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Self-concept in university mathematics courses

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Many researchers agree that mathematical self-concept is an important factor in (university) learning processes. Mathematics learning at university differs substantially from learning mathematics at school. Especially the character of the learning domain mathematics changes at the transition to university. In this contribution, we present newly developed instruments for self-concept that take the specific character of mathematics at university into account. We applied the instruments in a first-semester course with 344 students. The results of exploratory factor and correlation analyses indicates that it is possible to differentiate facets of self-concept according to different characters of the learning domain mathematics. Finally, we discuss how precise information concerning learners' self-concept can promote to support students at this challenging transition to university.

Keywords: Mathematical self-concept, Transition school-university, Mathematical practices, Learning prerequisite.

Introduction

There is no doubt that affective variables are important factors in successful, mathematical learning processes (Hannula, 2011). In this contribution, we concentrate on self-concept concerning mathematics. In a recent study, self-concept was identified as an essential learning prerequisite to predict achievement in school mathematics (Feng, Wang, & Rost, 2018). Moreover, self-concept substantially mediates the relation between achievement and emotions (Van der Breek, Van der Ven, Kroesbergen, & Leseman, 2017). Many existing studies deal with the role of self-concept in mathematical teaching and learning processes at school. In contrast, only few studies analyze its role in learning processes at university. As learning processes in these two institutions differ significantly from each other, we claim the need for specific research on the role of self-concept in mathematics courses at university and in particular during the transition to university mathematics.

Questionnaires are the most common instruments to survey mathematical self-concept. The learning domain, for which self-concept should be reported, is mostly broadly described using the word "mathematics". At the transition from school to university, however, it is not clear if students refer to school or to university mathematics when reporting their self-concept. To obtain a more differentiated insight into students' self-concept, we developed questionnaires for mathematical self-concept that take the specific learning domain at university into account. In this contribution, we present the conceptualization of these instruments in detail. In a study with 344 first-semester students, we studied if the assumed facets of self-concept can be measured and differentiated empirically.

The role of self-concept in mathematical learning processes

Self-concept, self-efficacy, and self-esteem are important constructs which describe students' views about themselves. The source of students' views about themselves are often experiences of past success or failure. As self-esteem has a focus on emotions and is not as prominent as the other two constructs in analyzing subject-specific learning processes, we concentrate on the constructs self-concept and self-efficacy. Self-concept has its focus on the persons' skills and abilities, whereas self-efficacy refers to one's beliefs to successfully perform a certain action in the future (Marsh et al., 2019). Researchers use both concepts to explain and predict learners' action and success (Bong & Skaalvik, 2003). As we are interested in students' views of themselves as learners in mathematics at the period of transition, we also want to analyze the sources of students' beliefs about their own mathematical knowledge and skills. That is why we use the construct self-concept. We refer to "mathematical self-concept (of ability)" as *students' beliefs about their own mathematical knowledge and skills*. Theoretically, self-concept is often placed between motivational and cognitive variables, since it is built on views (affect side) which refer to knowledge and skills (cognition side).

One mechanism leading to the relationship between self-concept and achievement might be that learners with a strong self-concept choose to engage in more demanding tasks, which results in better learning and higher achievement. Moreover, there is much evidence that underpins the relation between self-concept and other motivational variables, like interest (Cai, Viljaranta & Georgiou, 2018; Rach & Heinze, 2017). It is assumed that self-concept mediates the relation between achievement and emotions (van der Breek et al., 2017). In university contexts, explorative studies claim that a low self-concept and the decrease of self-concept in the first study year even of students with excellent learning prerequisites probably lead to dropout (Bampili, Zachariades, & Sakonidis, 2017; di Martino & Gregorio, 2018).

However, the studies mentioned above mainly relate to the school context (e.g. Cai et al., 2018). Analyses of learning processes at university often show only weak or non-significant relations between self-efficacy respectively self-concept and study success (Bengmark, Thunberg, & Winberg, 2017; Rach & Heinze, 2017). One reason for this unexpected result might lie in the differences of the learning domain between school and university. When students rate their mathematical self-concept in the first semester at university, they might refer to their beliefs about their knowledge and skills according to mathematics as a school subject, which could be less relevant for learning in this context than self-concept regarding university mathematics.

Teaching and learning mathematics at university

In Germany, as in many other countries all over the world (e.g. South Africa: Engelbrecht, 2010; France: Gueudet, 2008), there seems to be a substantial gap between school and university concerning teaching and learning of mathematics. Not only the social contexts (e.g. the peer group) and the learning opportunities and their use (e.g. from a more guided form in school to a more self-regulated form at university) change at this institutional transition, but also the learning domain itself. At school, one important goal of teaching and learning mathematics is to apply mathematics for solving real-world problems. Thus, classrooms instruction focuses on describing situations mathematically and performing calculations. We call this special character of mathematics "school

mathematics”. In contrast to that, “university mathematics” denotes the character of mathematics presented in mathematics university courses, which refer to mathematics as a scientific discipline that is built on formal definitions of concepts and deductive proofs (Engelbrecht, 2010). Central practices in the first year of studying mathematics at university include dealing with formal presentations of concepts and proving statements. As demands of proving tasks are mainly high and unfamiliar to freshmen at university, students often struggle in their first year of university and a substantial share of them drop out from their study program (Heublein, Richter, Schmelzer, & Sommer, 2014).

Summarizing, the learning subject changes at the transition from school to university from a school subject focusing on applications to a scientific discipline focusing on the structure of a mathematical theory. That is why instruments which measure mathematical self-concept in a generic way and results concerning the role of mathematical self-concept in learning processes at school might not be transferable to processes at university.

The current study

As part of the project SISMa (“Self-concept and Interest when Studying Mathematics”), it is the goal of this study to differentiate self-concept concerning different characters of the learning domain mathematics. The aim of the project is to clarify the role of affect in mathematical learning processes during the transition to university mathematics (see Ufer, Rach, & Kosiol, 2017). In this contribution, we focus on mathematical self-concept and present instruments that measure different facets of self-concept according to different characters of mathematics (Table 1, see also Schukajlow, Leiss, Pekrun, Blum, Müller, & Messner, 2012 for a similar approach concerning self-efficacy; see also Ufer et al., 2017 for the construct interest). To measure the different facets of self-concept we constructed two types of scales: The first type of self-concept scales surveys beliefs about knowledge and skills regarding mathematics as it has been experienced respectively anticipated in a specific context. These statements directly address one of the two institutions, in which mathematics is taught and learnt: school versus university. The second type of scales addresses self-concept regarding 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). These five scales were developed based on prominent models of self-concept taking into account different frames of reference (Bong & Skaalvik, 2003). In contrast to other scales, e.g. Kauper, Retelsdorf, Bauer, Rösler, Möller, and Prenzel (2012), different aspects of mathematics as points of reference for individual beliefs are specified.

To study whether these facets of self-concept can be differentiated empirically, we conduct a study with first-year mathematics students. The following questions deal with the structure of the questionnaires and the relation of the self-concept measures to other learning prerequisites:

- 1) *Is the theoretical structure of the subscales reflected in the factorial structure of the newly developed instruments?*

We expected that factor analyses would underpin the theoretical conceptualization of the subscales. Moreover, we expected self-concept in applying mathematics to be primarily correlated to self-concept concerning school mathematics and self-concept concerning

proving and dealing with formal representations to be primarily related to self-concept concerning university mathematics.

2) *Are the different facets of self-concept related to other learning prerequisites?*

We expected that self-concept concerning school mathematics relate to interest concerning school mathematics, the same pattern with university mathematics. In line with previous research (e.g., Cai et al., 2018), we expected a relationship between self-concept measures and mathematical knowledge respectively the school qualification grade.

3) *Is there a relation between facets of self-concept and study choice?*

As a mathematics teacher education program is not as much focused on mathematics as a mathematics bachelor program, we expected that, on average, students with lower mathematical self-concept concerning university mathematics respectively self-concept concerning proving and dealing with formal representations would be more likely to choose a teacher education program. This should result in lower average self-concept concerning university mathematics respectively proving and dealing with formal representations of the teacher education students than of mathematics bachelor students. We had no specific hypotheses regarding self-concept concerning school mathematics respectively concerning applying mathematics and using calculation techniques.

Method

The sample of this study comprised 344 first-semester-students of the mathematics courses “Analysis I” from one university in the southern part of Germany. In this course, mathematics is presented as a scientific discipline with a focus on formal concept definitions and deductive proofs. We use a complete survey of all students who start their study in a teacher education program or in a mathematics respectively business mathematics bachelor program. As the study took place in the first lecture of the first-semester mathematics courses “Analysis I” and students participated in the survey voluntarily, we can’t say anything about students who did not participate in the study. Most of the participating students were in a teacher education program for two secondary school tracks (Realschule, Gymnasium) in Germany, $N = 130$, and in a mathematics respectively business mathematics bachelor program, $N = 184$.

Self-concept scale		Sample item	M (SD)	Cronbach's α
General		I am very good in mathematics. (4 items)	2.07 (.50)	.76
<i>Institution</i>	<i>School mathematics</i>	The mathematics that I know from school is easy for me. (3 items)	2.35 (.57)	.73
	<i>University mathematics</i>	The mathematics that is done at university is easy for me. (3 items)	1.51 (.65)	.84
<i>Practice</i>	<i>Applying mathematics</i>	Applying mathematics to real-world problems is not so easy for me. (reversed item) (5 items)	2.00 (.51)	.80
	<i>Proof and formal</i>	Understanding mathematical proofs is easy	1.73	.82

	<i>mathematics</i>	for me. (8 items)	(.48)	
	<i>Using calculation techniques</i>	I am very good in transforming complex terms. (5 items)	1.91 (.47)	.71

Table 1: Measurement instruments for self-concept with means, standard deviations, and reliability coefficients, $N = 252-333$. Statements rated on a four-point Likert scale from 0 (disagree) to 3 (agree)

We used a general scale for mathematical self-concept (Kauper et al., 2012, for sample items see Table 1) to compare our newly developed instruments with an approved scale. Moreover, we applied the new self-concept scales as differentiated measures of self-concept (see Table 1). The participants were asked to assess all mixed statements on a four-point Likert scale from 0 (disagree) to 3 (agree). The individual mean value of a single student on a scale was computed if this student had answered at least half of the items of the scale. We assessed additional affective and cognitive variables in the first lecture: the school qualification grade (grades were recoded so that 4.0 is the best and 1.0 is the worst value), prior knowledge for advanced mathematics, and interest in school mathematics respectively university mathematics (see Ufer et al., 2017).

Results

Differentiated measures of self-concept

Table 1 shows the mean values, standard deviations, and reliability coefficients of the self-concept scales. There are no floor or ceiling effects.

Two explanatory factor analyses (Principal Component Analysis with Varimax rotation) – one for the three self-concept scales concerning practices and one for the two self-concept scales concerning the institutions – showed three respectively two factors, that were in line with the theoretical structure of the instruments. Reliability analyses underpin the internal consistency of the general self-concept scale and the five newly developed scales, as all scales show a moderate to good consistency. Correlation analyses also partly promote the expected structure: For example, self-concept concerning proving and dealing with formal representations correlates with self-concept concerning university mathematics strongly, $r = .65$ (Table 2). The lower correlation, $r = .26$ between self-concept concerning applying mathematics and self-concept concerning school mathematics was unexpected, because applying mathematics to real-world problems should be a prominent activity in mathematics classrooms. All specific facets of self-concept are correlated significantly and positively with the general measure. In sum, the different facets of self-concept can be separated empirically, and their correlational pattern reflects the assumed specific nature of university mathematics.

	General (SCG)	Application (SCA)	Calculation (SCC)	Proof and Formal (SCP)	School (SCS)	University (SCU)
SCG		.35**	.51**	.49**	.61**	.51**
SCA			.31**	.35**	.26**	.27**
SCC				.38**	.48**	.34**
SCP					.29**	.65**

SCS						.25**
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Table 2: Correlations for the self-concept scales, ** $p < .01$

Connection to other learning prerequisites

As expected, correlations of variables focusing the same character of mathematics, school respectively university mathematics, are stronger than correlations concerning variables on different characters of mathematics (Table 3). Only self-concept concerning school mathematics correlates with the school qualification grade significantly. Both self-concept scales weakly relate to mathematical knowledge.

	Interest school	Interest university	Mathematical knowledge	School qualification grade
Self-concept school	.34**	.18**	.13*	.20**
Self-concept university	-.01	.50**	.21**	.05

Table 3: Correlations of the self-concept scales with other learning prerequisites, ** $p < .01$, * $p < .05$

Differences between study programs and study choice

Table 4 shows mean values (and standard deviations) for students from the two programs on all facets of self-concepts. Group differences were tested for significance and we calculated effect sizes.

	General	Application	Calculation	Proof and formal	School	University
Mathematics bachelor program	2.13 (0.55)	2.00 (0.53)	1.88 (0.48)	1.80 (0.48)	2.36 (0.58)	1.61 (0.65)
Teacher education program	2.07 (0.39)	2.03 (0.50)	1.99 (0.46)	1.71 (0.45)	2.40 (0.54)	1.42 (0.62)
<i>d</i>	0.10	-0.05	- 0.23 ^t	0.19	-0.06	0.29*

Table 4: Mean values (standard deviation) and results of tests of group differences between study programs, * $p < .05$, ^t $p < .10$

As expected, students in the bachelor program show a moderately, but significantly higher self-concept than teacher education students concerning university mathematics, and, though not significantly, also concerning proof and formal representations.

Discussion

While the prominent role of self-concept for successful learning processes at school is well established (Cai et al., 2018), its role in the university context is yet worthy of discussion. With this project, we shed light on the role of self-concept in the transition to university mathematics using differentiated measures of self-concept. Applying newly developed instruments, we distinguish different facets of self-concept of first-semester students and relate these facets to other learning prerequisites respectively the choice of the study program. The results on correlations and group differences provide first evidence that the scales do differentiate between the theoretically conceptualized facets of mathematical self-concept. However, qualifications are warranted for a broad application of the scale. For example, the results indicate that students seem to judge their knowledge and skills to apply mathematics to real-world problems not primarily based on their beliefs about their knowledge and skills regarding school or university mathematics. This might reflect that authentic applications are not considered specific to university mathematics, but also rare in German school classrooms (Jordan et al., 2008). The small differences in self-concept between the two programs indicate that primarily self-concept regarding university mathematics is related to study choice. This facet of self-concept turned out to be related to prior mathematical knowledge, but not to the school qualification grade. It remains an open question, if the school qualification grade, which predicts success in the first semester above and beyond prior mathematical knowledge (Rach & Heinze, 2017), has an influence on study choice that is not mediated by self-concept. Of course, the results of our study are based on students' self-reports about their self-concept. To get a clearer picture of the impact of self-concept in concrete learning processes, it seems worthwhile to combine our approach with analyzing students' reported experiences and their concrete learning behavior in the first year of study (e.g. di Martino & Gregorio, 2018).

In sum, we presented the conceptualization of instruments to measure different facets of self-concept concerning school respectively university mathematics and corresponding mathematical practices. Using these measures, it is possible in the future (1) to investigate the development of these variables during students' learning processes and their effect on students' learning activities in undergraduate mathematics programs, and most importantly their tendency to drop out of a study program. (2) The differentiated measures may allow more differentiated insights into students' affect. This, in turn, may allow (3) to develop adequate approaches to support students during the challenging transition to a university mathematics program. One idea to support students is to adaptively select mathematical tasks in the courses that fit individual students' prior knowledge so that they can approach these tasks in a meaningful way. If students perceive competence (Deci & Ryan, 2002) when working on these tasks, this should probably lead to the development of self-concept concerning university mathematics, for example mediated by intrinsic motivation (see Krapp, 2005). A higher self-concept, in turn, might lead to a better learning behavior, specifically to students choosing more demanding tasks and showing more perseverance when dealing with these tasks. All in all, such interventions aiming at a higher, yet realistic self-concept, are a promising approach to decrease the rate of students dropping out of mathematics study programs.

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