International Journal of Science and Mathematics Education (2019) 17:1359–1380
https://doi.org/10.1007/s10763-018-9925-8

(Which) Mathematics Interest is Important for a Successful Transition to a University Study Program?

Timo Kosiol[1] · Stefanie Rach[2] · Stefan Ufer[1]

Received: 9 July 2017 / Accepted: 13 August 2018 / Published online: 6 September 2018

Abstract

Students' personal interest is hypothesized to be an important resource for learning, but only a few empirical studies have investigated the effect of interest on academic achievement and motivational outcomes of university studies. This lack of empirical studies is remarkable, because inadequate individual prerequisites are considered one reason for study drop-out. High drop-out rates in mathematics studies highlight students' difficulties at the transition from school to university mathematics. The main aim of this contribution is to analyze the impact of cognitive learning prerequisites and mathematics interest on the outcomes in the first semester of a university mathematics program. In line with person–object theories of interest, we differentiate interest facets that reflect the changing nature of mathematics at the transition. We report results of a prediction study with 202 students enrolled in a university mathematics program. Correlation analyses show weak relations between interest and cognitive prerequisites. Regression analyses indicate that interest in proof and formal representations is a strong predictor for study satisfaction and motivation, whereas only cognitive prerequisites show an impact on achievement. Our results indicate how and to what extent the specified instruments measuring individual interests may inform study guidance before and student support during the first semester of a university mathematics program.

Keywords Interest and learning · Interest in mathematics · Study satisfaction · Study success · Transition from school to university mathematics

✉ Timo Kosiol
kosiol@math.lmu.de

[1] Department of Mathematics, Ludwig-Maximilians-Universität München, Theresienstraße 39, 80333 München, Germany

[2] Faculty of Mathematics, Otto-von-Guericke-Universität Magdeburg, Universitätsplatz 2, 39106 Magdeburg, Germany

Introduction

Students' problems with the transition to university mathematics have been described internationally for more than a decade (Clark & Lovric, 2009; Gueudet, 2008; Tall, 2008; Ulriksen, Møller Madsen & Holmegaard, 2010). Higher drop-out rates in university mathematics programs than in other subjects support this impression (Dieter, 2012; Heublein, Richter, Schmelzer & Sommer, 2014). It has been suggested that during the transition to university mathematics, the content of mathematics learning, as well as the learning environment change (Rach, Kosiol & Ufer, 2017). One reason for students' problems might be that their individual learning prerequisites, such as interest and knowledge, are not well aligned with the learning environment at university. These learning prerequisites influence facets of study success, e.g., academic achievement or study satisfaction, and may inform student selection, advice, and support (Sonnert & Sadler, 2015; Trapmann, Hell, Weigand & Schuler, 2007). To design study advice materials and adjust the learning environment for students with less beneficial prerequisites, it is necessary to know what characterizes students who have trouble in the transition.

While the role of cognitive prerequisites, e.g., prior knowledge and prior achievement, for academic achievement in the transition to university mathematics is well established (e.g., Rach et al., 2017), the picture is less clear for other learning prerequisites. Radford (2015) argues that affect and cognition are inseparable; therefore, it seems necessary to investigate the relation of affective as well as cognitive variables. Interest is theoretically assumed to influence students' motivation, effort, and strategies (e.g., Krapp & Prenzel, 2011) as well as academic success, including satisfaction and achievement (Harackiewicz & Hulleman, 2010). Recent studies, however, have failed to identify an effect of interest on academic achievement (e.g., Rach et al., 2017). In contrast, interest has been found to influence study drop-out in the past (Schiefele, Streblow & Brinkmann, 2007).

One reason for the missing link between interest and achievement could be that the interest questionnaires applied in these studies are not well aligned with the learning content at university (Ufer, Rach & Kosiol, 2017). According to Holland's (1973) congruence hypothesis, such an alignment would be necessary to identify meaningful relations between interest and study success. Moreover, as interest reflects a person–object relationship and the learning content changes at the transition to university, it is not clear what mathematics students actually refer to in their general interest ratings. It has been proposed to differentiate interest in mathematics relating to university mathematics versus school mathematics, and the corresponding mathematical practices in both institutions (Ufer et al., 2017).

Another reason may be that the influence of interest on drop-out is not mediated strongly by academic achievement, but primarily by other variables that are relevant for students decision to continue or leave a study program, such as study satisfaction. Indeed, previous research from higher education in general indicates that interest may affect these subjective criteria of study success stronger than academic achievement (Nagy, 2006). However, empirical data on these subjective study success criteria are scarce in the transition to university mathematics, and it is yet unclear to which extent the respective relationships might depend on the specific facets of mathematics interest taken into account.

The main goal of this contribution is to provide empirical evidence about the specific roles of interest in school and university mathematics for academic achievement (in the sense of exam scores) in the transition to university mathematics, as well as for subjective criteria of study success (such as study satisfaction) when controlling cognitive prerequisites.

Background

The Transition from School to University Mathematics

High drop-out rates, especially in the early years of academic programs with a focus on scientific mathematics (Dieter, 2012; Heublein et al., 2014), have drawn researchers' attention towards the transition from school to university mathematics in the past years. Two major differences between school and university probably play an important role in this transition: (1) a changing character of mathematics as a scientific discipline, and (2) different cultures of learning (Clark & Lovric, 2009; Gueudet, 2008).

One main focus of school mathematics is on solving more or less realistic problems (KMK, 2012; Organization for Economic Co-operation and Development [OECD], 2016). Therefore, applications of mathematics to real-world problems and related calculations are central mathematical practices within school mathematics. In contrast, mathematics in the study entry phase is mostly presented as a scientific discipline in a definition–theorem–proof structure (Engelbrecht, 2010; Hoyles, Newman & Noss, 2001). Formal definitions of abstract concepts and formal-deductive proofs are characteristic. These differences between mathematics in upper secondary school and in the first semesters at university can be observed in textbooks from the two contexts, even when they relate to the same mathematical concepts (e.g., limit of functions: Vollstedt, Heinze, Gojdka & Rach, 2014). Summarizing, the character of mathematics shifts from a school subject with a focus on calculations and applications to a scientific discipline based on explicit definitions, deductive proofs, and formal representations (cf. Gueudet, 2008).

With regard to the second aspect, the transition to university mathematics is analyzed as an enculturation process to a new institution (cf. Gueudet, 2008). Students are confronted with a new culture of how mathematics is taught and learned. It is up to now unclear which learning prerequisites, such as knowledge or interest, support students in coping with this new learning culture (Rach et al., 2017). Researchers hypothesize that poor learning strategies, the unfamiliar pedagogical approach, and the need to construct a legitimate identity in this new context lead to difficulties at this transition to the new learning culture (Ulriksen et al., 2010).

As it is widely accepted that the shift in character and the new learning environment have a major impact on success and drop-out in a university mathematics program (cf. Gueudet, 2008), we analyze in this study how individual learning prerequisites, such as students' prior knowledge, achievement, and different interest facets affect different measures of study success.

Conceptualizing Study Success in the Transition Phase

Even though study success is often equated with successful graduation from university, current conceptualizations view it as a multidimensional construct (e.g., Nagy, 2006; Sorge, Petersen & Neumann, 2016). *Objective criteria* of study success comprise acquired knowledge, competence, skills, duration of studies, as well as drop-out (negative criterion). Following, for example, Nagy (2006), we integrate *certified indicators* such as grades in university courses or the graduation grade (Sorge et al., 2016) under the label *objective criteria*. *Subjective criteria* refer to students' ratings of study satisfaction, intentions to continue or leave a study program, (de-)motivation regarding the study program, or perceived learning gain. In the past, research on the transition to university mathematics has predominantly focused on objective criteria of study success (e.g., Halverscheid & Pustelnik, 2013; Rach et al., 2017; Ufer, 2015).

Study satisfaction, as one subjective criterion, refers to a person's appraisal of their study program that is based on affective experiences and cognitive comparisons. A definition of satisfaction as congruence of expectations and experiences would be too restrictive, because it ignores the affective element of study satisfaction (Blüthmann, 2012). Satisfaction is the result of a person's interaction with an environment. In this sense, satisfaction is a postdecision experience construct, as it refers to an environment that a person dealt with. Brandstätter, Grillich, and Farthofer (2006) report that low study satisfaction predicts drop-out in university programs even if achievement is controlled. For the development of study satisfaction, the entry phase of a study program seems to play an important role (Blüthmann, 2012), indicating a specific importance for the transition to university mathematics.

Furthermore, *demotivation* is considered another key reason for drop-out from study programs with a focus on mathematics. Schiefele et al. (2007) reports that students who drop out of their study program differ from the persistent students with regard to their motivation already at the start of their studies. Furthermore, student motivation has shown a high impact on students' study satisfaction (Blüthmann, 2012).

Summarizing, subjective criteria of study success such as study satisfaction and student motivation have turned out to be early indicators of study drop-out beyond objective criteria such as academic achievement (Brandstätter et al., 2006; Trapmann et al., 2007). Thus, they represent important learning outcomes during the transition to a university mathematics study. However, studies investigating study success in terms of different criteria simultaneously are scarce (Brandstätter et al., 2006; Nagy, 2006).

Predictors of Study Success

Blüthmann, Lepa, and Thiel (2008) distinguish four categories of factors influencing study success: students' prerequisites, conditions of the study program, students' studying and learning behavior, and situational factors. In this contribution, we focus on individual prerequisites, because they seem to have a stronger influence on study success in mathematics than, for example, situational factors (Sonnert & Sadler, 2015). Specifically, we investigate prior knowledge, prior school achievement, and interest in mathematics.

Interest as a Predictor of Study Success. The interest construct captures two of the components that have been subsumed under the term affect in the mathematical education literature in the past (Di Martino & Zan, 2015): emotions and values. Hannula (2011), as well as works from educational psychology (e.g., Hidi & Renninger, 2006), propose a strong link to motivation and, further, to action regulation. Following Zan, Brown, Evans, and Hannula (2006), we conceptualize interest not as an intrinsic property of an individual, but as a characteristic which researchers ascribe to individuals based on a specified theoretical understanding of the construct and observations of the individual.

In the context of person–object theories, interest is defined as a specific relation between an individual and an object (Krapp, 2002). This object may be any cognitively represented entity from the persons' life-space (Krapp, 2007), comprising objects, topics, ideas, or school subjects. *Situational* interest is seen as a certain motivational state (Hidi & Renninger, 2006). *Individual* interest, in contrast, describes a relatively stable personal trait which allows individuals to activate interest states in specific situations (Krapp, 2002; see also Hannula (2011) framework). Individual interest is understood as the multi-faceted associations of a person with the object of interest (Marsh, Trautwein, Lüdtke, Köller & Baumert, 2005). Schiefele, Krapp, and Winteler (1992) distinguish between (1) an emotional component of interest, usually related to joy or other positive emotions experienced when dealing with the object of interest, (2) a value-based component, referring to the value a person attributes to the object, and (3) an intrinsic component, understood as the individual's tendency to re-engage with the object mainly because of his or her relation to the object itself. The determinants of strength of motivation are studied within expectancy–value theories of motivation (Eccles & Wigfield, 2002) or self-efficacy theory (Schunk, 1991). Individual interest in this context can be hypothesized as an antecedent of situational interest and motivation, with a strong focus on a specific object (Schiefele, 2009).

Interest is assumed to be an important factor in learning processes (Hidi & Renninger, 2006) and for students' success in the transition phase to university mathematics (Pyzdrowski et al., 2013; Rach et al., 2017). It has been suggested that its positive effect on learning is caused by a sustained attention (Ainley, Hidi & Berndorff, 2002; Hidi & Renninger, 2006), a positive mood and goal-directed processing (Hidi & Renninger, 2006), and self-regulative processes (Lee, Lee & Bong, 2014; Richardson, Abraham & Bond, 2012) during learning. In addition, there is evidence that interest is related to the use of elaborative learning strategies, leading to an indirect influence of interest on achievement (Schiefele, Krapp & Wild, 1995).

Studies investigating the expected effect of interest on achievement in mathematics measured by grades and tests show seemingly inconsistent results. Some analyses have reported moderate correlations (around $r = .32$ in Schiefele et al., 1992) between interest and achievement in school mathematics (cf. Heinze, Reiss & Rudolph, 2005), and Schukajlow and Krug (2014) found correlations with performance in mathematics ($.18 < r < .40$ for task-specific and task-unspecific interest). However, it has not been possible to verify a direct influence of interest on achievement in longitudinal studies. Köller, Baumert, and Schnabel (2001) found only a small effect of interest on learning in school settings when prior achievement was controlled (cf. Marsh et al., 2005) and Rach et al. (2017) could not identify such an effect in the transition phase to university mathematics. The results of Köller et al. (2001) indicate that a longitudinal relation between mathematics interest and achievement is mediated at least partially by students' choices during their learning biography. Indeed, interest predicts the choice of study programs (Lapan, Shaughnessy & Boggs, 1996; Nagy, 2006).

As stated above, interest is linked to the use of deep-level learning strategies (Schiefele et al., 1995), which are assumed to stimulate understanding. However, newer results (e.g., Senko, Hama & Belmonte, 2013) indicate that sometimes surface-level learning strategies lead to better achievement due to a more goal-driven selection of course material, rather than following individual interests. Another reason for the missing effect of interest on achievement in the study entrance phase could be that students' reported interests mainly refer to school mathematics, and not to university mathematics (Ufer et al., 2017). The character of mathematics (object of interest) changes in the transition from school to university mathematics, and Liebendörfer and Hochmuth (2013) report that university mathematics students indeed differentiate between school and university mathematics as objects of interest. Thus, Holland's (1973) congruence hypothesis, which assumes that a positive relation between interest and study success can only be expected if individual interests correspond to the contents of a study program, would explain the missing effects. Ufer et al. (2017) distinguish between interest in school mathematics and interest in university mathematics, and corresponding mathematical practices (cf. Häussler & Hoffmann, 2000 for a similar approach in physics education). Without differentiating between different domains, Assouline and Meir's (1987) meta-analysis could not establish an effect of interest congruence on achievement. For studies in science, technology, engineering, and mathematics, Nagy (2006) reported a weak correlation between interest congruence and self-rated achievement. To the best of our knowledge, there are no studies on interest congruence from contexts where the object of interest changes its nature, as in the transition to university mathematics. Beyond the classical interpretation of the congruence hypothesis described above, interests which are not in line with the contents of the study program (e.g., interest in applying mathematics or in school mathematics) might even be detrimental to subjective and possibly also objective criteria of study success. However, results on such an *incongruence hypothesis* are even more scarce.

Concerning higher education in general, results on the influence of interest on subjective criteria of study success are more conclusive than for objective criteria. Without differentiating between different study programs, various researchers have found that domain-specific interest predicts study satisfaction even when controlling other individual characteristics (Blüthmann, 2012; Schiefele & Jacob-Ebbinghaus, 2006). Interest congruence has been found to go along with study satisfaction (Assouline & Meir, 1987; Nagy, 2006). Moreover, Bergmann (1992) found interest congruence to be a predictor of study satisfaction, especially in science and technology. Even though evidence is quite consistent for higher education in general, there are to our knowledge no studies investigating the effect of interest and interest congruence on subjective criteria of study success in the transition to university mathematics.

Summarizing, theoretical arguments support the conclusion that individual interest (person–object relationship) is an important learning prerequisite. However, empirical studies on the transition to university mathematics have failed to find a relation between interest and objective criteria of study success. On the one hand, this may be due to low interest congruence between general measures of interest applied in these studies and the specific contents of a university mathematics program (Ufer et al., 2017). On the other hand, interest may be more relevant for subjective criteria of study success than for objective criteria. Since subjective as well as objective criteria of study success predict drop-out (Blüthmann et al., 2008; Schiefele et al., 2007), it is of high relevance to understand the role of interest in the transition for both kinds of success criteria.

Cognitive Prerequisites and their Influence on Study Success. Prior research has mainly applied three measures of cognitive prerequisites and investigated their effect on study success: (overall) final school qualification grade,[1] mathematics school grades, and mathematics knowledge test scores (cf. Halverscheid & Pustelnik, 2013). Final school qualification grades are usually subsumed under cognitive variables, although they include non-cognitive aspects, such as willingness to learn, diligence etc. (Trapmann et al., 2007).

[1] The final school qualification grade is similar to the GPA and consists of grades in many courses in the last 2 years and performance in exams in the last year of schooling.

With respect to objective criteria of study success, some studies identify the (overall) school qualification grade as the strongest predictor of achievement in the transition to university mathematics (Rach et al., 2017; Ufer, 2015) and in tertiary education in general (Robbins et al., 2004; Trapmann et al., 2007). This holds for the first year of study (Rach et al., 2017; Ufer, 2015) and beyond (Blömeke, 2009; Geiser & Santelices, 2007). Evidence on the influence of mathematics school grades for achievement at university mathematics is rarely reported. The mathematics grade seems to be a significant, but weaker predictor of achievement at university than the (overall) school qualification grade (Bengmark, Thunberg & Winberg, 2017; Halverscheid & Pustelnik, 2013; Rach et al., 2017; Trapmann et al., 2007). Domain-specific knowledge, measured by specific tests, proved to be a valid predictor of later achievement in a university program in general (cf. Liston & O'Donoghue, 2009), as well as in mathematics programs (Halverscheid & Pustelnik, 2013; Kuncel, Hezlett & Ones, 2001; Rach et al., 2017; Ufer, 2015). Beyond objective criteria of study success, there are few studies on the predictive power of grades and knowledge test scores on study satisfaction and motivation in mathematical and technical programs (Blömeke, 2009).

Summarizing, it is well established that school qualification grades and, with a smaller effect, domain-specific prior knowledge predict objective criteria of study success in general, as well as in university mathematics programs. However, the influence of interest beyond prior knowledge is still an open question. Moreover, only few studies have investigated the effect of cognitive prerequisites on subjective criteria of study success. Based on the scarce evidence, only a small influence of cognitive prerequisites on study satisfaction may be expected during the transition to university mathematics.

The Current Study

The goal of the current study is to provide evidence about the effect of different facets of mathematics interest — relating to school and university mathematics and corresponding practices — on objective and subjective criteria of study success in the transition to a university mathematics program. It is part of the project "Self-Concept and Interest in the Study entry phase Mathematics, SISMa" (Ufer et al., 2017) that explores reasons for the seemingly inconsistent results regarding the role of affective variables in the transition phase. In a prediction study, we surveyed students' learning prerequisites at the first day of their studies. To measure the different facets of interest, we applied a scale that refers to mathematics as the object of interest in general terms, as well as specific interest scales (Ufer et al., 2017; see Table 1 and the Instruments subsection below). As indicators of study success, we measured satisfaction and demotivation regarding the study program after 8 weeks of study and we gathered data on exam achievement at the end of the first semester.

Our investigation aims to provide answers to the following questions:

1. To what extent is exam achievement at the end of the first semester of a university mathematics program predicted by cognitive learning prerequisites and different facets of interest in mathematics?

In line with prior studies (Rach et al., 2017; Trapmann et al., 2007), we expected that exam scores would be predicted strongly by school qualification grades and by prior knowledge for academic mathematics (H1.1). Also in line with prior studies on the transition to advanced mathematics (Rach et al., 2017), we did not expect a significant effect of general interest in mathematics on exam scores (H1.2). Regarding differentiated measures of interest, we did expect interest in proof and formal representations (H1.3) as well as interest in university mathematics (H1.4) to predict exam scores positively, in line with the congruence hypothesis. We had no specific hypotheses with regard to the interest in school mathematics, in using calculation techniques, and in applying mathematics.

2. To what extent are subjective criteria of study success during the first semester of a university mathematics program predicted by cognitive learning prerequisites and different facets of interest in mathematics?

We expected at most weak relations to cognitive learning prerequisites (H2.1; see Blömeke, 2009; Brandstätter et al., 2006; Nagy, 2006). Consistent with prior findings on satisfaction (Blüthmann, 2012) and motivation (Schiefele & Jacob-Ebbinghaus, 2006), we expected significant relations of general mathematics interest and subjective criteria of study success (H2.2). Based on the congruence hypothesis, we hypothesized that a high interest in proving and using formal representations (H2.3) and the interest in university mathematics (H2.4) predict lower demotivation and higher study satisfaction. We had no specific hypotheses about the effects of interest in school mathematics, in using calculation techniques, and in applying mathematics on subjective criteria. However, a negative relation would support an incongruence hypothesis, since both aspects play a minor role in first semester university mathematics courses.

Method

Design and Sample

The presented data is part of a prediction study with first semester mathematics students at one university in Germany. The study comprised three measurement occasions. Background data, interest, and cognitive learning prerequisites were surveyed in the first session of the first course of the semester (T_1). Eight weeks after the start of the first semester, students completed a questionnaire on study satisfaction and demotivation (T_2). At the end of the semester, students were asked to provide their exam scores of the course “Analysis I” (T_3).

Our sample consists of 202 first semester university mathematics students (95 female, 107 male; age M = 19.40, SD = 1.83), who participated in the study voluntarily, and based on informed consent. They were enrolled in three different study programs: two bachelor programs (“mathematics” and “business mathematics”, 128 students) and one mathematics teacher education program for the high-attaining secondary school track in Germany (“Gymnasium”, 74 students). All students participated in a specific course “Analysis I”, which is an obligatory standard course for first-semester mathematics students. The bachelor students and the students in the teacher education program attended slightly different “Analysis I” courses. Moreover, the mathematics bachelor students took courses in a minor subject, the business mathematics students had economy lectures, and the students in the teacher program studied a second subject and took courses in psychology and education. Ninety-one of the students participated in a 2-week preparatory course before the first semester started. Out of the students participating in the final exam, 120 agreed that their scores would be reported for use in the project (69 from the bachelor program, 51 from the teacher education program).

Statistical analyses (correlation and regression analyses) were conducted with Mplus 7 (Muthén & Muthén, 1998–2015), using full information maximum likelihood (FIML) estimations to account for missing data. To increase model stability, we included data into the background models for all prerequisites covered in this contribution from all those students in the respective study programs who participated in the first measurement.

Instruments

School Qualification Grade (T_1). On the first measurement, students were asked to report their school qualification grade, which is an aggregate of a variety of oral and written examinations from the final two years in upper secondary school as well as final examinations. Grades were recoded so that 4.0 is the best and 1.0 is the worst value (M = 3.12, SD = 0.59).

Prior Knowledge for Advanced Mathematics (T_1). A test of eight items was used to survey knowledge about a broad spectrum of school mathematics concepts which are relevant for benefiting from an "Analysis I" course (cf. Rach et al., 2017). The items targeted conceptual understanding of involved concepts beyond the typical tasks in upper secondary school (e.g., a multiple-choice item on the value of $\lim_{h\to 0}\frac{\sqrt{2+h}-\sqrt{2}}{h}$). Each item was scored dichotomously, awarding 1 point for a correct solution and 0 points for other or missing solutions. The scale's mean score was 3.24 (SD = 1.80, possible range from 0 to 8). The reliability (Cronbach's α) was .58, which was considered acceptable, as the test covered a broad spectrum of concepts.

Interest in Mathematics (T_1). As outlined, the character of mathematics changes as well as the learning environment. Therefore, it is reasonable to differentiate between different objects of interest to explore in which type of mathematics the students are interested. As such scales were not available, we developed two types of scales that differentiate between different objects of interest (Ufer et al., 2017). These developed and validated scales measure the individual relationship towards the object of interest based on emotion-related, value-related, and intrinsic components (Ufer et al., 2017). The first type of scale addresses the individual relationship towards mathematics as it has been experienced or is anticipated in a specific institutional context (school vs. university). A second type of scale (three scales) surveys interest in mathematical practices that are characteristic for university mathematics (proof and formal representations), school mathematics (applying mathematics), or for both contexts (using mathematical calculation techniques). The applied items can be found in Ufer et al. (2017). In addition, to compare the results of the newly developed scales to general interest in mathematics and to embed the results in the context of existing studies, we applied a widely-accepted scale of general interest in mathematics from Pekrun, Goetz, Titz, and Perry (2002).

Students were asked to rate the items on a four-point Likert scale from 0 (disagree) to 3 (agree). Table 1 shows the descriptive data for all interest scales. With regard to the

Table 1 Reliability, means, and standard derivation of the interest scales

	Example Item	N° of items	*N*	α	BA *M* (*SD*)	TE *M* (*SD*)
General interest in mathematics (IG)	Mathematics is one of the things that is most important for me, personally.	6	202	.76	2.32 (.42)	2.17 (.46)
Interest in applying mathematics (IA)	Solving problems from my own life with mathematics is fun for me.	6	202	.83	2.01 (.63)	2.03 (.53)
Interest in proof and formal representations (IP)	It is exciting for me to show that a mathematical statement is valid in general.	8	202	.81	2.02 (.52)	1.77 (.51)
Interest in using calculation techniques (IC)	I like to deal with complicated calculations.	5	202	.72	2.30 (.49)	2.37 (.48)
Interest in university mathematics (IU)	Mathematics as practiced in university is really important for me.	5	174	.87	2.17 (.57)	1.83 (.59)
Interest in school mathematics (IS)	I am interested in mathematics as it is practiced in school.	5	198	.77	2.03 (.56)	2.30 (.52)

N number of participants with less than half missing items on the scale, α Cronbach's alpha, *M* mean, *SD* standard derivation; Likert-scale from 0 (disagree) to 3 (agree), *BA* Bachelor program, *TE* Teacher education program

missing data on the interest in university mathematics scale, some of the students may have felt that they could not answer these items before starting their studies, although they had been instructed to report their interest as they anticipate university mathematics. Previous studies have shown that students do have realistic expectations of their studies in mathematics even on the first study day (Rach, Heinze & Ufer, 2014), so we used the existing data and applied missing data techniques.

Subjective Criteria of Study Success (T_2). We surveyed satisfaction with the study program, and demotivation as subjective criteria of study success using two different scales (see Table 2; Schiefele & Jacob-Ebbinghaus, 2006; Schiefele, Moschner & Husstegge, 2002). Students were asked to rate the items on a four-point Likert scale from 0 (disagree) to 3 (agree).

Exam Scores (T_3). To study objective criteria of study success, we asked for students' agreement to obtain their exam scores of the course "Analysis I" at the end of the semester. As the exams were different for the two study programs, this data was analyzed separately. In both courses, students had a second chance to retry the exam at the end of the semester break. Results from both exams were aligned on separate scales initially, which were then linked using linear regression models (in each study program) based on the data from students participating in both exams. We used the maximum of the two aligned scores (Table 2).

The correlation between the subjective criteria of study success is positive and high ($|r| = .681, p < .001$). The correlation coefficients between subjective and objective criteria (exam scores) are positive, but weak and not significant ($.060 < |r| < .095, p > .438$ for bachelor students; $.006 < |r| < .116, p > .417$ for students in a teacher education program).

Table 2 Reliability, means, and standard deviation of the study success scales

	Example Item	N° of items	*N*	α	*M* (*SD*)
Satisfaction with the study program	In total, I am content with my studies in mathematics.	7	202	.83	1.76 (.56)+
Demotivation in the study program	The studies in mathematics are really frustrating for me.	6	202	.85	1.00 (.66)+
Exam analysis I, bachelor program, maximum: 36 points		6	69	.85 .71	12.88 (8.06)
Exam analysis I, teacher education program, maximum: 60 points		6	51	.78 .67	22.54 (10.33)

N Number of participants with less than half missing items on the scale, there were no missing items in the exams, α Cronbach's alpha (main exam and retry exam), *M* mean, *SD* standard deviation, + Likert-scale from 0 (disagree) to 3 (agree)

Results

Preliminary Analyses

Low correlations between interest and the (overall) school qualification grade (Table 3) met our expectations, since this grade combines achievement over a range of subjects. In line with prior findings (Schiefele et al., 1992; Schukajlow & Krug, 2014), interest in university mathematics and interest in proof and formal representations correlated moderately positively with prior knowledge for advanced mathematics. Interest in school mathematics and interest in calculation techniques as well as applications correlated negatively with prior knowledge for advanced mathematics. This indicates that in our — highly selective — sample of mathematics university students, those participants with a low prior knowledge tend to be more interested in school mathematics, application, and calculation than those with high prior knowledge for advanced mathematics. General interest in mathematics can be considered an amalgam of the more specific interest facets to a large extent (Ufer et al., 2017). Thus, it is plausible that the opposite relations described above average out for the general interest measure, and lead to a non-significant correlation with prior knowledge.

We conducted regression analyses with the different criteria of study success as dependent variables. First, we entered the study program as a predictor (model 1, only

Table 3 Pearson correlations between measures of learning prerequisites

	IG	IA	IC	IP	IS	IU
School qualification grade	.12	−.06	.12	.12	.18*	.08
Prior knowledge of advanced mathematics	.09	−.21**	−.20**	.24**	−.26***	.11

IG general interest in mathematics, *IA* interest in applying mathematics, *IC* interest in using calculation techniques, *IP* interest in proof and formal representations, *IS* interest in school mathematics, *IU* interest in university mathematics

* $p < .05$, , ** $p < .01$, , *** $p < .001$

Table 4 Standardized regression coefficients and standard errors from regression analyses with dependent variable achievement bachelor

Independent variable	Mod. 2	Mod. 3	Mod. 4	Mod. 5	Mod. 6
School qualification grade	.51*** (.08)	.42*** (.08)	.42*** (.08)	.42*** (.08)	.44*** (.08)
Prior knowledge of advanced mathematics		.47*** (.08)	.47*** (.08)	.45*** (.09)	.44*** (.09)
General interest in mathematics			.06 (.11)	.14 (.14)	.07 (.13)
Interest in university mathematics				−.09 (.13)	
Interest in school mathematics				−.05 (.10)	
Interest in applying mathematics					.12 (.12)
Interest in proof and formal representations					.06 (.11)
Interest in using calculation techniques					−.16 (.11)
R^2	.26	.48	.48	.49	.51

N = 69 for dependent variable, N = 122 for background model, $^{***}p < .0011$

for subjective criteria) and then successively school qualification grade (model 2), prior knowledge (model 3), and general interest (model 4). In two separate further models, we added the measures of interest in mathematics as taught in the two different institutions (model 5) or the interest regarding the different practices (model 6). Model 7 contains all predictors, but was only estimated for subjective criteria due to small sample sizes for objective criteria.

Objective Criteria of Study Success (Exam Scores)

Bachelor Program Sample[2] The regression analyses (see Table 4) for exam scores of bachelor students show that across all models, school qualification grade and prior knowledge for advanced mathematics are significant predictors of roughly equal strength, confirming H1.1. Beyond these, general interest does not predict exam scores significantly (H1.2).[3] Contrary to H1.3 and H1.4, neither interest in university mathematics nor in proof and formal representations predict exam scores significantly. Also, no negative relation of interest in school mathematics or in applying mathematics could be identified.

Teacher Education Program Sample. The corresponding analyses for the teacher education program (Table 5) show that the school qualification grade is a significant

[2] Because the two subsamples in our study received different exams, the relation between learning prerequisites and exam scores was analyzed separately for each program.
[3] The sample size of each subsample (bachelor vs. teacher) provides sufficient statistical power to identify a medium effect for each predictor in the final model (α = .05, β = .80, f^2 = .15).

Table 5 Standardized regression coefficients and standard errors from regression analyses with dependent variable achievement teacher education

Independent variable	Mod. 2	Mod. 3	Mod. 4	Mod. 5	Mod. 6
School qualification grade	.53*** (.11)	.53*** (.11)	.49*** (.11)	.60*** (.12)	.52*** (.12)
Prior knowledge of advanced mathematics		.08 (.12)	.09 (.12)	.08 (.11)	.11 (.12)
General interest in mathematics			.12 (.12)	.30* (.15)	.21 (.17)
Interest in university mathematics				−.15 (.15)	
Interest in school mathematics				-.28t (.15)	
Interest in applying mathematics					.03 (.13)
Interest in proof and formal representations					−.13 (.15)
Interest in using calculation techniques					−.04 (.14)
R^2	.29	.29	.31	.38	.32

N = 51 for dependent variable, N = 73 for background model, $^{t}p < .10$, , * $p < .05$, , *** $p < .001$

predictor of exam scores in all models (model 2, first part of H1.1). Contrary to our expectations, the prior knowledge has no significant effect on exam scores (model 3). General interest does not predict exam scores beyond cognitive prerequisites (model 4), supporting H1.2. However, upon including interest in school mathematics, weak predictions in opposite directions occur for general interest (positively) and interest in school mathematics (negative tendency, model 5). Given the moderate correlation (r = .32; $p < .05$) between the two measures, this is probably not due to multi-collinearity. The result indicates that higher general interest only goes along with higher exam scores for students with a comparable level of interest in school mathematics. The other interest facets did not predict exam scores significantly (model 6).

Subjective Criteria of Study Success

We conducted separate regression analyses for the dependent variables satisfaction and demotivation (Tables 6 and 7). As expected, there are no significant effects of the school qualification grade and advanced mathematical knowledge in the pretest for both subjective criteria of study success, confirming H2.1 (models 2 and 3 in Tables 6 and 7).[4]

Study Satisfaction. Bachelor students report a slightly higher satisfaction with their study program (model 1), but this difference decreases strongly when entering interest

[4] The sample size provides sufficient statistical power to identify a small effect for each single predictor in the final model (α = .05, β = .80, f^2 = .04).

measures (models 4 and 5). This indicates that the differences in study satisfaction between the programs can be explained by different interest profiles. As expected, general interest positively predicts study satisfaction (model 4, H2.2), and beyond this both interest in university mathematics (H2.4, model 5) and in proof and formal representations (H2.3, model 6) contribute. The effect of interest in university mathematics is reduced substantially, but not significantly when all indicators are entered into the joint model 7 ($CI_{95\%}$: [.07, .35], model 5; $CI_{95\%}$: [−.07, .26], model 7). Beyond this, higher interest in school mathematics predicts lower study satisfaction (model 5), and this effect is mostly independent of interest in applying mathematics or performing mathematical calculations (models 6 and 7). General interest accounts for more than half (14%) of the variance share explained by interest measures (23%).

Demotivation. Even though there are no significant differences between the study programs in the initial model, the final model indicates that bachelor students report more demotivation compared to the teacher education students than would be expected based on their interest profile. The further pattern of results for demotivation is similar to study satisfaction: general interest, interest in university mathematics, and interest in proof and formal representations go along with lower demotivation, while interest in

Table 6 Standardized regression coefficients and standard errors from regression analyses with dependent variable satisfaction

Independent variable	Mod. 1	Mod. 2	Mod. 3	Mod. 4	Mod. 5	Mod. 6	Mod. 7
Study program[a]	.19** (.07)	.19** (.07)	.17* (.07)	.11 (.07)	.03 (.07)	.08 (.07)	.03 (.07)
School qualification grade		−.05 (.07)	−.06 (.07)	−.10 (.07)	−.05 (.07)	−.10 (.07)	−.06 (.07)
Prior knowledge of advanced mathematics			.09 (.07)	.08 (.07)	.01 (.07)	.03 (.07)	−.00 (.07)
General interest in mathematics				.38*** (.06)	.32*** (.09)	.21** (.08)	.24** (.09)
Interest in university mathematics					.22* (.09)		.10 (.10)
Interest in school mathematics					−.22** (.07)		−.22** (.08)
Interest in applying mathematics						.02 (.07)	.05 (.06)
Interest in proof and formal representations						.30*** (.08)	.23* (.09)
Interest in using calculation techniques						−.03 (.07)	.05 (.07)
R^2	.00	.04	.04	.18	.24	.23	.27

N = 202; [a] dummy coding; 1: bachelor program, 0: teacher education program

$^{*}p < .05$, , $^{**}p < .01$, , $^{***}p < .001$

Table 7 Standardized regression coefficients and standard errors from regression analyses with dependent variable demotivation

Independent variable	Mod. 1	Mod. 2	Mod. 3	Mod. 4	Mod. 5	Mod. 6	Mod. 7
Study program[a]	.09 (.07)	.09 (.07)	.10 (.07)	.15* (.07)	.24** (.07)	.19** (.07)	.24*** (.07)
School qualification grade		.05 (.07)	.06 (.07)	.09 (.07)	.05 (.07)	.09 (.07)	.06 (.07)
Prior knowledge of advanced mathematics			−.06 (.07)	−.05 (.07)	.01 (.07)	−.00 (.07)	.03 (.07)
General interest in mathematics				−.36*** (.06)	−.28** (.09)	−.17* (.08)	−.19* (.09)
Interest in university mathematics					−.24** (.09)		−.11 (.11)
Interest in school mathematics					.21** (.07)		.21** (.08)
Interest in applying mathematics						−.06 (.07)	−.09 (.07)
Interest in proof and formal representations						−.34*** (.08)	−.26** (.09)
Interest in using calculation techniques						.05 (.07)	−.02 (.08)
R^2	.00	.01	.01	.14	.20	.20	.23

N = 202; [a] dummy coding; 1: bachelor program, 0: teacher education program

* $p < .05$, ** $p < .01$, , *** $p < .001$

school mathematics predicts higher demotivation, supporting H2.2, H2.3 and H2.4. General interest accounts for about half (13%) of the variance share explained by interest measures (22%).

Discussion

The starting point of our study was the seemingly inconsistent results with regard to the role of students' interest for their study success in a university mathematics program (e.g., Rach et al., 2017) beyond cognitive learning prerequisites (Robbins et al., 2004; Trapmann et al., 2007). Moreover, we put a specific focus on learning outcomes that may indicate drop-out already in the transition phase to university mathematics (Brandstätter et al., 2006). Our study implements two main innovations: (1) we applied differentiated measures of interest to account for the changing nature of the object of interest "mathematics" in the transition phase (cf. Ufer et al., 2017) from an application-oriented school subject to a scientific discipline focusing on proof and formal representations (Engelbrecht, 2010; Gueudet, 2008; Hoyles et al., 2001), and (2) beyond exam scores as objective measures of study success, we also surveyed subjective measures such as study satisfaction and demotivation (Blüthmann, 2012).

Effects of Cognitive Learning Prerequisites

In line with prior research (Bengmark et al., 2017; Rach et al., 2017; Robbins et al., 2004; Trapmann et al., 2007), school qualification grade and prior knowledge for advanced mathematics showed a strong impact on exam scores (objective criteria of study success, H1.1). However, prior knowledge predicted exam scores only for students from a bachelor mathematics program. For students in the teacher education program, exam scores were largely independent of prior knowledge when controlling for school qualification grade. Future research could study possible reasons for this finding. For example, a lecturer in the teacher education program might have connected to students' prior understanding of mathematical concepts more explicitly, when trying to highlight the relevance of the content for students' teaching career. However, the importance of general prior achievement and domain-specific prior knowledge for the transition to university mathematics is well established.

Beyond this, our study extends prior evidence from higher education that subjective measures of study success in the transition phase are largely independent of cognitive learning prerequisites (H2.1, Blömeke, 2009; Brandstätter et al., 2006; Nagy, 2006). It may be of interest in the future to study the mutual influences between academic achievement and subjective appraisals, such as study satisfaction, later in the study program. Given the importance of study satisfaction for students' drop-out, this remains an important desideratum.

Effects of Interest as a Learning Prerequisite

Even though a relation would be expected from a theoretical perspective (Ainley et al., 2002; Krapp, 2002), past research has not succeeded in providing evidence that prior interest in mathematics predicts study success in the transition to university mathematics (Rach et al., 2017). Following the idea that existing interest scales may not sufficiently account for the changing character of the object of interest in the transition phase, we applied an instrument that differentiates between interest in school and university mathematics, and related practices (Ufer et al., 2017). The main background was the congruence hypothesis (Holland, 1973) that interest will only show an influence on study success if it is congruent with the contents of the program. Moreover, an incongruence hypothesis would posit that interests, which are incongruent with the contents, could even be detrimental for study success.

With regard to exam scores as objective criteria of study success, our results replicate the conclusion that general interest in mathematics has at most a small influence on learning gain in the first semester of a mathematics program (H1.2). However, the same must be admitted for the more differentiated measure of interest applied in our study. Neither interest in university mathematics (H1.3) or interest in proof and formal representation (H1.4) predicted learning gain positively, nor did the school-related interest facets such as applying mathematics or using calculation techniques show a negative relationship. In line with existing studies (Rach et al., 2017; Ufer, 2015), we could not find an indication that individual interest would matter strongly for exam achievement at the end of the first semester. Since past studies also only found weak effects of individual interest on learning, the influence of interest facets on achievement most likely requires large samples to be detected, and might even be too small to be of practical relevance. Even though small effects might not have been identified due to the small sample size, the (in)congruence hypotheses could not be supported by our results for objective measures of study success. Given the established role of situational interest in learning processes (Hidi & Renninger, 2006), it remains an open question which individual and contextual factors, beyond individual interest, determine situational interest during learning, and how the high levels of interest in university students may be put into effect for learning. Our results indicate, however, that low congruence of students' individual interest with the contents of the study program is not a strong reason for low learning gains. The link between interest and deep-level strategies (Schiefele et al., 1995) might have been hidden, because also surface-level learning may have a positive effect on performance under specific circumstances (Senko et al., 2013). Students focusing on the exam may achieve better exam scores due to an applied vigilance than students who follow their interest during exam preparation. Studying learning strategies might clarify this picture in future studies (Dinsmore & Alexander, 2012).

Our study adds to the few existing results on the *relation of interest and study satisfaction*. Coinciding with previous results (Blüthmann, 2012; Nagy, 2006; Schiefele & Jacob-Ebbinghaus, 2006), general interest in mathematics predicted subjective criteria of study success positively (H2.2). For subjective criteria, our approach to use differentiated measures of interest was powerful, indeed raising the amount of explained variance substantially. Interest in proof and formal representations (H2.3) and university mathematics (H2.4) predicted study satisfaction positively and demotivation negatively, beyond general interest. Since these practices are predominant in university mathematics (Engelbrecht, 2010; Hoyles et al., 2001), this finding supports the congruence hypothesis, extending first results by Bergmann (1992).

On the other hand, students reporting high interest in school mathematics seem to develop less positive appraisals of their programs. In line with an incongruence hypothesis, interest in school mathematics predicted lower study satisfaction and higher demotivation (Tables 6 and 7, models 5 and 7). Interestingly, this effect occurred only for the institution-related measure of interest, and not for the related practice of applying mathematics (Tables 6 and 7, models 6 and 7). Authentic application problems are rare in German school classrooms (Jordan et al., 2008) and are less valued by students than calculation problems (Krug & Schukajlow, 2013). Students might not connect (authentic) applications strongly with school mathematics, but rather expect them for later periods of their university studies.

Since study satisfaction predicts actual drop-out (Brandstätter et al., 2006; Schiefele et al., 2007), our results indicate that individual interests which are congruent to the contents of the program may support students to retain in the program during the transition to university mathematics. Moreover, incongruent interests seem to pose an additional risk for drop-out.

Limitations

The presented study has some limitations. First of all, we relied on self-reports of *individual* interest, since we were interested if easily accessible information about beginning mathematics students allows conclusions about later study success. Studying *situational* interest in learning situations may provide deeper insights into the role of interests for academic achievement. Moreover, even though students seem to have fairly realistic expectations about mathematics at university (Rach et al., 2014), students rated interest in school mathematics as they *experienced* it, while the rated interest in university as they *anticipated* it. Further research should thus address the development of interest facets as well as students' beliefs about the nature of mathematics when students get acquainted with university mathematics.

We included the school qualification grade as a predictor into our regression models. This is reasonable due to its undisputed status as a predictor of achievement. However, since grades also capture affective learning prerequisites (Trapmann et al., 2007), the unique effect of interest facets might have been underestimated. This is less probable for subjective criteria of study success, which are mostly independent of school grades, than for objective criteria.

Finally, we focused on interest and cognitive learning prerequisites, even though there are many factors influencing study success (Blüthmann et al., 2008). Interest is a variable that is clearly specific to the subject and particularly sensitive to the shift from school to university mathematics. However, future research should also consider other relevant subject-related factors, such as subject-specific emotions or mathematical self-concept (Di Martino & Gregorio, 2018), or more overarching student characteristics, such as resilience or conscientiousness (De Feyter, Caers, Vigna & Berings, 2012).

With regard to methodological aspects, our study was restricted with respect to small sample size, in particular when analyzing exam scores. While we considered this by including power analyses, replications are necessary. This applies also to replications in other countries, where similar shifts are present in the transition to university mathematics (France: Gueudet, 2008; China, Hong Kong: Luk, 2005; New Zealand and Canada: Clark & Lovric, 2009). In Germany, the situation in classrooms may differ from the intended curriculum that is described in the standards (KMK, 2012). It is an open question whether the effects of the shift might be even stronger if the standards were implemented to a larger extent. Larger studies could also explore if and how the specific design and context of the study programs moderates the observed relations. Furthermore, the first semester of a mathematics program might be considered a very special context to study the effects of interest, facing students with diverse challenges. Although researchers have repeatedly highlighted the importance of the first semester for study success (Blüthmann, 2012; Brandstätter et al., 2006), the long-term effects of interest on study success remain an open desideratum. Long-term studies could also gather data on dropout beyond students' self-reports. In this context, it might be promising to differentiate between students who drop out of the program and those who retain. Finally, we applied self-developed scales of interest that differentiate between different mathematical practices. To our knowledge, there are no other scales measuring specific facets of mathematics interest in a similar way; therefore, it remains an open question if other ways to differentiate interest facets would yield results regarding the role of these interest facets in the transition phase.

Conclusion

Despite its limitations, our study indicates that beyond the school qualification grade, students' reports of individual interest at the start do not carry strong information that allows to predict achievement at the end of the first semester. In addition, differentiating facets of mathematics interests does not improve this. However, results indicate that interest may still be relevant for later drop-out from a mathematics university study because a possible effect may be mediated by subjective appraisals such as study satisfaction and demotivation. To predict these, congruence of interests with the contents of the mathematics program is important.

Based on our results, three practical implications can be drawn:

(1) Study advice for students aiming at a university mathematics program should take into account not only students' school grades and prior knowledge, but also their individual interests with respect to different facets of mathematics and mathematical practices. It may be a useful idea to inform students explicitly about the central differences between school and university mathematics.

(2) Study support might take students' interest profile into consideration more carefully and try to support interest development. Studies from the school context have successfully evaluated approaches based on Deci and Ryan's (2002) self-determination theory. For example, professional classroom communication (Kiemer, Gröschner, Pehmer & Seidel, 2015) and a structured organization of instruction and student involvement (Stroet, Opdenakker & Minnaert, 2015) were positively connected to the development of interests and motivation.

(3) Given the strong influence of cognitive aspects, interventions that support students with less prior knowledge concerning central practices in the first semester should be explored, e.g. by explicitly connecting formal mathematical definitions and theorems to the understanding of mathematical concepts from school instruction.

References

Ainley, M., Hidi, S. & Berndorff, D. (2002). Interest, learning and the psychological processes that mediate their relationship. *Journal of Educational Psychology, 94*(3), 545–561.

Assouline, M. & Meir, E. I. (1987). Meta-analysis of the relationship between congruence and well-being measures. *Journal of Vocational Behaviour, 31*(3), 319–332.

Bengmark, S., Thunberg, H. & Winberg, T. M. (2017). Success-factors in transition to university mathematics. *International Journal of Mathematical Education in Science and Technology, 48*(7), 988–1001.

Bergmann, C. (1992). Schulisch-berufliche Interessen als Determinanten der Studien- bzw. Berufswahl und -bewältigung [Educational-vocational interests as determinants of choice for major and career and coping with it]. In A. Krapp & M. Prenzel (Eds.), *Interesse, Lernen, Leistung: Neuere Ansätze einer pädagogisch-psychologischen Interessenforschung* [Interest, learning, achievement: New approaches of a pedagogical-psychological research on interest] (pp. 195–220). Münster, Germany: Aschendorff.

Blömeke, S. (2009). Ausbildungs- und Berufserfolg im Lehramtsstudium im Vergleich zum Diplom-Studium [Vocational and career success in teacher education programs in comparison to diploma study programmes]. *Zeitschrift für Erziehungswissenschaft, 12*(1), 82–110.

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.

Blüthmann, I., Lepa, S. & Thiel, F. (2008). Studienabbruch und -wechsel in den neuen Bachelorstudiengängen. Untersuchung und Analyse von Abbruchgründen [Drop-out and change of subject in the new bachelor study programs. Analysis of reasons for drop-out]. *Zeitschrift für Erziehungswissenschaften, 11*(3), 406–429.

Brandstätter, H., Grillich, L. & Farthofer, A. (2006). Prognose des Studienabbruchs [Prediction of drop-out]. *Zeitschrift für Entwicklungspsychologie und Pädagogische Psychologie, 38*(3), 121–131.

Clark, M. & Lovric, M. (2009). Understanding secondary–tertiary transition in mathematics. *International Journal of Mathematical Education in Science and Technology, 40*(6), 755–776.

De Feyter, T., Caers, R., Vigna, C. & Berings, D. (2012). Unraveling the impact of the big five personality traits on academic performance: The moderating and mediating effects of self-efficacy and academic motivation. *Learning and Individual Differences, 22*(4), 439–448.

Deci, E. L. & Ryan, R. M. (2002). *Handbook of self-determination research*. Rochester, NY: Univ. of Rochester Press.

Di Martino, P. & Gregorio, F. (2018). The mathematical crisis in secondary–tertiary transition. *International Journal of Science and Mathematics Education*. https://doi.org/10.1007/s10763-018-9894-y.

Di Martino, P. & Zan, R. (2015). The construct of attitude in mathematics education. In B. Pepin & B. Roesken-Winter (Eds.), *From beliefs to dynamic affect systems in mathematics education* (pp. 51–72). Cham, Switzerland: Springer.

Dieter, M. (2012). *Studienabbruch und Studienfachwechsel in der Mathematik* [Drop-out and change of subject when studying mathematics] (Doctoral dissertation). Retrieved from http://duepublico.uni-duisburg-essen.de/servlets/DerivateServlet/Derivate-30759/Dieter_Miriam.pdf .

Dinsmore, D. L. & Alexander, P. A. (2012). A critical discussion of deep and surface processing: What it means, how it is measured, the role of context, and model specification. *Educational Psychology Review, 24*(4), 499–567.

Eccles, J. & Wigfield, A. (2002). Motivational beliefs, values, and goals. *Annual Review of Psychology, 53*, 109–132.

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.

Geiser, S. & Santelices, M. V. (2007). *Validity of high-school grades in predicting student success beyond the freshman year: High-school record vs. standardized tests as indicators of four-year college outcomes*. Center for Studies in Higher Education at the University of California, Berkeley CSHE 6.07.

Gueudet, G. (2008). Investigating the secondary–tertiary transition. *Educational Studies in Mathematics, 67*(3), 237–254.

Halverscheid, S. & Pustelnik, K. (2013). Studying math at the university: Is drop-out 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). Kiel, Germany: PME.

Hannula, M. S. (2011). The structure and dynamics of affect in mathematical thinking and learning. In M. Pytlak, T. Rowland & E. Swoboda (Eds.), *Proceedings of the 7th Congress of the European Society for Research in Mathematics Education* (pp. 34–60). Poland: University of Rzesów.

Harackiewicz, J. M. & Hulleman, C. S. (2010). The importance of interest: The role of achievement goals and task values in promoting the development of interest. *Social and Personality Psychology Compass, 4*(1), 42–52.

Häussler, P. & Hoffmann, L. (2000). A curricular frame for physics education: development, comparison with students' interests, and impact on students' achievement and self-concept. *Science Education, 84*, 689–705.

Heinze, A., Reiss, K. & Rudolph, F. (2005). Mathematics achievement and interest in mathematics form a differential perspective. *ZDM, 37*(3), 212–220.

Heublein, U., Richter, J., Schmelzer, R. & Sommer, D. (2014). *Die Entwicklung der Studienabbruchquoten an den deutschen Hochschulen*. [The development of drop-out rates at German universities]. Hannover, Germany: DZHW.

Hidi, S. & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist, 41*(2), 111–127.

Holland, J. L. (1973). *Making vocational choices: A theory of careers*. Upper Saddle River, NJ: Prentice Hall.

Hoyles, C., Newman, K. & Noss, R. (2001). Changing patterns of transition from school to university mathematics. *International Journal of Mathematical Education in Science and Technology, 32*(6), 829–845.

Jordan, A., Krauss, S., Löwen, K., Blum, W., Neubrand, M., Brunner, M. & Baumert, J. (2008). Aufgaben im COACTIV-Projekt: Zeugnisse des kognitiven Aktivierungspotentials im deutschen Mathematikunterricht [Tasks in the COACTIV-project: Evidence of the potential for cognitive activation in German mathematics classes]. *Journal für Mathematik-Didaktik, 29*(2), 83–107.

Kiemer, K., Gröschner, A., Pehmer, A.-K. & Seidel, T. (2015). Effects of a classroom discourse intervention on teachers' practice and students' motivation to learn mathematics and science. *Learning and Instruction, 35*, 94–103.

KMK (2012). *Bildungsstandards im Fach Mathematik für die Allgemeine Hochschulreife* [Education standards in mathematics for the higher education entrance qualification]. Retrieved from http://www.kmk.org/fileadmin/Dateien/veroeffentlichungen_beschluesse/2012/2012_10_18-Bildungsstandards-Mathe-Abi.pdf.

Köller, O., Baumert, J. & Schnabel, K. (2001). Does interest matter? The relationship between academic interest and achievement in mathematics. *Journal for Research in Mathematics Education, 32*(5), 448–470.
Krapp, A. (2002). Structural and dynamic aspects of interest development: Theoretical considerations from an ontogenetic perspective. *Learning and Instruction, 12*(4), 383–409.
Krapp, A. (2007). An educational-psychological conceptualisation of interest. *International Journal for Educational and Vocational Guidance, 7*(1), 5–21.
Krapp, A. & Prenzel, M. (2011). Research on interest in science: Theories, methods, and findings. *International Journal of Science Education, 33*(1), 27–50.
Krug, A. & Schukajlow, S. (2013). Problems with and without connection to reality and students' task-specific interest. In A. M. Lindmeier & A. Heinze (Eds.), *Proceedings of the 37th Conference of the International Group for the Psychology of Mathematics Education* (Vol. 3, pp. 209–216). Kiel, Germany: PME.
Kuncel, N. R., Hezlett, S. A. & Ones, D. S. (2001). A comprehensive meta-analysis of the predictive validity of the graduate record examinations: Implications for graduate student selection and performance. *Psychological Bulletin, 127*(1), 162–181.
Lapan, R., Shaughnessy, P. & Boggs, K. (1996). Efficacy expectations and vocational interests as mediators between sex and choice of math/science college majors: A longitudinal study. *Journal of Vocational Behavior, 49*(3), 277–291.
Lee, W., Lee, M.-J. & Bong, M. (2014). Testing interest and self-efficacy as predictors of academic self-regulation and achievement. *Contemporary Educational Psychology, 39*(2), 86–99.
Liebendörfer, M. & Hochmuth, R. (2013). Interest in mathematics and the first steps at the university. In B. Ubuz, C. Haser & M. A. Mariotti (Eds.), *Proceedings of the 8th Congress of the European Society for Research in Mathematics Education* (pp. 2386–2395). Antalya, Turkey: ERME.
Liston, M. & O'Donoghue, J. (2009). Factors influencing the transition to university service mathematics: Part I a quantitative study. *Teaching Mathematics and Its Applications, 28*(2), 77–87.
Luk, H. S. (2005). The gap between secondary school and university mathematics. *International Journal of Mathematical Education in Science and Technology, 36*(2–3), 161–174.
Marsh, H. W., Trautwein, U., Lüdtke, O., Köller, O. & Baumert, J. (2005). Academic self-concept, interest, grades, and standardized test scores: Reciprocal effects models of causal ordering. *Child Development, 76*(2), 397–416.
Muthén, B. & Muthén, L. (1998–2015). *Mplus* (Version 7). LA: Muthén & Muthén.
Nagy, G. (2006). *Berufliche Interessen, kognitive und fachgebundene Kompetenzen: Ihre Bedeutung für die Studienfachwahl und die Bewährung im Studium* [Vocational interests, cognitive and subject-related competences: Their significance for chosing a major and coping with the studies] (Doctoral dissertation). Retrieved from http://www.diss.fu-berlin.de/diss/receive/FUDISS_thesis_000000002714.
Organization for Economic Co-operation and Development (2016). "*PISA 2015 mathematics framework*". *PISA 2015 assessment and analytical framework: Science, reading, mathematics and financial literacy*. Paris, France: Author.
Pekrun, R., Goetz, T., Titz, W. & Perry, R. P. (2002). Positive emotions in education. In E. Frydenberg (Ed.), *Beyond coping. Meeting goals, visions, and challenges* (pp. 149–173). Oxford, England: Oxford University Press.
Pyzdrowski, L. J., Sun, Y., Curtis, R., Miller, D., Winn, G. & Hensel, R. A. M. (2013). Readiness and attitudes as indicators for success in college calculus. *International Journal of Science and Mathematics Education, 11*(3), 529–554.
Rach, S., Heinze, A. & Ufer, S. (2014). Welche mathematischen Anforderungen erwarten Studierende im ersten Semester des Mathematikstudiums? [Which mathematical requirements do students expect in the first semester of studying mathematics?]. *Journal für Mathematik-Didaktik, 35*(2), 205–228.
Rach, S., Kosiol, T. & Ufer, S. (2017). Interest and self-concept concerning two characters of mathematics: All the same, or different effects? In R. Göller, R. Biehler, R. Hochmuth & H.-G. Rück (Eds.), *Didactics of Mathematics in Higher Education as a Scientific Discipline – Conference Proceedings* (khdm-report 17-05, pp. 294–298). Kassel, Germany: khdm.
Radford, L. (2015). Of love, frustration, and mathematics: A cultural-historical approach to emotions in mathematics teaching and learning. In B. Pepin & B. Roesken-Winter (Eds.), *From beliefs to dynamic affect systems in mathematics education* (pp. 25–49). Cham, Switzerland: Springer.
Richardson, M., Abraham, C. & Bond, R. (2012). Psychological correlates of university students' academic performance: A systematic review and meta-analysis. *Psychological Bulletin, 138*(2), 353–387.
Robbins, S. B., Lauver, K., Le, H., Davis, D., Langley, R. & Carlstrom, A. (2004). Do psychosocial and study skill factors predict college outcomes? A meta-analysis. *Psychological Bulletin, 130*(2), 261–288.
Schiefele, U. (2009). Situational and individual interest. In K. R. Wentzel & A. Wigfield (Eds.), *Handbook of motivation at school. Educational psychology handbook series* (pp. 197–222). New York, NY: Routledge.

Schiefele, U. & Jacob-Ebbinghaus, L. (2006). Lernmerkmale und Lehrqualität als Bedingungsfaktoren der Studienzufriedenheit [Features of learning and teaching as conditional factors of satisfaction with the study program]. *Zeitschrift für Pädagogische Psychologie, 20*(3), 199–212.
Schiefele, U., Krapp, A. & Wild, K.-P. (1995). *Course-specific interest and extrinsic motivation as predictors of specific learning strategies and course grades.* Paper prepared for presentation at the 6th EARLI Conference at Nijmegen.
Schiefele, U., Krapp, A. & Winteler, A. (1992). Interest as a predictor of academic achievement: A meta-analyisis of research. In K. A. Renninger, S. Hidi & A. Krapp (Eds.), *The role of interest in learning and development* (pp. 183–211). Hillsdale, MI: Erlbaum.
Schiefele, U., Moschner, B. & Husstegge, R. (2002). *Skalenhandbuch SMILE-Projekt* [Guide of scales from the SMILE project]. Bielefeld, Germany: Universität Bielefeld.
Schiefele, U., Streblow, L. & Brinkmann, J. (2007). Aussteigen oder Durchhalten. Was unterscheidet Studienabbrecher von anderen Studierenden? [drop-out or persist. What differentiates students that drop-out from other students]. *Zeitschrift für Entwicklungspsychologie und Pädagogische Psychologie, 39*(3), 127–140.
Schukajlow, S. & Krug, A. (2014). Are interest and enjoyment important for students' performance? In P. Liljedahl, C. Nicol, S. Oesterle & D. Allan (Eds.), *Proceedings of the 38th Conference of the International Group for the Psychology of Mathematics Education and the 36th Conference of the North American Chapter of the Psychology of Mathematics Education* (Vol. 5, pp. 129–136). Vancouver: PME.
Schunk, D. H. (1991). Self-efficacy and academic motivation. *Educational Psychologist, 26*(3,4), 207–231.
Senko, C., Hama, H. & Belmonte, K. (2013). Achievement goals, study strategies, and achievement: A test of the "learning agenda" framework. *Learning and Individual Differences, 24*, 1–10.
Sonnert, G. & Sadler, P. (2015). The impact of instructor and institutional factors on students' attitudes. In D. Bressoud, V. Mesa & C. Rasmussen (Eds.), *Insights and recommendations from the MAA National Study of College Calculus* (pp. 17–30). Washington, DC: Mathematical Association of America Press.
Sorge, S., Petersen, S. & Neumann, K. (2016). Die Bedeutung der Studierfähigkeit für den Studienerfolg im 1. Semester in Physik [The significance of the ability to study for the study success in the first semester in physics]. *Zeitschrift für Didaktik der Naturwissenschaften, 22*(1), 165–180.
Stroet, K., Opdenakker, M. C. & Minnaert, A. (2015). What motivates early adolescents for school? A longitudinal analysis of associations between observed teaching and motivation. *Contemporary Educational Psychology, 42*, 129–140.
Tall, D. (2008). The transition to formal thinking in mathematics. *Mathematics Education Research Journal, 20*(2), 5–24.
Trapmann, S., Hell, B., Weigand, S. & Schuler, H. (2007). Die Validität von Schulnoten zur Vorhersage des Studienerfolgs — Eine Metaanalyse [Validity of school grades predicting study success — A meta-analysis]. *Zeitschrift für Pädagogische Psychologie, 21*(1), 11–27.
Ufer, S. (2015). The role of study motives and learning activities for success in first semester mathematics studies. In K. Beswick, T. Muir & J. Wells (Eds.), *Proceedings of the 39th Conference of the International Group for the Psychology of Mathematics Education* (Vol. 4, pp. 265–272). Hobart, Australia: PME.
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 The International Journal on Mathematics Education, 49*(3), 397–409.
Ulriksen, L., Møller Madsen, L. & Holmegaard, H. T. (2010). What do we know about explanations for drop-out/opt out among young people from STM higher education programmes? *Studies in Science Education, 46*(2), 209–244.
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). New York, NY: Springer.
Zan, R., Brown, L., Evans, J. & Hannula, M. S. (2006). Affect in mathematics education: An introduction. *Educational Studies in Mathematics, 63*(2), 113–121.