students' affect has been added. Adding these constructs increases the explained variance in dropout to 27%. Students' interest in university mathematics and their self-concept at the beginning of the program (T1) are still negative predictors of dropout. The analysis confirms our hypothesis concerning the affect development: increasing interest in university mathematics as well as increasing self-concept reduces the risk for dropout (hypotheses 4 and 5).

# 4 Study 2

## 4.1 Research question

As according to study 1 mathematical self-concept and its development plays an important role in predicting dropout, we concentrate in study 2 on this affective characteristic. As we assume that not only the level of self-concept investigated in study 1 predicts dropout but also its development in the first semester, we wanted to identify learning situations that probably influence this development. When identifying situational factors that characterize these learning situations, we had in mind theoretical frameworks, which explain the progress of self-concept, such as organizational and content-related aspects of mathematics programs in Germany (see Section 2.1) as well as different frames of references (see Section 2.2.3). As these frameworks are seldom used in the university mathematics context, our investigation has an exploratory character, focusing on the following question:

> Which learning situations do students associate with their actual level of self-concept in the first semester and in which way are these situations related to different frames of references as antecedents of self-concept?

## 4.2 Sample and methods

In order to identify possible learning situations that affect students' self-concept, we used a sample of 18 students that attended the first-semester lecture course linear algebra and were enrolled in a bachelor program (pure mathematics) at a medium German university. This program is very similar to the program that students from study 1 attended: the bachelor program lasts three years and students attend the lecture courses real analysis and linear algebra during the first year. These students were asked three times in the semester to answer an online questionnaire. We applied this questionnaire three times in the semester to identify as many different learning situations as possible. The first questionnaire was distributed during the second week of the semester. The second and third questionnaire had to be filled out during the fifth and eights week. As the participation was voluntary, not all students participated in every measurement point. The first questionnaire was filled out by ten students (5 female, 5 male) and the second by twelve students (6 female, 5 male, 1 no answer) while the third questionnaire was answered by eight students (4 female, 3 male, 1 no answer).

During each measurement point, students were asked to rate their self-concept on a single item ("I am quite "fit" regarding the mathematics that is done at university"; Rach et al., 2022). Students rated this item on a six-point likert scale format (only the extremities were named: *total disagreement* = 1 and *total agreement* = 6). The single item was accompanied by an open-ended item to describe situations in the previous week that were connected to students' rating ("Describe situations from last week in which this became apparent to you!"). It is worth noting that — as a consequence of this design — in their reports, the students themselves established the connection to mathematical self-concept.

Students' answers to this open-ended item were analyzed through various theoretical lenses presented above: in a first step, we categorized the situations mentioned by the students deductively according to the relevant organizational and content-related characteristics of mathematics study programs in Germany (see Section 2.1): lectures, homework sheets, sections, and preparatory courses (organizational) and mathematical activities like proving as well as mathematical content like concrete topics (content-related). As pointed out in Section 2.2.3, for adjusting their self-concept, learners use a frame of reference. Hence, we were interested in the frame of reference students used when describing learning situations that are related to the rating of their self-concept. In this context, we draw on the four frames of reference: dimensional (internal), social (external), temporal, and criterial. Thus, in a second step, we deductively coded the situations based on these four categories. During this analysis, all statements were aggregated and treated independently from students and time-points.

### 4.3 Results

In the first step of the analysis, we coded the learning situations that students themselves connected to their mathematical self-concept deductively according to the relevant organizational and content-related characteristics of mathematics study programs. As some students referred to more than one situation and participated in more than one measurement point, we identified 37 statements from the answers formulated by 18 students.

Regarding organizational characteristics, in twelve answers, students mentioned the homework sheets (e.g., "I have problems to solve the tasks on the homework sheets" or "I always manage to solve all the homework tasks"). With regard to the lecture, six statements could be identified, again both positively ("It is relatively easy for me to follow the lectures") and negatively connoted ("It usually takes me a super long time to understand the content of the lecture"). In the description of three learning situations, students mentioned the sections and the answer given by one student stands out in particular: "I had to contact the teaching assistant of my section because I did not understand in principle one homework task". The wording "I had to" is remarkable and we will come back to this in the discussion. In two cases, students referred to the preparatory course, which both illustrate its relevance although the statements were formulated from different points of view. The student who participated in the preparatory course stated: "Fortunately, I attended the preparatory course. It has been extremely helpful". The student who did not participate in the preparatory course formulated: "In the lectures, many things (from the preparatory course) are expected, and I stumble over again and again because I did not attend it."

With regard to content-related characteristics, 16 statements could be identified. Ten students clearly referred to mathematical activities, like conducting proofs or defining ("I am not able to prove"), and six students mentioned specific mathematical content, like matrices or vectors ("We did not calculate with matrices in school").

In the second step of the analysis, we focused on students' frame of reference, and all four references could be identified in their answers. Concerning the dimensional frame of reference, there was only one student who explicitly referred to her performances in different domains' respective topics (within the lecture course linear algebra): "I get along quite well with the tasks but there are always topics that are difficult to understand." Two students compared themselves with other students who attended the lecture course together with them (social frame of reference). In one case, the comparison was in favor of the student as he was glad to have participated in the preparatory course: "My fellow students who did not attend the preparatory course have greater problems than me." In the case of the other student, the comparison was to the disadvantage of the student. As some of the topics, like matrices or limits, were not covered deeply in school, the other students could do better than her. A temporal reference could be identified in two student answers. Whereas one student referred to her experiences at school, the other student compared his performance within the lecture course: "I think the mathematical notation is still difficult for me but the approach to solving tasks has improved considerably." In almost all students' explanations on the learning situations, we found statements revealing a criterial reference. This was particularly evident in connection with the homework sheets where some students performed very well ("I got all the points for the tasks on the homework sheet") and others poorly ("More and more frequently, there are situations where I sit in front of the homework tasks and feel somewhat lost"), based on the criterial feedback they got for their handed-in solutions or their own assessment when working on the tasks. Criterial references also often became obvious in connection with the lecture. Some students emphasized that it takes a long time to catch up and understand the large amount of content: "Despite efforts and repetitions, I do not manage to remember all definitions, theorems, etc. In addition, the lecture is still very fast, so I have the feeling that I cannot keep up, at least not to the extent that I would like to. I would like to understand the connections."

Altogether, the students mentioned in various ways the organizational and content-related characteristics of mathematics study programs when describing the learning situations that they themselves associated to their mathematical self-concept. Moreover, in combination with the various characteristics, the four references became obvious in students' descriptions. Especially, homework tasks that have to be worked on and handed in by students play a central role. The situations mentioned in this context are often associated with criterial references in form of received points for handed-in solutions.

# 5 Discussion

## 5.1 Summary and theoretical implications

Dropout from mathematics programs is a serious problem in many countries. While there is a long discussion about the influence of cognitive aspects (e.g., prior knowledge, difficulties with proof and formal definition) at the transition, the role of affective aspects are only focused in a few studies. In this contribution, we concentrate in particular on the development of affective aspects in a mathematics program.

Within *study 1*, we used a quantitative approach in order to examine the influence of students' mathematics-related affect and its development in the first semester on dropout. Our results indicate that interest in school mathematics is not related to dropout — as expected in hypothesis 1. This result is in line with and extends previous studies that reported neither an influence of interest in school mathematics on achievement nor on study satisfaction (Kosiol et al., 2019). This may be explained by the fact that school mathematics is not the learning content in German university mathematics courses (see Section 2.1). In contrast, supporting hypotheses 2 and 3, students' interest in university mathematics as well as their mathematical self-concept was associated with less risk to drop out. This concretizes the role of interest in university mathematics and self-concept for a successful transition from school to university (Kosiol et al., 2019). Guided by recent studies that assume different development patterns of mathematics-related affect between successful and unsuccessful students (e.g., Di Martino & Gregorio, 2019; Geisler & Rolka, 2021; Rach & Heinze, 2013), we further took a closer look at these patterns in order to better explain dropout behavior. We could confirm our hypotheses 4 and 5 that the development of affect has a negative effect on dropout: the development of interest in university mathematics and the development of mathematical self-concept are notable predictors of dropout. The mean values of these two variables changed only little in the whole sample during the first semester, however there are intra-individual changes in interest and self-concept and these changes relate to dropout. Thus, it seems plausible that increasing interest in university mathematics as well as increasing self-concept go along with less risk to drop out while decreasing interest in university mathematics and self-concept is more prevalent among students who drop out. Summarizing, many students who dropped out after the first study year already began their studies with unfavorable affect and underwent an unflattering development. The new insight of this study is that not only the initial level of affects at the beginning of study but also the change of affects in the first semester have a substantial influence on study dropout. This important result can foster our understanding of the phenomenon dropout and reveals practical implications for supporting students who are at risk to drop out (see Section 5.3).

Within *study 2*, we used a qualitative approach to identify features of learning situations in a university mathematics program, which influence students' self-concept. For this, we asked students three times during the first semester to describe learning situations in relation to their mathematical self-concept.

Most situations students stated were associated with criterial frames of references — like the points earned on the weekly homework sheets, which is a typical learning situation in German university courses. Social and temporal frames of reference have been less prevalent. In this sample, the *big-fish-little-pond effect* seems to be not very influential. Our results are in line with the results of Liebendörfer (2018) who found that students often used criterial frames of references to adjust their self-concept. Dimensional frames of references were only mentioned by one student. This might be due to the fact that only students enrolled in a pure mathematics program were involved in the study. These students might lack comparisons with other study subjects. Having pre-service teachers in a sample who study a second subject may lead to an occurrence of dimensional comparisons. Summarizing, contrary to studies in the school context, in the university context the criterial reference dominates for adjusting the own mathematical self-concept.

The question, whether they had attended the mathematics preparatory courses offered by the university prior to the beginning of the mathematics programs, seemed to be crucial for some students. Students mentioned the preparatory course in relation with the feeling of possessing enough or not enough prior knowledge for their program. Most studies that analyzed the effects of preparatory courses, offered in German universities (see Section 2.1), show a positive impact on students' knowledge development (cf. Greefrath et al., 2017). A reciprocal relationship between (prior) knowledge and self-concept has been discussed in the literature before (Marsh & Köller, 2004).

Besides rather concrete situations, students also mentioned mathematical contents and mathematical activities. Interestingly, activities (not related to a distinct content) like conducting proofs or working with definitions were mentioned more often than concrete content like vectors. It seems that these activities are a hurdle for students, which influences their self-concept independent from the specific mathematical content.

The two studies together address the role of students' affective characteristics in a university mathematics program: affective characteristics are relevant predictors of students' success in this learning environment and may be influenced by situations in this learning environment.

### 5.2 Limitations and strengths

Limitations of *study 1* can be found in the sample. We recruited the sample of this study only from one university but as three consecutive cohorts were involved, our results do not depend strongly on the way a single lecturer organized the course. As the survey took place during the lectures, some students, who did not attend lectures regularly, were not covered. It seems plausible that students at risk to drop out are therefore underrepresented in our sample. As students who dropped out undergo a less beneficial development of their affect, the predictive strength of this development for dropout might even be underestimated. To diminish this effect, we applied the full information maximum likelihood algorithm for handling missing data.

A strength of *study 1* is that we considered students' affect development in addition to their affect at the beginning of their program, revealing that both — initial level at the beginning of the program and development — are influential with regard to dropout. Besides, we rely on actual dropout instead of substitute-criteria like dropout intention or exam attendance that come with uncertainty concerning the actual dropout behavior (cf. Sarcletti & Müller, 2011).

As only a small sample was involved in *study 2*, the results are rather exploratory and a first step to identify features of learning situations which have an impact on students' self-concept. Some of the students' answers remain rather superficial and due to the design (online questionnaire), it was not possible to pose clarification questions. However, using data reported by the students at several occasions directly during the semester, we believe that our results are less biased than data from retrospective reports that cover a longer time span like the whole semester (cf. Schwarz, 2007).

### 5.3 Practical implications

Since *study 1* showed that a high level of interest and self-concept at the beginning of a mathematics study program as well as a positive development of both variables during the first semester went along with decreasing risk of dropout, potential didactical interventions should preferably consider both aspects: fostering students' interest and self-concept before entering a study program and supporting a positive (or at least preventing a negative) development during the first weeks at university. Informed by students' experiences reported in *study 2*, we propose possible actions to achieve these aims.

#### 5.3.1 Fostering students' interest and self-concept prior to the beginning of a study program

Dropout students already started their studies with less interest in university mathematics. According to Daskalogianni & Simpson (2002), low interest in university mathematics can be the result of a misfit between students' expectations about and their experiences of the mathematical content during the first weeks. Moreover, Balkis (2013) reported that realistic expectations went along with more study satisfaction. Therefore, it seems relevant to support students so that they form realistic expectations, which characteristics of mathematics dominate in the first study year and with which requirements they have to cope. Within *study 2*, it became evident that some students were surprised or frustrated in view of the amount of time that they have to spend in order to understand the content of the lectures and to work on the homework tasks. Prospective students should be informed that it is normal to spend a lot of time thinking about university mathematics and that a certain tenacity while working on homework tasks is necessary. Following this idea, Rach and Engelmann (2018) proposed workshops for upper-secondary students to inform them about the characteristics and requirements of mathematics programs at university. Such workshops can lead to the perception that the study program does not fit to the own personal characteristics and to the decision not to enroll in a mathematics study program. However, some students may be also fascinated by the university mathematics that differ substantially from school mathematics and decide to enroll in a mathematics program. In both cases, such workshops before the university can lead to a more appropriate study choice.

In *study 2*, one recurring theme in students' description of situations related to their self-concept was their feeling of being insufficiently prepared and lacking necessary prior knowledge for understanding their courses. While sometimes students' preparation in school is criticized (e.g., Hourigan & O'Donoghue, 2007), the participating students also referred to the university preparatory course as a source of relevant prior knowledge. Students who participated in the course felt that they were rather well prepared compared with their classmates who did not. Under the present circumstances, this underlines the relevance of preparatory courses and the need to strongly encourage all students to participate in these courses (Greefrath et al., 2017). However, to smoothen the transition for future students and to ensure that students acquire the relevant knowledge for their study programs, a closer communication between schools and universities would be desirable. A first approach implementing structured and moderated collaborations between schools and universities is recently reported by Weber et al. (2022).

### 5.3.2 Fostering a beneficial development of interest and self-concept during the semester

Since individual interest can emerge through recurring instances of situational interest (Krapp, 2002), fostering students' situational interest can lead to a beneficial interest development (see Liebendörfer & Schukajlow, 2020). Students' situational interest during advanced mathematics lectures is dependent on their current experience of autonomy and competence (Rach, 2020). The way in which lecturers can help students experience competence is described below.

Most self-concept-related situations mentioned by students in *study 2* involved the weekly homework sheets. Therefore, homework tasks seem to be a crucial factor for fostering or hindering the development of students' self-concept. According to Blömeke (2016), tasks with different levels of complexity and from varying contexts should be used to allow all students to work on cognitively demanding tasks on the one hand and to have experiences of competence on the other hand. In the school context, students' self-concept increases if teachers use for feedback the individual frame of reference (Lüdtke & Köller, 2002).

One student in *study 2* indicated that he felt uncomfortable to have to ask the teaching assistant for help during sections. Overcoming the shame to talk about problems with one's mathematical tasks and to ask questions seems crucial during the transition (Di Martino & Gregorio, 2019). Therefore, students should be encouraged to ask questions during lectures and sections.

### 5.4 Conclusion

Our paper shows how important a combination of a quantitative and qualitative approach is to analyze essential questions about the role of mathematics-related affect in university study programs. While the quantitative approach indicated to which degree affect and its development in the first semester predicts dropout, the qualitative approach explored how university teachers can support students in their development process of self-concept by giving students a voice. While the studies presented in this paper were located in the German context, the insights into main characteristics of mathematics study programs and their relation to self-concept probably will hold for other educational systems as well.

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