DO BELIEFS PREDICT INTEREST AND SELF-CONCEPT (DEVELOPMENT) IN UNIVERSITY MATHEMATICS? A LATENT CHANGE-SCORE APPROACH

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High dropout rates illustrate students' difficulties with university mathematics. Previous studies showed that interest and self-concept for university mathematics as well as the development thereof predict dropout. Therefore, this study examined the effects of students' beliefs on interest, self-concept and the development of both variables. Using latent change score models, data from 286 first year students was analysed. The results show that students' beliefs are related to interest and self-concept regarding university mathematics at the beginning of the first term, but beliefs do not predict the development of interest and self-concept. Moreover, beliefs regarding university mathematics were more relevant than beliefs regarding school mathematics. Implications for teaching and further research are discussed.

INTRODUCTION

The transition from school to university mathematics is challenging for many students, which is documented by high dropout rates in many mathematics programs around the world (e.g., Heublein et al., 2022). Recent studies have shown that interest and self-concept for university mathematics as well as the development of both variables predict achievement, satisfaction and dropout in the first year of mathematics programs (Geisler & Rach, 2022; Kirsten et al., online first). Unfortunately, students' interest and self-concept often decrease in the first term at university (e.g., Sonnert et al., 2015).

Researchers have argued that students' mathematical beliefs may influence interest and self-concept development, with unfavourable beliefs hindering a beneficial development of interest and self-concept (Daskalogianni & Simpson, 2001; 2002). Indeed, students' beliefs are related to interest (Liebendörfer & Schukajlow, 2017). However, most previous studies have not distinguished between school mathematics and university mathematics when conceptualising interest, self-concept and beliefs. Given the substantial differences between school and university mathematics, this distinction seems necessary (Ufer et al., 2017). In this study, the influence of students' beliefs concerning the nature of school and university mathematics on interest and self-concept for university mathematics as well as on their development is analysed.

THEORETICAL BACKGROUND

Beliefs, Interest and Self-Concept

Philipp (2007) describes beliefs as "propositions and premises about the world that are thought to be true". Beliefs are always referring to a specific beliefs object – for

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example the nature of mathematics (what one believes mathematics is). Grigutsch and Törner (1998) have proposed a classification for beliefs concerning the nature of mathematics, distinguishing four main aspects regarding mathematics. The *process aspect* highlights that mathematics is a vivid field of research and that (at least subjective) new insights are possible for everyone. Moreover, people with strong *process* beliefs emphasise the process of solving mathematical tasks over the finished solution. Following the *application aspect*, mathematics is relevant for everyday life and the society and has application in other fields of science. The *formalism aspect* stresses that rigid formalism is foundational for mathematics. Thus, rigorous definitions and deductive proof are viewed as exceptionally important. The *schema aspect* focuses on schematic calculations, formulae and rules as well as algorithmic aspects of mathematics. People with strong *schema* beliefs even see mathematics as a toolbox of unconnected rules and formulae to solve routine tasks. According to Grigutsch and Törner (1998) these aspects are not antagonists and people can agree to all aspects with varying degree.

Interest is considered as a special relationship between an (abstract) object and a person, comprising of emotion related (pleasant feelings when engaging with the object of interest) and value related (subjective high esteem for the object of interest) valences (Krapp, 2007). Moreover, interest has an intrinsic character and people tend to want to extend their knowledge on the object of interest. Thus, interest leads to more attention and is considered beneficial for learning processes (Krapp, 2007).

"In very broad terms, *self-concept* is a person's perception of himself…" (Shavelson et al., 1967). The mathematical self-concept describes students' perception of their own competences as a learner and user of mathematics. Self-concept and achievement are reciprocally related to each other, as students with higher self-concept usually put more effort into tasks, leading to more achievement. In reverse, mastery experiences lead to a stronger self-concept (Bong & Skaalvik, 2003).

Differences between School and University Mathematics

As discussed frequently, mathematics at school and at university differ clearly (see Engelbrecht (2010) and Gueudet (2008) for a detailed discussion). In school, new content is usually introduced in a rather inductive way using examples and real-life connections, yielding at an intuitive understanding. At university, new content is introduced via formal definitions. Moreover, rigorous deductive proof is emphasised in university lectures, while students get only little experiences with proof in school. Most tasks at university require proofs. In school, schematic calculations and real-world applications are more frequent in tasks, but both play no major role at university.

Beliefs, Interest and Self-Concept in the Transition to University Mathematics

Given the aforementioned differences between school and university mathematics, it seems to be necessary to differentiate students' interest, self-concept and beliefs regarding these both facets of mathematics, when analysing their effects during the

transition from school to university (cf. Ufer et al., 2017). However, so far only a few studies made this distinction.

Indeed, interest and self-concept for university mathematics predict students' satisfaction, achievement and ultimately dropout behaviour while interest and self-concept for school mathematics are less relevant (Geisler & Rach, 2022; Kirsten et al., online first). Unfortunately, several studies reported decreasing interest and self-concept among students during the first term of mathematics programs (e.g., Sonnert et al., 2015). Geisler and Rach (2022) showed that there are interindividual differences in the development of students' interest and self-concept and that these differences are related to students' dropout risk. Moreover, Kirsten et al. (online first) found that the development of interest and self-concept regarding university mathematics is related to satisfaction and achievement. Thus, not only students' interest and self-concept for university mathematics at the beginning of one's studies but also the development of both variables seem relevant for a successful transition.

Researchers have argued, that students' beliefs are related with interest and self-concept and that unfavourable beliefs, that do not fit to university mathematics, might lead to decreasing interest and self-concept (e.g., Daskalogianni & Simpson, 2001; 2002). Theoretically, *process* and *formalism* aspect should be beneficial for university mathematics, as most university tasks require challenging proof processes and formal definitions, theorems and proofs are fundamental to mathematics lectures. Holding strong *schema* and *application* beliefs could be problematic because most tasks at university cannot be solved using schematic approaches and tasks involving real-world applications are nearly absent (Daskalogianni & Simpson, 2001). Indeed, Kaya (2007) found positive relations between *process* beliefs and interest. In contrast, Liebendörfer and Schukajlow (2017) reported correlations between *application* as well as *process* beliefs and interest at university. However, these studies did not differentiate between school and university mathematics with regard to students' beliefs and interest.

THE CURRENT STUDY

Research Questions

As interest and self-concept for university mathematics and their development predict a successful transition to university mathematics, investigating factors influencing these motivational variables is worthwhile. In this study, the effects of beliefs concerning the nature of school and university mathematics are analysed. In particular, the following research questions and hypotheses guided the study:

1) In which way are students' beliefs regarding the nature of school and university mathematics related to their interest and self-concept for university mathematics at the beginning of their studies?

We expect a positive relation of process and formalism beliefs for university mathematics with interest (H1) and self-concept (H2), while application and schema aspect regarding university mathematics will be related negatively with interest (H3)

and self-concept (H4). Beliefs regarding school mathematics will not be related to interest and self-concept at the beginning of students' first term (H5).

2) How do beliefs regarding the nature of school and university mathematics predict the development of interest and self-concept for university mathematics during the first term at university?

Similarly, process and formalism beliefs for university mathematics will predict a positive development of interest (H6) and self-concept (H7). Application and schema beliefs for university mathematics will predict a negative development of interest (H8) and self-concept (H9). Beliefs concerning the nature of school mathematics will not predict the development of interest and self-concept (H10)

Sample, Design and Instruments

In this study, 286 first year university students (47% female, *M*(Age)=19,7) from 5 public universities in Germany participated voluntarily. These students were enrolled in programs for mathematics majors or upper secondary pre-service teachers. In Germany, first year lectures in programs for mathematics majors and teacher education programs for upper secondary mathematics cover the same topics (often students from both programs visit the same courses) and are focused on definitions and proofs.

Table 1: Beliefs scales (Geisler, 2024) with number of items and reliability

Beliefs Object:	**University Math**		**School Math**	
	#/α	Example Item	#/α	Example Item
Formalism	5 / .85	Of major importance for math, as it is done at university, is its logic rigour and precision.	5 / .88	Mathematical thinking in school is characterized by abstraction and logic.
Schema	5 / .90	Nearly all math problems in university can be solved by directly using known rules, formula and routines.	5 / .79	Math, as it is done in school, contains learning, remembering and application.
Application	5 / .84	Many aspects of university math have a practical benefit or direct applications.	5 / .82	In school math one works on tasks that have a practical use.
Process	5 / .86	Mathematical tasks and problems at university can be solved correctly in different ways.	5 / .84	Doing school math means understanding facts, seeing relations and having ideas.

Students answered a questionnaire concerning their beliefs regarding the nature of school and university mathematics (Geisler, 2024) as well as their interest (Ufer et al.

(2017), 5 items, α=.79, "The kind of mathematics that is done at university is fun for me") and self-concept (Rach et al. (2021), 3 items, α=.80, "I am very good at the mathematics I learned at university") for university mathematics at the end of the first week of the first term (T1). Eight weeks later, in the middle of the first term (T2), students reported again their interest (α=.92) and self-concept (α=.89) for university mathematics. The used scales to measure beliefs are summarized in Table 1. All used items were answered on a 6-point Likert scale (1=totally disagree, 6=totally agree) and the scales showed sufficient reliability.

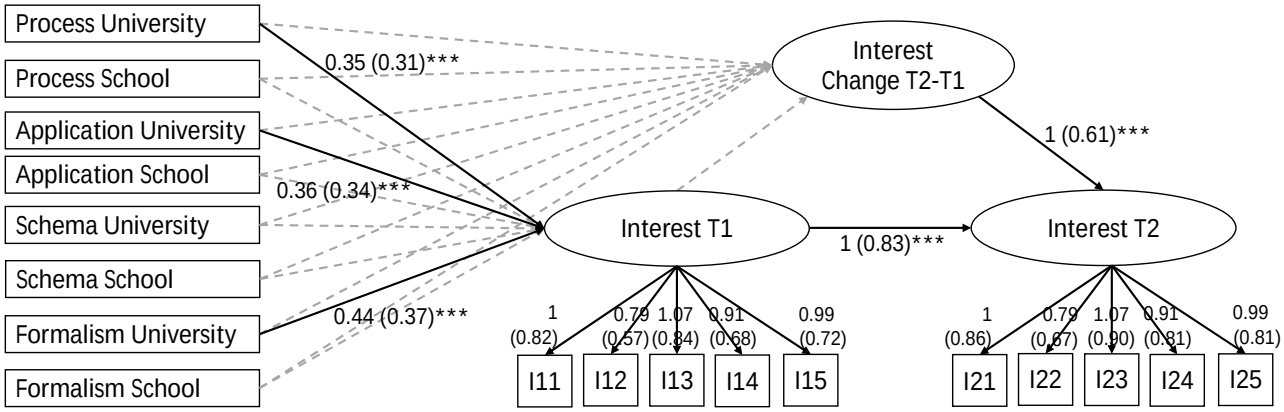
Analysis Strategy

As the change in interest and self-concept between the two measurement points is relevant, a latent change score model is an appropriate choice. This model allows to specify a latent change variable that accounts for true change in the construct separated from possible measurement errors (Geiser, 2021). This separation is particularly important, as a manifest change score would suffer from and sum up measurement errors of both timepoints. Thus, interest and self-concept as well as their change have been modelled as latent variables with factor loadings and intercepts of the items set equal over time (strong factorial invariance as important requirement for latent change score models). For interest, indicator specific residual factors as proposed by Geiser (2021) have been used. Two separate latent change score models have been calculated for interest and self-concept. Given the relatively small sample size and good reliabilities (see Table 1), students' beliefs have been modelled as manifest variables. Missing values have been treated using the full information maximum likelihood algorithm in Mplus 8.11. Both models showed acceptable fit (see Figure 1 and 2).

RESULTS

The results for interest in university mathematics are illustrated in Figure 1.

Figure 1: Latent Change Score Model for Interest. Insignificant paths are dotted. Standardized estimates are presented in brackets. $\chi^2(96)=162.046$, $p<.001$, CFI=.96, RMSEA=.05, SRMR=.05, $N=286$, ***$p<.001$



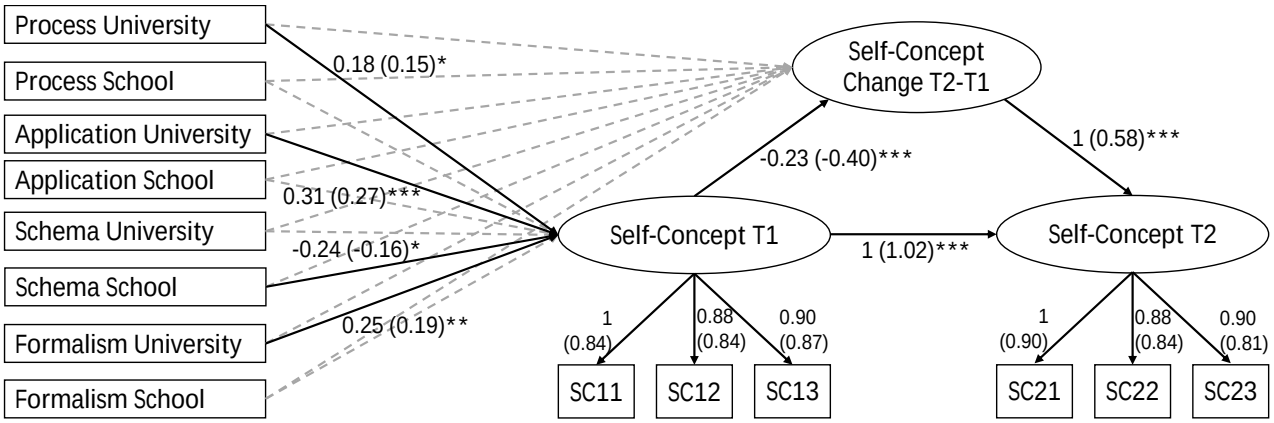
Students' beliefs are related to interest at the beginning of the first term and can explain nearly 60 % of the variance in interest (R^2=.57). As expected, only beliefs regarding

university mathematics are related to interest in university mathematics, while beliefs regarding school mathematics are not relevant in this case (H5). In line with the hypothesis (H1), *process aspect* and *formalism aspect* for university mathematics go along with more interest in university mathematics. However, against the expectation, the *application aspect* for university mathematics is also positive related to interest in university mathematics, while no association between *schema aspect* and interest is found. Thus, H3 has to be rejected. Students' beliefs did not predict the change in interest during the first term. Therefore, H6 and H8 could not be confirmed.

Figure 2 summarizes the results concerning self-concept. Similar to interest, no effects of students' beliefs could be found on the change of self-concept regarding university mathematics. Thus, H7 and H9 could not be confirmed. The change was only predicted by students' self-concept at the beginning of the term: students with higher self-concept at the begin of their studies are more likely to experience decreasing self-concept. 18 % of the variance in self-concept change could be explained (R^2=.18).

As expected, positive relations between *process aspect* as well as *formalism aspect* for university mathematics and self-concept for university mathematics could be confirmed (H2). The *schema aspect* regarding school mathematics is negatively associated to self-concept. Against the hypothesis (H4), there is a positive relation between *application aspect* regarding university mathematics and self-concept. Students' beliefs can explain 20 % of the variance in self-concept at T1 (R^2=.20).

Figure 2: Latent Change Score Model for Self-Concept. Insignificant paths are dotted. Standardized estimates are presented in brackets. $\chi^2(44)=62.078$, $p<.05$, CFI=.98, RMSEA=.04, SRMR=.04, N=286, *$p<.05$ **$p<.01$ ***$p<.001$



DISCUSSION

Interest, self-concept and a positive development of both variables are related to satisfaction, achievement and decreasing risk to dropout (Geisler & Rach, 2022; Kirsten et al., online first). In line with previous studies, *process beliefs* as well as *application beliefs* regarding university mathematics were related to students' interest and self-concept for university mathematics (Liebendörfer & Schukajlow, 2017; Kaya, 2007). Given the prevalence of challenging proof processes in lectures and tasks (cf.

Gueudet, 2009), the clear effects of *process aspect* are not surprising. However, against the expectations *application aspect* was also related to interest and self-concept despite application tasks are nearly absent in mathematics programs at university (e.g., Engelbrecht, 2010; Gueudet, 2009). While the aforementioned studies found no effects of *formalism beliefs*, in the current study, formalism regarding university mathematics showed a positive relation to interest and self-concept. One reason could be the strict differentiation between beliefs concerning school and university mathematics in this study and that rigid formalism is constitutional for university mathematics but not for school mathematics (e.g., Engelbrecht, 2010; Gueudet, 2009). The fact that beliefs regarding university mathematics were clearly more relevant than beliefs regarding school mathematics underlines the necessity of this differentiation for beliefs, similar to the case of interest and self-concept (cf. Rach et al., 2021; Ufer et al., 2017).

Unlike argued by Daskalogianni and Simpson (2001; 2002) students' beliefs at the beginning of their mathematics programs did not predict interest and self-concept development. Besides a negative relation between self-concept at the beginning of the mathematics programs and the self-concept development – which is in line with results from Kirsten et al. (online first) – determinants of this development remain unclear.

Limitations and Outlook

One limitation of the study at hand is that all results rely on self-reports that can be biased. Moreover, we asked for students' beliefs only at the beginning of their mathematics programs. Like interest and self-concept, beliefs could develop during the first weeks of university and be more stable predictors later.

Given the positive relation of *process*, *formalism* as well as *application* aspect for university mathematics and interest respective self-concept, these beliefs should be fostered even prior to the transition, for example by incorporating more formal aspects of definitions and more proofs in upper secondary mathematics lessons. Highlighting the process behind proofs in lectures (e.g., developing proof ideas) instead of presenting only finished rigorous proofs could further foster students' *process aspect*.

In order to explain the development of interest and self-concept for university mathematics, the characteristics of lecture courses and tasks should be taken into account in future studies in addition to students' characteristics (like beliefs).

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