ZDM Mathematics Education (2017) 49:397–409
DOI 10.1007/s11858-016-0828-2

ORIGINAL ARTICLE

Interest in mathematics = interest in mathematics? What general measures of interest reflect when the object of interest changes

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Accepted: 28 November 2016 / Published online: 16 December 2016

Abstract Students' motivational characteristics, e.g., subject-related interest, are considered important predictors for successful learning processes. However, few empirical studies provide evidence for the assumed chain of effects between high interest and high achievement in mathematics. One reason for this result might be that the applied measures of learners' interest in mathematics are not well aligned with the characteristics of the learning content in the respective educational settings. At the transition from school to university, the character of mathematics shifts from a strongly application oriented school subject to a scientific discipline. When students are asked to rate their interest concerning mathematics learning in general, it is not clear which character of mathematics they refer to (in their ratings). To provide a more differentiated picture of learners' interest, we developed questionnaires that survey students' interest concerning the different characters of mathematics explicitly. With a sample of 323 students from academic mathematics programs, we analysed the quality of the developed scales and whether it is possible to differentiate interest facets according to the different characters of mathematics. In this contribution, we present the development of the instruments. The results of exploratory factor analyses and correlation analyses provide support for the quality of the developed instruments. Our results indicate that indeed the character of mathematics addressed in the questionnaire strongly influences students' self-reports. Finally, we study how the differentiated interest constructs are related to general ratings of interest in mathematics.

Keywords Interest in mathematics · Differentiated measures of interest · Transition from school to university mathematics · Interest as a person-object relationship

1 Introduction

While there are many arguments that put forward the importance of interest for learning (Ainley et al. 2002; Hidi 1990, 1995; Hidi and Renninger 2006; Krapp and Prenzel 2011; Marsh et al. 2005), many studies report only weak correlations between students' interest and their achievement (Heinze et al. 2005; Lee et al. 2014; Malmivuori 2006; Schiefele et al. 1992). Also results on the influence of mathematics-related interest on students' learning are inconsistent, at best. While some studies report a weak relation between interest and students' achievement (Schiefele et al. 1992; Malmivuori 2006; Lee et al. 2014), studies at the transition phase fail to find such connections (Eilerts 2009; Rach and Heinze 2016). We argue that one reason for these results might be the use of instruments that are not specific to survey students' interest in mathematics. For the transition to tertiary mathematics programs, for example, researchers have hypothesized that some students lack an adequate level of interest towards the contents of their study program (Liebendörfer and Hochmuth 2013) or that students bring along interests in aspects of mathematics that are not aligned with mathematics as it is taught at the university (Rach 2014).

Electronic supplementary material The online version of this article (doi:10.1007/s11858-016-0828-2) contains supplementary material, which is available to authorized users.

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Recent studies have indicated that some frequent observations regarding interest, such as its decrease during secondary school in subjects such as science and mathematics, can be explained when considering facets of interest as a person-object relationship in detail (e.g., Frenzel et al. 2012). While students' relation towards mathematics seems to change during secondary school, the transition to a university mathematics program has frequently been characterized by a strong shift in the nature of the discipline mathematics. Inconsistent findings on the development of interest and its relations to success in university mathematics studies might be explained by a failure of the applied instruments to capture this shift in the object of interest, mathematics.

Our main goal in this article is to contribute to the understanding of university students' interest in mathematics at the transition from school to university mathematics and to propose and study a more differentiated approach towards students' interest during this transition. Starting from theoretical descriptions of mathematics as it is treated at school and university, we describe this shift in the character of mathematics as the domain that is targeted in learning processes. Based on a common definition of interest as a person-object relationship, we discuss the role of a changing character of the domain in this context. We describe our approach to the construct "interest in mathematics" and its measurement at the transition to university mathematics. Then we describe the conceptualization of instruments that are based on this more differentiated perspective, and present data on the quality of these instruments.

1.1 Mathematics as a school subject and as a scientific discipline

High drop-out rates in academic study programs with a focus on mathematics (e.g., Dieter 2012) have drawn researchers' attention towards the transition phase from school to university mathematics. Most authors describe changes in two relevant aspects of the learning environment at this transition: a shift in the character of the learning domain, mathematics, and a change in the learning opportunities and their use. These descriptions are mainly based on theoretical analyses and sometimes on anecdotic evidence from students and teaching staff (e.g., Engelbrecht 2010; Gueudet 2008; Thomas and Klymchuk 2012). Empirical studies supporting the existence of these shifts and their effects on student learning are scarce.

In this paper we focus on the changing character of the learning domain mathematics. One central goal of mathematics instruction at school is—among others—to use mathematics for solving real-world problems. National standard documents (CCSSI 2010; KMK 2012) as well as frameworks of international comparison studies of student achievement (OECD 2016) illustrate this goal. Thus, describing realistic situations mathematically, doing computations and applying mathematical procedures are central. University mathematics, on the contrary, is usually described as a scientific discipline based on formal definitions of mathematical concepts and formal-deductive proofs. In particular, the scientific discipline "mathematics" focuses primarily on building coherent and consistent theories based on abstract concepts and assumptions, without aiming at a direct connection to real world phenomena (Dörfler and McLone 1986). Mathematics, in this sense, is characterized by formal-deductive proofs (Gueudet 2008; Healy and Hoyles 1998) as well as formal-symbolic representations of mathematical concepts (e.g., Epp 2003; Ottinger et al. 2016). Many authors describe that this character of mathematics as a scientific discipline strongly shapes teaching at the university, e.g., by a strong focus on the DTP (Definition–Theorem–Proof) structure (Engelbrecht 2010; Hoyles et al. 2001).

While students deal with similar mathematical concepts in the upper secondary school and in the first semester of mathematics, such as differentiable functions or limits, textbook analyses unveil differences: There is indeed a strong focus on computational techniques, like algebraic manipulations or calculating derivatives, and their application to more or less realistic word-problems in secondary school, while university mathematics is dominated by a strong focus on proving mathematical statements (Vollstedt et al. 2014). A survey of institutions shows that 50% of all tasks in school examinations are computational tasks, whereas only 10% require proving a mathematical statement (Burn et al. 2015). Using computational techniques is usually seen as relevant for both contexts, but the role of applications and word-problems decreases during the transition from school to university mathematics, while proof and formal representations of mathematical ideas become more important.

These theoretical explanations and descriptive results open a very broad spectrum of possible approaches for intervention (Engelbrecht 2010; Gueudet 2008; Thomas and Klymchuk 2012). To provide students with well-planned support at the transition, it is necessary to identify the individual and institutional reasons for students' problems. In the past years, several studies have attempted to identify individual characteristics that allow some students to cope with the transition. Cognitive prerequisites, like prior knowledge of mathematics and general prior school achievement usually turn out to be predictive for student success (Hailikari et al. 2008; Rach and Heinze 2016; Ufer 2015). The theoretical assumption that interest is important for students' success (Fenollar et al. 2007; Rach and Heinze 2016) could not be consistently supported in prior research (Eilerts 2009; Rach 2014).

Summarizing, the character of the domain "mathematics" shifts from a school subject with a strong focus on computations and applications of mathematics in word-problems to a scientific discipline based on formal definitions and deductive proof at the transition from school to university in many countries. It is not yet understood which individual characteristics might help students to cope with these challenges successfully. In particular, research has failed to clarify the role of affective-motivational predictors like interest in the past. In the sequel, we argue that the shift in the character of mathematics might be one reason for problems in identifying the effect of interest on student learning at the transition to university mathematics.

1.2 Interest as a motivational variable in students' mathematics learning

1.2.1 Facets of interest as a person-object relation

While, from an everyday usage of the word, interest seems to be an important motivational prerequisite of students' individual learning processes, explicit definitions of the term and their empirical operationalizations vary in the literature (Eccles and Wigfield 2002; Krapp and Prenzel 2011; Murphy and Alexander 2000). Firstly, the term *interest* is often used to describe a certain motivational state during specific learning situations, which is closely related to intrinsic motivation (situational interest; Hidi and Renninger 2006). Research from this perspective studies how situational interest may support learning, or how it may develop into a more enduring individual (trait) interest (Hidi and Renninger 2006). It is assumed that this process is supported by students' perceptions of autonomy, competence, and social-relatedness (Deci and Ryan 2000; Hidi and Renninger 2006). Secondly, *interest* is also used to describe the relatively enduring characteristic of individuals that allows them to activate interest states in specific situations (personal or individual interest, Krapp 2002). This conceptualization goes back to person-object theories of interest (Krapp 2002). Interest in this sense describes a specific *relation* between an individual (*person*) and an *object* of interest, which may be any cognitively represented entity from the individuals' "life-space" (*Lebensraum*, Krapp 2002). Such objects of interest may refer to concrete objects, topics, ideas, or also school subjects. In this sense, interest can be characterized by the qualities that a person connects with the relation. Marsh et al. (2005) illustrate this multi-faceted nature of interest when saying that "Academic interests are postulated to be dispositions based on mental schemata associating the objects of interest with positive experiences and a personal value system that are activated in the form of interest-driven actions" (p. 399). Schiefele et al. (1992) distinguish between three components of interest: (a) an *emotional component*, usually related to joy or other positive emotions experienced when dealing with the object of interest, (b) a component describing the *value* a person attributes to the object, and (c) an *intrinsic component* that addresses the individual tendency to re-engage with the object for reasons that are primarily connected with the object itself.

In the past, the relation of interest to more general personality traits has been studied, in particular with openness to experience (e.g., Wiernik et al. 2016) and curiosity (e.g., Silvia 2005). Openness describes "the breadth, depth, originality, and complexity of an individuals' mental and experiential life" (John et al. 2010, p. 138). Past research has shown that openness to experience is associated more strongly with interest in artistic domains than with interest in investigative domains such as mathematics (Wiernik et al. 2016). Epistemic curiosity "refers to individual differences in seeking out opportunities for intellectual engagement" (Stumm et al. 2011, p. 576). When the object of interest changes, epistemic curiosity might trigger exploration of new facets of the subject and interest development (Silvia 2005). It is still an open question to which extent reports of subject-related interest reflect general personality traits, or the specific person-object relation that is the focus of the questionnaire.

Several authors hypothesize that interest can trigger successful learning. It is assumed to have a positive influence on learning processes and learning gain, because it should induce a positive mood during learning (Hidi and Renninger 2006), sustained attention (Ainley et al. 2002; Hidi and Renninger 2006), goal-directed processing (Hidi and Renninger 2006), self-regulative processes (Lee et al. 2014), and deep levels of learning (Hidi and Renninger 2006). In view of these arguments, interest has been put forward as an important antecedent of academic learning in general (Hidi and Renninger 2006), and specifically in the transition phase to university mathematics (Eilerts 2009; Rach and Heinze 2016). However, these assumptions could not be confirmed in many empirical studies. Although Schiefele et al. (1992) report a correlation of 0.32 between interest and achievement in mathematics in their meta-analyses of cross-sectional studies in grades 8–12 (cf. Heinze et al. 2005; Marsh et al. 2005) and Schukajlow and Krug (2014) found correlations ranging between 0.18 and 0.40 for task-specific and task-unspecific interest and performance in mathematics, longitudinal studies could not identify an influence of interest on learning success beyond students' prior achievement in the school context (Köller et al. 2001, cf.; Schiefele 2009) and during the transition phase (Eilerts 2009; Rach and Heinze 2016). As the study of Köller et al. (2001) indicates, a longitudinal relation between mathematics interest and achievement is mediated at least partially by students' choice during their learning biography (cf. Krapp and Prenzel 2011). Indeed, Lapan et al. (1996) found that interest in mathematics predicts the choice of a mathematics major in university, and Rach (2014) showed that students from a mathematics teacher education program show substantially lower interest in mathematics than students from a mathematics bachelor's program.

1.2.2 *Shifts in the nature of interest as a person-object relationship*

Starting from lower secondary school, a decline of students' interest in mathematics (Frenzel et al. 2010; Köller et al. 2001) and other subjects (e.g., science: Krapp and Prenzel 2011) has been replicated repeatedly. Gogol et al. (2016) report a weaker stability of interest in mathematics than in other subjects (French and German) in 7th and 9th graders from Luxembourg. Sonnert and Sadler (2015) also found decreasing interests in Calculus 1 courses for university engineering or science students, Rach (2014) reports similar results for first year mathematics students, and Kolter et al. (2016) for students in the first semester of a primary teacher education program.

Different explanations have been offered for this decline in the past, including the quality of instruction, too few possibilities to experience competency, autonomy, and social-relatedness (Deci and Ryan 2000), or the role of other developmental tasks in adolescence. Recently, researchers also propose that interests might differentiate into diverse interest facets during individual identity development (Krapp and Prenzel 2011). New light has been shed on these ideas by an analysis of a large scale longitudinal data set by Frenzel et al. (2012). When analyzing the factor loadings of questionnaire items relating to different components of interest (emotional versus cognitive), they found indications that the decline in students' mean ratings of interest was at least partially due to a shift in the nature of students' person-object relation towards mathematics from an emotional to a more cognitive relation. This result indicates that, in particular when studying interest over periods of time, it is necessary to ensure that the quality of the person-object relationship does not change substantially. Since usual interest questionnaires refer to the object of interest in rather general terms like "mathematics" (e.g., "I enjoy doing mathematics" in Sonnert and Sadler 2015), we argue that it is not clear which character of mathematics students refer to when they report their emotions, their values, and their intrinsic connection to "mathematics".

Summarizing, personal interest can be conceptualized as a person-object relationship that is characterized by qualities such as positive emotions, high value, and its intrinsic quality. Empirical results indicate that changes in the nature of this person-object relation might at least partially explain phenomena that have been interpreted as declining interest in the past. We argue that, in the transition to a university mathematics program, the object of interest has to be considered with care. It is still an open question to which extent the shift in the nature of mathematics at this transition might affect analyses that use general measures of interest (Eilerts 2009; Rach and Heinze 2016).

2 The current study

The starting point for the project *Self-concept and Interest when Studying Mathematics* (SISMa; Rach et al., accepted) was the gap between theoretical arguments that support an important role of interest when coping with the transition phase to university mathematics, and the missing empirical evidence for its effects. Based on a conceptualization of interest as a person-object relationship, and the fact that measures of interest might be biased by shifts in person-object relation (e.g., Frenzel et al. 2012), we propose that the changing character of the domain 'mathematics' during the transition to university mathematics might be an important factor to take into account. The goal of the SISMa project is to develop interest measures that are sensitive to this shift and to study the development and impact of individual interest during the study entrance phase in academic mathematics programs. Our main goal in the current paper is to study the internal structure of the newly developed scales, investigate their potential to detect differences between study programs and analyse their relation to general measures of interest.

Based on several available questionnaires (e.g., Pekrun et al. 2002; Schiefele et al. 1992), we developed two types of interest scales, which vary in the way they present specific aspects of mathematics.[1] The first type of scales surveys the relationship to mathematics as it has been experienced in a specific context or as it is anticipated (when using the instrument before the start of university studies). These items directly address one of the two institutions, in which mathematics is taught and learnt: school vs. university. The second type of scales (four scales) addresses interest in mathematical practices, which are characteristic for school mathematics (applying mathematics), for university mathematics (proving and dealing with formal representations), or for both contexts (using mathematical calculation techniques).

The instruments were piloted with 52 students of computer science in their second semester, and revised based

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[1] Also similar self-concept measures were developed, and an additional type of interest scales that use concrete mathematical tasks as stimuli to situate the interest items (cf. Rach et al., accepted).

Table 1 Overview of measurement instruments for interest (Rach et al., accepted)

	School mathematics	University mathematics
Institution	In school, mathematics was always very important for me (IS; 5 items)	I am interested in the kind of mathematics that is done at university (IU; 5 items)
Practice	*Using calculation techniques* I think it is exciting to solve difficult equations (IC; 6 items)	
	Applying mathematics I think it is interesting to solve real-world problems using mathematics (IA; 6 items)	*Proving* Reading mathematical proofs is fun (4 items)
		Dealing with formal representations It is fun for me to define mathematical concepts exactly (IP; 4 items)

on these results. In Table 1, we present sample items for each scale. The original German versions as well as English translations can be found in the electronic supplementary materials for this manuscript.

We applied our questionnaire on the first day of mathematics study programs with a sample of students from mathematics bachelor's programs as well as teacher education programs. In this paper, we first focus on the feasibility of our approach to measure interest in mathematics at the transition from school to university. The first three questions focus on construct validity evidence (cf. Cronbach and Meehl 1955) for the newly developed measures. In particular, we study if the theoretically assumed facets of interest can be differentiated, if they show theoretically expected differences between students from different study programs, and if they reveal theoretically expected relations with each other and other personality traits. Finally, we investigate what general questionnaires of interest actually measure during this transition phase.

1. Is the theoretical structure of subscales, that guided their development, reflected in the factorial structure of the newly developed instruments?

   We expected that the instrument would differentiate interest in school mathematics and university mathematics. Regarding the practices, we were aware that a small number of items referring to calculation might also show connections to interest in the other facets, since calculations are usually necessary when solving more complex problems. We expected moderate to good reliability coefficients for the scales.
2. Are the subscales sensitive to the expected differences between the study programs?
   We based our expectations on the role of interest for choices in the learning biography (Lapan et al. 1996; Köller et al. 2001; Krapp and Prenzel 2011; Rach 2014) and the fact that school mathematics can be considered more important for teacher education programs and the professional work of teachers, than for mathematics bachelor's programs. We expected that students from the teacher education programs would show less general interest in mathematics as reported by Rach (2014), but also less interest in proof, formal representations, and university mathematics as compared to mathematics bachelor students. We also expected that teacher education students would show more interest in school mathematics and the practices connected to it.
3. (a) Is interest in mathematics at a specific institution correlated primarily with interest in those practices, which are characteristic for that institution?
   Based on the conceptualization of the instruments, we expected interest in applications to be primarily correlated to interest in school mathematics, interest in proof and in formal representations to be primarily related to interest in university mathematics, and interest in using calculation techniques to be related to interest in school as well as university mathematics.
   (b) Are interest facets that address new aspects of university mathematics related more strongly with epistemic curiosity than with openness to experience?
   We expected this pattern, since epistemic curiosity might support engagement with new aspects and interest development, while openness to experience has been show to be only weakly related to interest in mathematics (Wiernik et al. 2016).
4. Which specific facets of interest explain variations in general interest ratings in mathematics, particularly between students from different study programs, when surveyed at the transition from school to university mathematics?
   Given a lack of prior research, we had no clear expectations about the results. We anticipated that variance in general interest would be explained by interest in school as well as university mathematics. Since our sample comprised students who chose a mathematics program deliberately, we also expected connections to interest in proof and formal representations. However, we could not derive any definitive hypothesis about the connection to interest in calculation and application.

3 Method

3.1 Design of this study and sample

We present data from the first measurement of a longitudinal study with first semester mathematics students at one German university. Our sample consists of 323 participants (162 female, 161 male; age $M=20$ years, $SD=3.0$ years) of the mathematics courses *Analysis I* which are standard courses for first-year mathematics students. These students were enrolled in the bachelor's programs "mathematics", "business mathematics", or a mathematics teacher education program for one of the two higher attaining secondary school tracks in Germany (Gymnasium or Realschule). Altogether 186 students from the mathematics bachelor's programs and 137 from mathematics teacher education programs participated. Mathematics students have some courses in a minor subject, the business mathematics students take part in an economics lecture, and the teacher education students have courses in a second subject, education and psychology, as well as subject education. The survey was administered during the first session of the courses *Analysis I*.

3.2 Instruments

We applied the self-developed interest questionnaire, which was described in the section above, as a differentiated measure of interest. The items referring to mathematical practices and items referring to institutions were presented in separate blocks, and the items in every block were arranged in a random order. To study the additional value of our new instrument over more generic instruments, we measured learners' *general interest in mathematics* with an approved and frequently used questionnaire (Pekrun et al. 2002, example item: "Mathematics is one of the things that is most important for me, personally". These items also cover the emotional component, the value component, as well as the intrinsic component of interest.

We surveyed students' openness to new experiences and epistemic curiosity with the questionnaires by Schupp and Gerlitz (2014) and Bless et al. (1991) respectively. Sample items to these scales are "I see myself as someone who values aesthetic experiences" (openness to experience, 3 items; $\alpha=0.62$; $M=2.0$; $SD=0.64$) and "Having to find new solutions for a problem is really fun" (epistemic curiosity, 8 items; $\alpha=0.72$; $M=2.2$; $SD=0.41$). The students were asked to assess all statements on a four-point likert scale from 0 (disagree) to 3 (agree).

4 Results

4.1 Quality of the instruments

To evaluate the internal consistence of the scales, we conducted two separate exploratory factor analyses with categorical indicators on the items concerning mathematical practices as well as on the items focusing on school and university mathematics. We used the WLSMV estimator with Geomin rotation as implemented in the software MPlus (Muthén and Muthén 1998–2015), since the FIML[2] algorithm allowed us to include cases that had missing values on some of the items. The mean data coverage for the pairwise correlations was $M=98\%$ ($SD=1.2\%$) in the first, and $M=87\%$ ($SD=7.2\%$) in the second factor analysis. The number of factors was decided primarily according to theoretical considerations. Moreover, in each case also χ^2 tests indicated a significantly better fit of the chosen solution as compared to the solution with fewer factors.

Regarding the practices, we expected to find a four-factor solution. Contrary to our expectations, the items on interest in proof and in formal representations in mathematics loaded strongly on a common factor in this solution, whereas the fourth factor did not allow a substantial theoretical explanation. Thus, we decided to focus on a three-factor solution, expecting factors that would reflect interest in applications, calculation techniques, and proof and formal representations respectively. Based on this solution, we decided to exclude one item addressing interest in calculations, since it showed a substantial loading on the calculation as well as on the application factor ("Situations, in which I can use mathematical calculation techniques, are important for me"). The factor loadings from the resulting solution are presented in Table 2.

Generally, the expected structure of the questionnaire—with interest in proof and formal representations loading on one factor—was confirmed by the model. Two items ("It is important for me to be able to apply calculation rules correctly", "I think it is interesting to apply mathematical calculation techniques") showed weak positive cross-loadings on the application factor. Since calculation techniques are frequently used in other mathematical practices, we had expected few positive cross-loadings. One item ("It is fun for me to manipulate long algebraic expressions") showed a negative cross-loading on the factor describing interest in proof and formal representations, indicating a negative relation with an emotional connotation of calculation techniques. We had not expected this result, but it seems plausible that persons who are primarily interested in more

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[2] FIML: Full Information Maximum Likelihood.

Table 2 Factor loadings for exploratory factor analyses on items addressing interest in mathematical practices

Item	Factor loadings		
	Factor 1	Factor 2	Factor 3
Application 1	**0.732**	*−0.055*	*−0.298*
Application 2	**0.763**	*0.221*	*−0.006*
Application 3	**0.710**	*0.108*	*0.087*
Application 4	**0.535**	*0.230*	*0.083*
Application 5	**0.899**	*0.025*	*−0.155*
Application 6	**0.797**	*−0.030*	*−0.237*
Proving 1	*−0.005*	**0.784**	*0.024*
Proving 2	*−0.021*	**0.681**	*0.005*
Proving 3	*−0.062*	**0.667**	*0.035*
Proving 4	*−0.143*	**0.749**	*−0.119*
Formal representations 1	*0.124*	**0.646**	*0.004*
Formal representations 2	*−0.065*	**0.659**	*0.015*
Formal representations 3	*0.026*	**0.566**	*0.027*
Formal representations 4	*0.053*	**0.600**	*−0.073*
Calculation 1	*0.062*	−0.120	**0.677**
Calculation 2	*Excluded from the analysis*		
Calculation 3	0.324	*0.001*	0.484
Calculation 4	0.314	*0.105*	**0.612**
Calculation 5	*−0.026*	−0.356	**0.738**
Calculation 6	*0.114*	*−0.041*	**0.710**

Loadings >.50 are bold, loadings <.30 are italics, $\chi^2(133) = 396.5$; CFI = .93; RMSEA = .08; SRMR = .06

Table 3 Factor loadings for exploratory factor analyses on items addressing interest in university resp. school

Item	Factor loadings	
	Factor 1	Factor 2
University 1	**0.757**	*−0.134*
University 2	**0.804**	*0.152*
University 3	**0.826**	*−0.125*
University 4	**0.826**	*0.000*
University 5	**0.809**	*0.083*
School 1	*−0.002*	**0.862**
School 2	−0.320	**0.794**
School 3	*0.012*	**0.589**
School 4	0.375	**0.527**
School 5	*0.170*	**0.581**

Loadings >.50 are bold, loadings <.30 are italics $\chi^2(26) = 160.5$; CFI = .94; RMSEA = .13; SRMR = .07

scientifically oriented aspects of mathematics would not show positive feelings towards tedious calculations.

Similarly, we conducted an exploratory factor analysis for the second block of items addressing interest in school and university mathematics (scales concerning institutions). Based on the construction of the questionnaire, we expected to find a two-factor solution. The factor loadings from this solution are presented in Table 3.

Also here, our expectations were confirmed in general. One item from the school mathematics scale ("I am interested in the kind of mathematics that I learned at school") showed a negative loading on the "university mathematics" factor, and another item ("If I can learn something new about the kind of mathematics that I learned at school, I am willing to spend leisure time for this") showed a positive cross loading. Since the two loadings were weak compared to the substantial expected loadings, and indicated relations in different directions, we decided to keep the scales as planned initially.

Subsequently, we analysed the reliabilities of the separate scales. Table 4 presents the mean values, standard deviations, and reliabilities of each scale in the questionnaire, including the general mathematics interest scale (Pekrun et al. 2002).

Summarizing, the expected structure of our questionnaires was mostly confirmed. One exception is that the items measuring interest in proof and items addressing formal representations had to be integrated into one joint scale. The reliabilities of the scales are satisfactory for newly developed instruments. For the subsequent analyses, individual (per-case) mean values were computed for each scale, whenever at least half of the items had non-missing values. Again, the FIML algorithm in MPlus was used for the following analyses to include all available cases, in spite of a few missing values (one value for 54 cases, more than one value for 10 cases).

4.2 Differences between study programs

Table 5 shows mean values for students from the two programs on all facets of mathematics interest. Group differences were tested for significance using regression analyses with the study program as dichotomous predictor in MPlus to include cases with missing values. Moreover, we calculated effect sizes for the observed score differences.

The analysis shows that, as expected, students in the bachelor's program report lower interest in school mathematics and higher interest in university mathematics than their peers who chose a teacher education program. While the bachelor students also report higher interest in proof and formal representations, there are no significant differences regarding the interest in applications and using calculation techniques. Moreover, bachelor students report a higher general interest in mathematics.

Finally, students in the teacher education program show more openness to new experiences, which might explain differences in interest ratings (e.g., Silvia 2005). The small differences in epistemic curiosity did not reach significance.

Table 4 Mean values, standard deviations, and reliability coefficients for the interest scales

	Interest scale					
	General (IG)	Application (IA)	Calculation (IC)	Proof and formal (IP)	School (IS)	University (IU)
M	2.24	2.03	2.21	1.86	2.11	2.02
SD	0.41	0.58	0.45	0.56	0.55	0.58
Cronbach's α	.70	.82	.69	.82	.73	.85

Table 5 Mean values and results of tests of group differences for the interest measures

	Mathematics bachelor's program	Teacher education program	β	d
General interest in mathematics (IG)	**2.31**	2.16	.18**	.36
Interest in school mathematics (IS)	2.02	**2.24**	−.19***	−.39
Interest in university mathematics (IU)	**2.18**	1.76	.34***	.72
Interest in applying mathematics (IA)	2.02	2.05	−.03	−.07
Interest in using calculation techniques (IC)	2.21	2.21	.01	.02
Interest in proof and formal representations (IP)	**1.97**	1.71	.23***	.47
Openness to new experience	1.86	**2.07**	−.16**	−.33
Epistemic curiosity	2.18	2.12	.08	.15

Where group differences are significant, the higher mean value is set in bold text

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

Table 6 Correlations for the interest scales

	Interest scale					
	IG	IA	IC	IP	IS	IU
Applying mathematics (IA)	.05	–	–	–	–	
Using calculation techniques (IC)	.36***	.26***	–	–	–	
Proof and formal (IP)	.55***	−.07	.17**	–	–	
School mathematics (IS)	.25***	.19**	.44***	.03	–	
University mathematics (IU)	.62***	.05	.21***	.68***	.13*	
Openness to new experiences	.06	.15**	.05	.11	.03	.08
Epistemic curiosity	.45***	.08	.29***	.45***	.07	.45***

IG general interest in mathematics

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

4.3 Relation between interest facets

To study how the different facets of interest measured by our instrument are interrelated, we analysed the correlations between the mean ratings (Table 6).

The correlational pattern between the newly developed scales was largely as expected. Interest in school mathematics is only loosely connected to interest in university mathematics ($r = .13$, CI$_{95\%}$ [0.02; 0.24]). Interest in proof and formal representations in mathematics correlates significantly more strongly with interest in university mathematics ($r = .68$, CI$_{95\%}$ [0.62; 0.74]) than with interest in school mathematics ($r = .03$, CI$_{95\%}$ [−0.08; 0.14]). Interest in using calculation techniques significantly correlates with interest in the other two practices ($r = .26$, CI$_{95\%}$ [0.16; 0.36]), for application, ($r = .17$, CI$_{95\%}$ [0.06; 0.28]), for proof and formal representations, and it correlates significantly more strongly with interest in school mathematics ($r = .44$, CI$_{95\%}$ [0.35; 0.52]) than with interest in university mathematics ($r = .21$, CI$_{95\%}$ [0.10; 0.31]). Interest in applications is only weakly related to interest in school mathematics ($r = .19$, CI$_{95\%}$ [0.08; 0.29]), in university mathematics and interest in mathematics in general ($r = .05$, CI$_{95\%}$ [−0.06; 0.16] for both). All other specific facets of interest are correlated significantly and positively with the general measure.

Table 7 Unstandardized regression coefficients from regression analyses with dependent variable *general interest in mathematics*

Independent variable	Model 1	Model 2	Model 3	Model 4
Teacher education program[a]	−.15**	−.01	−.01	−.01
Interest in school mathematics		.13***	.08*	.09**
Interest in university mathematics		.43***	.29***	.26***
Interest in applying mathematics			−.02	−.02
Interest in using calculation techniques			.18***	.15***
Interest in proof and formal representations			.18***	.15***
Openness for new experiences				−.01
Epistemic curiosity				.15*
R^2	.03	.41	.48	.50

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

[a] Dummy coding, 1: teacher education program, 0: bachelor's program

Regarding the personality traits, a significant, but small correlation between openness to experience and interest in applications occurred ($r = .15$, $\mathrm{CI}_{95\%}$ [0.04; 0.26]). Interest in university mathematics and in proof and formal representations correlate more strongly with epistemic curiosity ($r = .45$, $\mathrm{CI}_{95\%}$ [0.36; 0.53] for both measures) than with openness to experience (university mathematics: $r = .08$, $\mathrm{CI}_{95\%}$ [−0.03; 0.19]; proof and formal representations: $r = .11$, $\mathrm{CI}_{95\%}$ [0.00; 0.22]).

4.4 Explaining differences in general mathematics interest

To gather insights into which facets of interest are actually captured by a general mathematics interest questionnaire, when it is used in the transition phase from school to university mathematics, we report regression analyses with general mathematics interest as a dependent variable (Table 7).

The regression analysis replicates the significant differences between the two student groups reported before (model 1). These differences disappear almost completely when interest in school and university mathematics are controlled (model 2). The higher interest in university mathematics of bachelor students seems to explain the differences in reported general interest between students from the two programs. When interests towards the different mathematical practices are included, the coefficients for school and university mathematics are reduced (model 3). This result indicates that not only the context in which the mathematics is situated (school vs. university), but also the mathematical practices within these contexts, plays a substantial role for students' reports of general interest in mathematics. In particular, a higher general interest goes along with higher interest in using calculation techniques as well as in proof and formal representations. Surprisingly, interest in applying mathematics does not predict general mathematical interest. Finally, we included the general personality traits, which might explain common variation in interest reports (model 4): The pattern of results remains largely unchanged, but epistemic curiosity predicts a significant amount of further variance in the students' general interest ratings.[3]

5 Discussion

The starting point for our study was the issue of mixed results on the role of interest for a successful transition into a university mathematics program, which are usually based on general measures of mathematics interest. Starting from the characterization of interest as a person-object relationship (Schiefele et al. 1992) as well as the postulated change in the nature of the "object of learning" mathematics at the transition (Dörfler and McLone 1986; Engelbrecht 2010; Gueudet 2008; Thomas and Klymchuk 2012), we argue that it is promising to differentiate interest in mathematics with respect to the character of mathematics. We constructed scales for interest in school and university mathematics as well as interest in mathematical practices like applying mathematics, using mathematical calculation techniques, proving and using formal representations of mathematics. We then applied our instrument with a sample of first year mathematics students from a German university.

The results of exploratory factor analyses replicated the expected internal structure of the instrument, with the exception of some small cross loadings. The differentiation of interest in proof and in formal representations was not supported by the factor analyses. One reason might be that students on the very first day of their university study have

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[3] Inclusion of prior knowledge on calculus and secondary school qualification grade did not change the results from model 4. Both new predictors did not show a substantial contribution to variance explanation.

differentiated their interests between the two institutions, but not yet between different aspects of university mathematics. Further research is necessary, however, to clarify whether a differentiation of interest in these university related practices occurs during ongoing university studies. Apart from combining these two scales, we take this as a first hint that our scales capture different facets of interest in mathematics during at the school-university transition. The reliabilities of the newly developed scales turned out to be satisfactory for a first development. However, items with cross-loadings on different scales in the exploratory factor analysis may require further improvement. We then compared the reports from bachelor's mathematics programs and teacher education programs. In accordance with studies that have shown that interest influences choices in the learning biography (Köller et al. 2001; Krapp and Prenzel 2011), students from a bachelor's mathematics program reported higher interest in facets that related to mathematics as a scientific discipline. The observed differences indicate that the developed scales allow researchers to identify theoretically expected profiles of mathematics interest and thus provide support for future interpretations of scale means for student groups from different study programs. This implication has to be qualified however, for the applications scale (see below).

Students' interest reports support a differentiation between interest in school mathematics and in university mathematics, including the related practices. The correlations between the scales mostly reflect the conceptualization of the interest construct. This result provides evidence that the scale scores can be interpreted as reflecting the different theoretically conceptualized facets of the person-object relationship. For the application scale, however, qualifications are warranted. Contrary to our expectations, it showed only weak relations to the general and school-related interests. Krug and Schukajlow (2013) found that secondary school students valued authentic application problems less than calculation problems. Moreover, authentic applications are rare in German school classrooms (Jordan et al. 2008). It might be that beginning mathematics students are interested in these applications, but just regard them as marginally relevant to mathematics as it is taught at school as well as university.

Altogether, the results support our assumption that it is possible to differentiate facets of interest in mathematics in the transition from school to university mathematics, and to capture specific differentiation processes in the structure of individual interest in this context, which have been described more generally in the past (Krapp and Prenzel 2011). The current analyses cannot contribute further validity evidence, for example regarding the predictive value of the scales above general interest scales. Unless future research provides this evidence, predictive interpretations of the (general and specific) interest scores remain only weakly warranted for the context of our study.

We also studied which specific facets of interest are actually reflected in general measures that refer to mathematics in a rather undifferentiated way, when they are used during the school-university transition (Eilerts 2009; Rach and Heinze 2016). Theoretically, this issue concerns which aspect of mathematics students actually activate when they rate general interest items. Regression analyses showed that interest in school mathematics contributes weakly to general interest ratings, while interest in university mathematics and in practices connected to university mathematics explain a substantial amount of variance in ratings of general interest in mathematics. It might be specific to our sample of future mathematics university students, that they connect their interest in mathematics substantially with university mathematics and weakly with school mathematics. This result contradicts prior assumptions that students are not aware of those aspects of the subject, which are central to mathematics university study (Liebendörfer and Hochmuth 2013). Summarizing, these results suggest that, in the context of our study, general measures of interest capture interest facets that relate to university mathematics, but also other individual student characteristics, such as interest in school mathematics. The weak relations between interest and learning success at the entrance phase to university mathematics (Eilerts 2009; Rach and Heinze 2016) might be at least partially due to this mixture of interest facets. Given that a central characteristic of interest is that it is specific to an *object*, we argue that it is promising to consider the more specific interest measures when studying the effects of interest on further learning processes at the study entrance phase, in which the character of mathematics changes substantially.

Our approach, as well as the conduct of the presented study, have some limitations. One might argue that students at the start of their university study, in particular on the very first day, lack sufficient knowledge about "university mathematics" to actually judge their interest towards it. However, we can assume that students gather some information about the programs they consider for their university study, e.g., from websites, peers, preparatory courses, or their mathematics teachers. For example, 36% of our students participated in a bridging course to university mathematics before the first semester. Moreover, practices that correspond to university mathematics, such as proving or dealing with formal representations, are also part of school mathematics to a certain extent, as for example standard documents indicate (e.g., KMK 2012). One has to be cautious about what the institutional interest scales reflect in our sample on the first day of university study: While one scale may reflect interest in school mathematics as students *have experienced* it, the other scale will more likely reflect interest in university mathematics as students *anticipate* it. It remains an issue for further research to study the development of students' interest over the first weeks of their university study, when they become more acquainted with university mathematics.

Apart from this, our first feasibility study has some methodological limitations. For example, we used a questionnaire to survey students' interest. It could be explored how similar differentiations of interest by its "object" can be implemented with other methods such as forced-choice items or behavioural measures (e.g., Silvia 2005) and if the differentiation we found can be replicated. Because of our relatively small sample, we refrained from using confirmatory factor analysis for an in-depth study of different CFA models for our data. Future research with larger samples could study more elaborate hypotheses about the empirical structure of our instrument, like nested factor or bifactor models.

Finally, our results are surely specific to the transition situation and the sample of beginning university mathematics students. For example, the non-significant correlation between interest in the application of mathematics and general interest in mathematics would surely be unexpected for a sample of secondary school students. The new scales were specifically developed for this context, and they should not be used in a different context unless there is sufficient evidence that they also reflect the theoretical constructs under different conditions. What might be interesting is if similar differentiations of individual interest occur at other points of school mathematics, e.g., at the transition from arithmetic to algebra in primary and early secondary school. Moreover, the transition problem has been discussed internationally, in the past (e.g., Dörfler and McLone 1986; Gueudet 2008), but it remains an open question to which extent our results can be extended to other educational systems.

Regarding the development of students' interest in university mathematics, our results indicate that it is important to give a realistic picture of the discipline, and support early interest differentiation, before students choose a study program. Concrete approaches to develop students' interest based on Deci and Ryan's (2000) self-determination theory have been successfully evaluated. For example, Stroet et al. (2015) found that teacher practices addressing a structured organization of instruction and students' involvement were connected with the development of students' interest. Moreover, Kiemer et al. (2015) showed that students' increase in interest after a teacher training course in classroom communication was predicted by changes in perceived autonomy and competence support. Adaptations of these ideas to the university context have been rarely studied, but may be promising.

The main goal of the SISMa project is to study the development and effects of personal interest in mathematics during the transition phase from school to a university mathematics program with a specific focus on students' problems during this transition (Rach et al., accepted). Our results show that the use of general measures of interest in mathematics might be problematic in phases in which the "object of interest" changes its nature. Further steps in the project will be studying the development of interest in mathematics during the first weeks of university study, and also its effects on study success in the first semester. These analyses are important not only for understanding the role of interest for learning during mathematics university study. If such relations between specific interest facets and study success can be substantiated in the future, this result would be an argument to use these measures in advising students before they choose a university mathematics program.

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.

Bless, H., Fellhauer, R., Bohner, G., & Schwarz, N. (1991). *Need for cognition: eine Skala zur Erfassung von Engagement und Freude bei Denkaufgaben* [*Need for cognition: A scale for measuring commitment and joy when solving problems*]. Retrieved April 29, 2016, from http://www.ssoar.info/ssoar/handle/document/6889.

Burn, H., Mesa, V., & Arbor, A. (2015). The Calculus I curriculum. In D. Bressoud, V. Mesa & C. Rasmussen (Eds.), *Insights and recommendations from the MAA National Study of College Calculus* (pp. 45–58). MAA press.

CCSSI. (2010). *Common core state standards for mathematics*. Retrieved April 30, 2016, from http://www.corestandards.org/wp-content/uploads/Math_Standards1.pdf.

Cronbach, L., & Meehl, P. (1955). Construct validity in psychological tests. *Psychological Bulletin, 52*(4), 281–302.

Deci, R., & Ryan, E. (2000). Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being. *American Psychologist, 55*(1), 68–78.

Dieter, M. (2012). *Studienabbruch und Studienfachwechsel in der Mathematik: Quantitative Bezifferung und empirische Untersuchung von Bedingungsfaktoren* [*Drop-out and change of study in mathematics: Quantification and empirical analysis of factors*] (Doctoral dissertation). Retrieved August 29, 2016, from http://duepublico.uni-duisburg-essen.de/servlets/DocumentServlet?id=28564.

Dörfler, W., & McLone, R. (1986). Mathematics as a school subject. In B. Christiansen, A. Howson & M. Otte (Eds.), *Perspectives on mathematics education* (pp. 49–97). Dordrecht: Reidel.

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

Eilerts, K. (2009). *Kompetenzorientierung in der Mathematik-Lehrerausbildung: Empirische Untersuchung zu ihrer Implementierung [Competence orientation in mathematics teacher education: An empirical study about its implementation]*. Zürich: LIT Verlag.

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.

Epp, S. (2003). The role of logic in teaching proof. *The American Mathematical Monthly, 110*(10), 886–899.

Fenollar, P., Román, S., & Cuestas, P. (2007). University students' academic performance: An integrative conceptual framework and empirical analysis. *The British Psychological Society, 77*(4), 873–891.

Frenzel, A., Pekrun, R., Dicke, A.-L., & Goetz, T. (2012). Beyond quantitative decline: Conceptual shifts in adolescents' development of interest in mathematics. *Developmental Psychology, 48*(4), 1069–1082.

Frenzel, A. C., Goetz, T., Pekrun, R., & Watt, H. (2010). Development of mathematics interest in adolescence: Influences of gender, family, and school context. *Journal of Research on Adolescence, 20*(2), 507–537.

Gogol, K., Brunner, M., Preckel, F., Goetz, T., & Martin, R. (2016). Developmental dynamics of general and school-subject-specific components of academic self-concept, academic interest, and academic anxiety. *Frontiers in Psychology, 7*, 356.

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

Hailikari, T., Nevgi, A., & Komulainen, E. (2008). Academic self-beliefs and prior knowledge as predictors of student achievement in mathematics: A structural model. *Educational Psychology: An International Journal of Experimental Educational Psychology, 28*(1), 59–71.

Healy, L., & Hoyles, C. (1998). *Technical report on the nationwide survey: Justifying and proving in school mathematics*. London: University of London.

Heinze, A., Reiss, K., & Rudolph, F. (2005). Mathematics achievement and interest in mathematics from a differential perspective. *ZDM-The International Journal on Mathematics Education, 37*(3), 212–220.

Hidi, S. (1990). Interest and its contribution as a mental resource for learning. *Review of Educational Research, 60*(4), 549–571.

Hidi, S. (1995). A reexamination of the role of attention in learning from text. *Educational Psychology Review, 7*(4), 323–350.

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

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.

John, P., Naumann, L., & Soto, C. (2010). Paradigm shift to the integrative big five trait taxonomy: History, measurement, and conceptual issues. In P. John, R. Robins & L. Perwin. (Eds.), *Handbook of personality: Theory and practice* (pp. 114–159). New York: Guilford Press.

Jordan, A., Krauss, S., Löwen, K., Blum, W., Neubrand, M., Brunner, M., et al. (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. doi:10.1016/j.learninstruc.2014.10.003.

KMK (2012). *Bildungsstandard im Fach Mathematik für die Allgemeine Hochschulreife [Education standards in mathematics for the higher education entrance qualification]*. Retrieved April 29, 2016, 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.

Kolter, J., Liebendörfer, M., & Schukajlow, S. (2016). Mathe–nein danke? Interesse, Beliefs und Lernstrategien im Mathematikstudium bei Grundschullehramtsstudierenden mit Pflichtfach [Mathematics–no thanks? Interest, beliefs, and learning strategies of primary teacher students with compulsory subject mathematics]. In A. Hoppenbrock, R. Biehler, R. Hochmuth & H.-G. Rück (Eds.), *Lehren und Lernen von Mathematik in der Studieneingangsphase* (pp. 567–583). Wiesbaden: Springer Spektrum.

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., & 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. 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: PME.

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., & Bing, M. (2014). Testing interest and self-efficacy as predictors of academic self-regulation and achievement. *Contemporary Educational Psychology, 39*, 86–99.

Liebendörfer, M., & Hochmuth, R. (2013). Interest in mathematics and the first steps at the university. In *Proceedings of the Eighth Conference of European Research in Mathematics Education* (pp. 2386–2395).

Malmivuori, M.-L. (2006). Affect and self-regulation. *Educational Studies in Mathematics, 63*(2), 149–164.

Marsh, H., 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.

Murphy, P., & Alexander, P. A. (2000). A motivated exploration of motivation terminology. *Contemporary Educational Psychology, 25*, 3–53.

Muthén, B., & Muthén, L. (1998–2015). *Mplus (Version 7)*. Los Angeles, CA: Muthén & Muthén.

OECD (2016). "PISA 2015 mathematics framework". In: *PISA 2015 assessment and analytical framework: Science, reading, mathematic and financial literacy*. Paris: OECD Publishing.

Ottinger, S., Kollar, I., & Ufer, S. (2016). Content and form: All the same or different qualities of mathematical arguments? In C. Csíkos, A. Rausch, A., J. & Szitányi (Eds.), *Proceedings of the 40th Conference of the International Group for the Psychology of Mathematics Education* (Vol. 4, pp. 19–26). Szeged, Hungary: PME.

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: Oxford University Press.

Rach, S. (2014). *Charakteristika von Lehr-Lern-Prozessen im Mathematikstudium: Bedingungsfaktoren für den Studienerfolg im ersten Semester [Characteristics of teaching-learning-processes: Conditional factors of study success in the first semester]*. Münster: Waxmann.

Rach, S., & Heinze, A. (2016). The transition from school to university in mathematics: Which influence do school-related variables have? *International Journal of Science and Mathematics Education* (online first). doi:10.1007/s10763-016-9744-8.

Rach, S., Kosiol, T., & Ufer, S. (accepted). Interest and self-concept concerning two characters of mathematics: All the same, or different effects? *KHDM-reports*.

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: Routledge.

Schiefele, U., Krapp, A., & Winteler, A. (1992). Interest as a predictor of academic achievement: A meta-analysis of research. In K. A. Renninger, S. Hidi & A. Krapp (Eds.), *The role of interest in learning and development* (pp. 183–212). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

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.

Schupp, J., & Gerlitz, J.-Y. (2014). *Big five inventory-SOEP* (*BFI-S*). *Zusammenstellung sozialwissenschaftlicher Items und Skalen*. [*Big five inventory-SOEP* (*BFI-S*): Compilation of sociological items and scales]. doi:10.6102/zis54.

Silvia, P. (2005). What is interesting? Exploring the appraisal structure of interest. *Emotion, 5*(1), 89–102.

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). MAA press.

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.

Thomas, M., & Klymchuk, S. (2012). The school-tertiary interface in mathematics: Teaching style and assessment practice. *Mathematics Education Research Journal, 24*(3), 283–300.

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.

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: Springer.

von Stumm, S., Hell, B., & Chamorro-Premuzic, T. (2011). The hungry mind: Intellectual curiosity is the third pillar of academic performance. *Perspectives on Psychological Science, 6*(6), 574–588. doi:10.1177/1745691611421204.

Wiernik, B. M., Dilchert, S., & Ones, D. S. (2016). Creative interests and personality: Scientific versus artistic creativity. *Zeitschrift für Arbeits-und Organisationspsychologie, 60*(2), 65–78.