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What role do students' beliefs play in a successful transition from school to university mathematics?

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ABSTRACT
The transition from school to university is a challenging process for many students which is reflected in high dropout and low examination success rates during the first year at university. Qualitative studies have found hints that students' beliefs play an important role during the transition. Due to their dialectic nature with cognitive as well as affective valences, it is sensible to assume that beliefs influence rather cognitive and objective criteria of a successful transition such as exam achievement as well as subjective criteria like satisfaction that draw on affective sources. However, quantitative studies have been mostly focusing on the role of students' beliefs for study achievement, neglecting possible effects on students' satisfaction and actual dropout. In this contribution, I draw a more holistic picture of the effects of beliefs during the transition by analysing effects on students' achievement, students' satisfaction and students' actual dropout behaviour. Data from over 600 first-year students in a longitudinal quantitative study show that dynamic beliefs (that emphasize the process character of mathematics and the usability of mathematics in everyday life and other disciplines) have a positive impact during the transition, while static beliefs (focusing on schematic aspects of mathematics) are problematic.

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Beliefs concerning the nature of mathematics; transition from school to university; dropout; satisfaction; achievement

1. Introduction

The transition from school to university is challenging for many students, especially in mathematics-demanding study programmes. Across different educational systems, mathematics belongs to those subjects with the highest dropout rates (Chen, 2013; Heublein et al., 2017). In particular, many students drop out from university mathematics during the first year of their programme (Dieter & Törner, 2012) as a result of a problematic transition. Moreover, low success rates in exams during the first year further highlight students' problems during the transition (Geisler & Rolka, 2018).

Beliefs are considered to affect learning processes in various ways (cf. Schoenfeld, 1985). Therefore, many scholars have argued that students' mathematics-related beliefs are relevant for a successful transition (Andrà et al., 2011; Daskalogianni & Simpson, 2001).

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While students' achievement in exams is an important indicator for a successful transition, it is questionable whether achievement is the only relevant factor for success during the transition. Qualitative studies show that also high-achieving students' drop out from mathematics programmes (e.g. Geisler, 2018). However, quantitative studies have mainly focused on the relation between beliefs and exam achievement (e.g. Bengmark et al., 2017; Crawford et al., 1994) neglecting other criteria of a successful transition. In order to draw a more holistic picture of the influence of beliefs during the transition, I report a longitudinal quantitative study with over 600 students. Using regression analysis, relations between students' mathematics-related beliefs and different criteria of a successful transition are analysed.

2. Theoretical background

Before discussing relevant research results concerning beliefs, I give an overview of the context in which I study beliefs: the transition from school to university.

2.1. Different criteria of a successful transition

Since a successful transition should lead to academic success and therefore to a successful completation of one's study programme, graduation in a certain amount of time and with good grades can be considered the most valid and global criterium for a successful transition. However, the criterion graduation represents a long-term perspective and is often not possible to assess empirically in an appropriate way due to the long timespan between the transition and the final graduation. Therefore, other criteria of a successful transition are needed. York et al. (2015) presented a multifaceted model of academic success that takes into account further long-term criteria like career success after graduation as well as criteria that can be assessed at various times during students' studies. These criteria involve dropout (vis-a-vis retention), satisfaction as a rather subjective criterion and achievement-related criteria that can be considered as rather objective. Since the scope of this paper is a successful transition, long-term criteria such as graduation or career success are of lesser interest than the latter mentioned criteria that can be bound more closely to the transition.

While dropout can occur during the whole timespan of one's studies, previous research shows that the vast majority of mathematics students who drop out, do so during the first year of their programme, whereas late dropout after a few years is seldom (e.g. Dieter & Törner, 2012). Likewise, early dropout can be considered as a useful (negative) criterion for a successful transition. I hereby count those students as dropped out, who left university without graduation as well as those who quit their mathematics programme in order to switch to another programme.

Most studies focus on achievement-related criteria such as grades in exams (e.g. Bengmark et al., 2017; Hailikari et al., 2008) as they are objective, easy to assess and can give insights in which way students reached the course goals (York et al., 2015). However, achievement-related criteria should not be used as sole indicator for a successful transition. Qualitative research has indicated that even high-achieving students decide to drop out during the transition (e.g. Geisler, 2018). Subjective criteria like satisfaction can be insightful to explain those cases of an unsuccessful transition. Blüthmann (2012) describes satisfaction as a subjective evaluation based on both: affective reactions and cognitive comparisons between experiences and expectations.

2.2. Beliefs concerning the nature of mathematics

Mathematics-related beliefs have been of growing interest during the last decades (Di Martino & Zan, 2011). However, different researchers have proposed a wide variety of conceptualizations for beliefs, leading to what Pajares (1992) called a 'messy construct'. In this contribution, I follow Philipp (2007) who describes beliefs as 'psychologically held understandings, premises, or propositions about the world that are thought to be true' (Philipp, 2007, p. 259). Whether beliefs are rather cognitive or affective in nature has also been a point of discussion among researchers. While many researchers that work in the broader field of affect consider beliefs as affective, others who primarily work on teacher beliefs disagree (Philipp, 2007). According to McLeod (1992), beliefs are part of the affective domain but are more cognitive in nature than attitudes or emotions (see also Hannula, 2012). Pehkonen and Pietilä (2003) see beliefs as subjective knowledge. In contrast to more general knowledge, beliefs can be held with more or less conviction (Philipp, 2007) and are not necessarily shared within a community.

With regard to possible outcomes, it is theorized that beliefs influence affective as well as cognitive processes and therefore have an important impact on learning. Beliefs are considered crucial for the development of attitudes and emotions (McLeod, 1992). Schoenfeld (1985) states that beliefs influence in which way mathematical problems are approached and how much effort is put into solving them. Furthermore, beliefs function as a filter and influence which information is learned (Pehkonen & Törner, 1996; Philipp, 2007).

Beliefs can refer to different objects. With regard to mathematics-related beliefs, Grigutsch and Törner (1998) state that beliefs can refer to the nature of mathematics (what one believes mathematics is), to the teaching and learning of mathematics (what one believes in which way mathematics should be taught and learned) and to oneself as learner or user of mathematics (what one believes about one's own abilities regarding mathematics). Whereas beliefs concerning one's own abilities – such as mathematical self-concept or self-efficacy – have been widely studied with regard to the transition (e.g. Bengmark et al., 2017; Eichler & Gradwohl, 2021; Rach & Heinze, 2017), I focus on beliefs concerning the nature of mathematics that have not been acknowledged in the same way so far. Törner and Grigutsch (1994) identified two core positions concerning the nature of mathematics: one rather static and one rather dynamic view of mathematics. The static view includes beliefs that mathematics is a summary of unconnected rules, facts and formula and is sometimes described as toolbox belief. Furthermore, in the static view mathematics is characterized via its rigour and strict formalism and as a finished system. In contrast, the dynamic view highlights that mathematics is a vivid discipline involving creativity and new insights. This includes the belief that doing mathematics is an active process and that this process of 'doing' mathematics is equally important or more important than the possible results of the process. Furthermore, the dynamic view stresses that mathematics can be applied in other disciplines as well as in everyday live and therefore takes into account the relevance of mathematics for society. According to Törner and Grigutsch (1994), both views are legitimate to some extend and represent different facets of mathematics. Likewise, both sets of beliefs are not necessarily antagonists but rather independent dimensions in the sense that people can agree with both views and held dynamic as well as static beliefs with varying conviction.

Summarizing, mathematics-related beliefs can be seen as dualistic in nature with affective as well as cognitive valences. Therefore, effects of beliefs on different (objective as well as subjective) criteria of success during the transition are likely.

2.3. The role of beliefs during the transition

Several scholars have hypothesized that beliefs play an important role during the transition from school to university mathematics (Andrà et al., 2011; Daskalogianni & Simpson, 2001). Students enter university with mathematics-related beliefs that have evolved over a longer time during school, but it is yet an open question, which beliefs students bring with them at the beginning of the transition, due to inconsistent results of previous studies (e.g. Baumert et al., 2000; Geisler & Rolka, 2018; Törner & Grigutsch, 1994). However, mathematics at school and at university differ in several ways (e.g. Engelbrecht, 2010; Gueudet, 2008) and beliefs that were adequate for learning processes at school could not be beneficial at university anymore. Therefore, students might have to adapt their beliefs so that they fit to the new mathematics they get to know. Unfortunately, beliefs are rather stable and not always easy to change (cf. McLeod, 1992). Thus, students can fail to adapt their beliefs, developed at school and hold on to beliefs during the transition that are not beneficial because they do not fit to university mathematics. Daskalogianni and Simpson (2001) talk about beliefs-overhang in this case.

The question, which beliefs fit best to the mathematics that students encounter during the transition and are therefore beneficial for students' success, is not easy to answer on a theoretical level. In a rather simplifying way, university mathematics is often described as very theoretical and formal compared to mathematics in school (cf. Tall, 2008). In school, new concepts are usually learned via experiences with examples and counterexamples and the deduction of the concept's characteristics from these experiences (Tall, 2008). Hence, there is a focus on the formation of an adequate concept image while formal concept definitions are not emphasized. Engelbrecht (2010) argued that as a consequence many students are not used to work with formal definitions and do not see those as relevant when entering university. Furthermore, many tasks in school can be considered routine tasks that can be solved using schematic calculations. Findings of empirical studies like COACTIV or TALIS (Jordan et al., 2008; OECD, 2020) show that complex tasks involving real problem solving are seldom in many classrooms and thus, students cannot experience the dynamic aspects of mathematics. Likewise, according to Engelbrecht (2010), most students think that (school) mathematics mainly involves calculating.

In contrast, in advanced mathematics courses at university new concepts are introduced via formal concept definitions from which the concept's properties are derived (Tall, 2008). Beliefs highlighting the rigid formalism of mathematics could be beneficial when dealing with these ways of learning new concepts. Furthermore, proofs are usually presented in a finished form during lectures, while the process behind remains invisible for the students (Hersh, 1991; Pinto, 2017). Therefore, the presentation of proofs in most lectures seems to fit to beliefs that mathematics is a static and finished system – those beliefs might be beneficial when coping with mathematics lectures.

With regard to typical tasks that students have to work on, a shift to tasks involving proofs can be seen (Vollstedt et al., 2014; Weber & Lindmeier, 2020). Therefore, it is often argued that schematic calculations play no big role at university anymore while proving processes are prevalent. Following this argumentation, dynamic beliefs that focus on the process character of mathematics could be an advantage over static beliefs that see mathematics as a summary of facts, rules and algorithms. However, taking a closer look on the tasks that students work on during the transition offers a more differentiated perspective: Weber and Lindmeier (2020) categorized tasks from different lecture courses and found that nearly 30% of the tasks involved merely schematic procedures. Although the majority of tasks involved proofs, nearly a quarter of the tasks were proofs that could be performed using calculations. Furthermore, some proofs – such like mathematical induction – can be seen as algorithmic in nature. Therefore, beliefs involving that mathematics are seen as a summary of facts, rules and algorithms might be suitable with regard to university mathematics as well. Summarizing, on a theoretical basis dynamic as well as static beliefs could fit to the mathematics that students get to know during the transition and thus could both be beneficial for students' learning processes. This assumption is supported by the study of Grigutsch and Törner (1998) who report that mathematics university teachers hold static as well as dynamic beliefs. Likewise, most university teachers see dynamic as well as static beliefs as relevant prerequisites for studying mathematics (Deeken et al., 2020). Nevertheless, some lecturers indicate that they want to foster students' dynamic beliefs (Kuklinski et al., 2018) indicating that they see dynamic beliefs as beneficial.

Empirical results concerning beliefs in the transition draw a picture in favour for dynamic beliefs. Most of the quantitative studies focus on the relation between beliefs and students' achievement in exams or competence tests. Geisler and Rolka (2018) found that mathematics freshmen who succeeded in their final real analysis exam started their studies with higher consent to dynamic beliefs than those students who failed in the exam. Crawford et al. (1994) reported that students who believed that mathematics is a summary of unconnected facts and rules – as a rather static view – earned less points in their exams than students who had a rather cohesive view of mathematics. With regard to engineering students, Bengmark et al. (2017) report that beliefs concerning the nature of mathematics can predict students' exam achievement. Especially static beliefs seem to be a negative predictor of students' achievement (Tossavainen et al., 2020). Given that static as well as dynamic beliefs could theoretically fit to university mathematics, it seems remarkable that empirical results clearly suggest that dynamic beliefs are more beneficial with regard to students' achievement. One can assume that dynamic beliefs have a more positive impact on the learning process – independent from the specific content. Indeed, dynamic beliefs seem to be associated with a deep learning approach while static beliefs are related to a surface approach to learning (Crawford et al., 1994, 1998; Liston & O'Dnoghue, 2009; Manderfeld & Siller, 2018).

Beneath studies, which analyse the relation between beliefs and achievement, results concerning satisfaction and dropout are of interest for the study at hand. However, studies that directly link beliefs concerning the nature of mathematics and satisfaction are scarce. In an interview study, Geisler (2018) found hints that static beliefs could lead to low satisfaction and are associated with decisions to drop out (see also Andrà et al., 2011). To the best of our knowledge, there are no quantitative studies investigating the relation between beliefs and satisfaction respectively dropout. However, some studies have focused on beliefs' impact on other variables which have been found to be associated with satisfaction. Dynamic beliefs are positively co-related with students' interest (Liebendörfer & Schukajlow, 2017; Kolter et al., 2016). Furthermore, students with dynamic beliefs have more positive perceptions concerning their study programme than students with static ones (Crawford et al., 1998). These perceptions include the quality of teaching, the workload as well as the clearness of the course goals.

With regard to the relations between beliefs and possible outcomes, the timepoint for measuring the beliefs seems to be crucial. Even though beliefs are rather stable, recent studies have shown that beliefs can change during the transition (e.g. Kolter et al., 2016). Likewise, Bengmark et al. (2017) found that beliefs measured close to students' exams were more predictive for students' achievement than beliefs measured at the begin of their studies. Similar results have been found before for other affective predictors (e.g. Pajares & Miller, 1994) as well as for predictors related to dropout (Schiefele et al., 2007).

3. The current study

The purpose of the current study is to provide a broader insight into the role of beliefs for a successful transition to university. Before explicitly addressing the impact of beliefs during the transition, it seems relevant which beliefs students hold during the transition. This leads to the first research question:

1. Which beliefs (static and dynamic) do first-year students hold at the beginning and during the first semester? In which way are the two views (static and dynamic) related to each other?

Given the inconsistent results concerning the beliefs that students hold when entering university, this question is still rather explorative and no explicit hypothesis emerges from the theory or previous studies. However, one can assume rather weak relations between static and dynamic beliefs (H1), because both are considered to be rather independent dimensions.

The impact of beliefs during the transition is addressed in this study in a holistic way by considering different criteria for a successful transition, in particular, early dropout, students' satisfaction and students' achievement. Furthermore, the study compares different timepoints for measuring students' beliefs. Considering different timepoints pays attention to different and possibly competing aims: on the one hand, measuring beliefs early in students' mathematics programmes could help to identify students at risk to fail the transition and to support them in time. On the other hand, measuring beliefs later during the transition might lead to a more robust and accurate prediction of a successful transition (cf. Bengmark et al., 2017; Schiefele et al., 2007). Against this background, the following research question emerged:

2. In which way are students' beliefs concerning the nature of mathematics at the beginning of the first term and during the first term related to (1) early dropout, (2) achievement and (3) satisfaction?

As described before, theoretical static as well as dynamic beliefs could be beneficial during the transition. Due to the lack of empirical studies linking beliefs and dropout behaviour, I have no explicit hypotheses concerning this relation. However, previous research shows that dynamic beliefs are more beneficial with regard to students' achievement. Therefore, I assume that dynamic beliefs are associated with more achievement (H2.1) while static beliefs predict lower achievement (H2.2). I have similar hypotheses concerning the relations with students' satisfaction: Because dynamic beliefs go ahead with more interest and with positive perceptions about study programmes, I expect that dynamic beliefs predict higher satisfaction (H3.1) while static beliefs are a negative predictor of satisfaction (H3.1). Finally, I expect that students' beliefs in the middle of the first term will be stronger predictors for a successful transition than the beliefs at the beginning of the term (H4).

3.1. Sample

In total, 602 first-year mathematics students participated voluntarily in this study ($M(\text{age}) = 20$, $SD = 3.12$, 50% female). These students belonged to three consecutive cohorts at a large public German university and were enrolled in a pure mathematics bachelor programme ($N = 150$) or a bachelor programme for upper secondary pre-service teachers ($N = 452$). The mathematics programmes at the university are not selective. Eighty-five per cent of the students indicated that the subject mathematics was their first choice to study. Students in both programmes (pure mathematics and teacher education) attended the exactly same mathematics lecture courses during their first year. Besides, pure mathematics students had some courses in a minor subject and pre-service teachers took courses in a second subject.

3.2. Instruments and data collection

A longitudinal design with two questionnaires was used to collect the students' data. The first questionnaire was given to the students during the real analysis lecture in the first week of the winter term (T1). Besides questions concerning demographical data (age, gender, school leaving marks), this questionnaire contained two scales measuring students' beliefs concerning the nature of mathematics. Both scales were taken from the TEDS-M inventory (Laschke & Blömeke, 2013). The first scale summarized six items representing beliefs belonging to the static view, i.e. mathematics is a collection of rules, facts and algorithm (sample item: 'Mathematics is a collection of rules and procedures that prescribe how to solve a problem.') as well as beliefs that mathematics is characterized by its formalism (sample item: 'Fundamental to mathematics is its logical rigor and preciseness.'). The second scale represented the dynamic view of mathematics and contained six items referring to the process character of mathematics (sample item: 'Mathematics involves creativity and new ideas.') as well as items concerning the belief that mathematics can be applied in other disciplines and everyday life (sample item: 'Many aspects of mathematics have practical relevance.').

Students filled out the second questionnaire 8 weeks later in the middle of December which was also in the middle of the first term (T2). The timepoint was chosen carefully because the experiences have shown that many students drop out by the end of December.

Table 1. Instruments with number of items, reliability (cronbach's α) and sample items.

Construct	Source	# Items	α(T1) / α(T2)	Sample Item
Beliefs dynamic	Laschke and Blömeke (2013)	6	0.69 / 0.78	Mathematics involves creativity and new ideas.
Beliefs static	Laschke and Blömeke (2013)	6 (5)	0.53 (0.57) / 0.61 (0.64)	Mathematics means learning, remembering and applying.
Satisfaction	Schiefele and Jacob-Ebbinghaus (2006)	4	/ 0.83	All in all, I am satisfied with my studies of mathematics.

The questionnaire was handed out during the real analysis lecture again. Besides the two TEDS-M scales that were used once again to measure students' beliefs, the questionnaire contained a scale concerning students' satisfaction with their mathematics programme (Schiefele and Jacob-Ebbinghaus (2006), four items, sample item: 'I am so satisfied with my mathematics studies that I would choose the program again'). All items had to be answered on a five-point Likert scale from *1 = totally disagree* to *5 = totally agree*. Table 1 gives an overview of the used scales.

According to Cronbach's alpha (Cronbach, 1951), all used scales had acceptable to good reliability except the static beliefs scale. An exploratory factor-analysis was applied in order to check the dimensionality of the beliefs scales. The scree-plot showed that two factors describe the data most appropriate. The factor-analysis revealed that only one item ('Fundamental to mathematics is its logical rigor and preciseness.') from the static beliefs scale did not load clearly on one of the two intended factors (dynamic view and static view). This item was excluded from the scale which also let to a slight increase in reliability – reliability in brackets in Table 1. All other items had main loadings larger than .45 with cross loadings smaller than .15.

Beneath satisfaction, students' achievement and dropout behaviour were used as criteria for a successful transition. In order to assess students' achievement, the points earned in the final real analysis exam at the end of the first term were used. Furthermore, I checked whether students were still enrolled in their mathematics programme after one year. All students who were not enrolled anymore in their mathematics programme were considered to be dropped out (regardless whether they had left university completely or changed to another subject).

3.3. Analysis

As not all students answered every item, multiple imputation (cf. Rubin, 1987) with 20 imputed datasets as implemented in SPSS 27 was used to handle missing data. During the whole analysis students' school leaving marks (reaching from *1 = sufficient* to *4 = very good*) were controlled in order to prevent an overestimation of the beliefs' effects on dropout, satisfaction and achievement. Since students' achievement was assessed via their points earned in the real analysis exam and the sample is composed of three consecutive cohorts, I standardized the earned points in every cohort. Linear and logistic regression analyses were used to answer the research questions (cf. Andreß et al., 1997). Multicollinearity was no issue for these analyses (VIF $<$ 1.65; Tolerance $>$ 0.6) (O'brien, 2007).

Table 2. Descriptive data and correlations concerning students' beliefs.

	M	SD	1	2	3	4
1 Beliefs dynamic T1	3.68	0.58	–			
2 Beliefs static T1	3.63	0.55	−.23**	–		
3 Beliefs dynamic T2	3.31	0.66	.56**	−.27**	–	
4 Beliefs static T2	3.62	0.58	−.09	.47**	−.24**	–
5 School leaving marks	2.29	0.66	.20**	−.18**	.23**	−.17**

Note: $N = 602$, $^{**}p < .01$, answers between *1 = totally disagree* and *5 = totally agree*, school leaving marks between *1 = sufficient* and *4 = very good*.

4. Results

Table 2 gives an overview of the descriptive data concerning students' beliefs at the beginning of their programme (T1) and in the middle of the first term (T2) and their school leaving marks.

As can be seen, static and dynamic beliefs are similarly common amongst students' when entering university. However, the consent to dynamic beliefs seems to decrease slightly during the first term whereas the consent to static beliefs remains stable. Across both timepoints, dynamic beliefs and static beliefs are negatively correlated with small effect-size which supports H1. It seems that students with high consent to dynamic beliefs report lower consent to static beliefs and vice versa. Furthermore, students' school leaving marks are significantly co-related with students' beliefs with small effect-sizes. In particular, there is a weak positive relation between marks and dynamic beliefs and a weak negative relation between marks and static beliefs. Thus, controlling for students' school leaving marks during the further analysis is indeed relevant to avoid overestimations of the beliefs' effects.

In the following, the results concerning the relation between students' beliefs and a successful transition are presented ordered by indicators for a successful transition.

4.1. Beliefs and early dropout

To analyse the relation between students' beliefs and early dropout during the first year of their programmes hierarchical logistic regressions were used. The results can be found in Table 3. Model 1 only consists of students' school leaving marks. Better school leaving marks are associated with a smaller risk to drop out. However, Model 1 can only explain 4% of the variance in students' dropout behaviour. In Model 2, students' beliefs at the beginning of their programme (T1) were added while the school leaving marks were still controlled. Dynamic beliefs are a significant negative predictor of dropout in the sense that higher consent to dynamic beliefs is associated with less risk for dropout. In contrast, the static beliefs at the beginning of the mathematics programme are not significantly associated with students' later dropout behaviour. The explained variance is still rather low (8%). Model 3 additionally contains students' beliefs in the middle of the first term (T2). While students' dynamic beliefs at T1 are still a significant negative predictor, the dynamic beliefs in the middle of the term are not significantly associated with dropout. However, students' static beliefs are weakly related with growing risk to drop out. Summarizing, dynamic beliefs seem to be beneficial in the sense that they go ahead with decreasing risk for dropout. Nevertheless, the impact of students' beliefs on early dropout is rather weak as can be assumed

Table 3. Results (standardized regression coefficients B) of logistic regressions with dependent variable dropout.

Independent variable	Model 1	Model 2	Model 3
School leaving marks	−0.34***	−0.26**	−0.23*
Beliefs dynamic T1		−0.33***	−0.31*
Beliefs static T1		0.14	0.01
Beliefs dynamic T2			−0.08
Beliefs static T2			0.27^t
Nagelkerkes[a] R^2	.04	.08	.10
ΔR^2	–	.01	.02

Note: $N = 602$, method inclusion.

[a]Nagelkerkes R^2 is used instead of other pseudo-R^2 because those usually underestimate the explained variance. Another advantage of Nagelkerkes R^2 over Cox and Snells R^2 is that a value of 1 can be reached in case of a perfect model-fit (Nagelkerke, 1991).

$^t p < .10$ $^* p < .05$ $^{**} p < .01$ $^{***} p < .001$.

Table 4. Results (standardized regression coefficients) of linear regressions with dependent variable exam achievement.

Independent variable	Model 1	Model 2	Model 3
School leaving marks	0.56***	0.50***	0.48***
Beliefs dynamic T1		0.18*	0.23^t
Beliefs static T1		−0.14^t	−0.03
Beliefs dynamic T2			−0.09
Beliefs static T2			−0.26*
R^2	.21	.25	.29
ΔR^2	-	.05*	.03*

Note: $N = 602$, method inclusion.

$^t p < .10$ $^* p < .05$ $^{***} p < .001$.

with regard to the low explained variance in students' dropout behaviour. With regard to dropout, the hypothesis that students' beliefs in the middle of the first term will be stronger predictors than the beliefs at the beginning of the programme cannot be confirmed (H4).

4.2. Beliefs and achievement

Hierarchical linear regressions were used to analyse the relation between beliefs and students' achievement in the final real analysis exam (Table 4). Again, Model 1 only consists of the school leaving marks which are a strong significant predictor of students' achievement. Unsurprisingly, good school leaving marks are associated with high achievement. The school leaving marks alone are suitable to explain 21% of the variance in the achievement which can be considered a very strong effect. Adding students' beliefs at T1 in Model 2 significantly increases the explained variance to 25%. However, the school leaving marks are still the strongest predictor in the model. Nevertheless, dynamic beliefs at the beginning of the mathematics programmes are positively related to achievement whereas static beliefs have a weak negative effect. In the middle of the first term (T2) only the static beliefs are significantly related to less achievement when all other variables are controlled. Therefore, H2.1 and H2.2 can be supported by the data. Furthermore, Model 3 shows that students' beliefs in the middle of the first term are stronger predictors than the beliefs at the beginning of the term (H4).

Table 5. Results (standardized regression coefficients) of linear regressions with dependent variable satisfaction.

Independent variable	Model 1	Model 2	Model 3
School leaving marks	−0.09	−0.01	0.05
Beliefs dynamic T1		0.29***	0.06
Beliefs static T1		−0.11*	−0.02
Beliefs dynamic T2			0.46***
Beliefs static T2			−0.09
R^2	.01	.11	.26
ΔR^2	–	.13***	.17***

Note: $N = 602$, method inclusion.
$^{*}p < .05$ $^{**}p < .01$ $^{***}p < .001$.

4.3. Beliefs and satisfaction

Hierarchical linear regressions were used again to investigate the relation between beliefs and satisfaction (Table 5). The school leaving marks are not associated with students' satisfaction (Model 1). Likewise, they are not suitable to explain a reasonable amount of variance in students' satisfaction (only 1%). Both, static and dynamic beliefs at the beginning of the term are related with satisfaction (Model 2). Adding the beliefs increases the explained variance to 11% and shows that dynamic beliefs go along with more satisfaction while higher consent with static beliefs is related to less satisfaction. However, dynamic beliefs are the stronger predictor. These results support hypotheses H3.1 and H3.2. In Model 3, students' beliefs in the middle of the term were added. In this case, students' beliefs at the beginning of the term are no significant predictors anymore while the dynamic in the middle of the term are a strong predictor which supports H4.

5. Discussion

5.1. Summary

Amongst the students in this sample, the consent to static and to dynamic beliefs (Table 2) seems to be distributed quite similar. None of the two views is clearly prevailing in the sample. Nevertheless, both views are negatively co-related. These results are interesting from different perspectives. Firstly, previous research has found inconsistent results concerning the beliefs that students hold. Baumert et al. (2000) found that German upper secondary students hold rather static than dynamic beliefs concerning the nature of mathematics. This is in line with the results of Geisler and Rolka (2018) who identified a higher consent to static than to dynamic beliefs among mathematics undergraduates. However, Törner and Grigutsch (1994) identified rather dynamic beliefs among mathematics freshmen. It is an open question whether students' beliefs have shifted somewhat towards static ones since these early studies from Törner and Grigutsch. Secondly, even if students on average seem to agree with both views in a similar way, it seems that the individual students rather tend to one of both views supporting that static and dynamic view represent to some degree antagonistic perspectives on mathematics. Thirdly, the fact that both views are similar strong among the freshmen is relevant with regard to the further results concerning the impact of beliefs on the transition.

Previous predominately qualitative studies have raised the hypothesis that beliefs are associated to students' decisions to drop out (Andrà et al., 2011; Geisler, 2018). However, in the study at hand, the impact of students' beliefs on dropout behaviour is only weak. Considering beliefs does not significantly improve the prediction of dropout when students' school leaving marks are already controlled. Therefore, it is questionable if beliefs play an important role for dropout decisions or if other (affective and cognitive) characteristics are more suitable to explain dropout. Nevertheless, students' beliefs could have indirect effects on dropout that are mediated by other variables: for example, students' beliefs could influence students' interest (cf. Liebendörfer & Schukajlow, 2017) that in turn affects students' dropout behaviour.

The results concerning students' achievement are in line with prior findings in the sense that dynamic beliefs go ahead with more achievement while static beliefs have the opposite effect (Crawford et al., 1994; Geisler & Rolka, 2018). Although the beliefs have a unique contribution to the explained variance in students' achievement, their impact is rather small compared to the school leaving marks. The school leaving marks turned out to be strong predictors of both: dropout and students' achievement highlighting the impact that students' experiences and achievement in school have for a successful transition to university mathematics. In contrast, school leaving marks are not associated with students' satisfaction while the beliefs explain a substantial amount of variance in students' satisfaction. This new finding enhances the existing body of knowledge of the impact that beliefs have during the transition.

With regard to the measurement timepoint of different predictors for a successful transition, previous studies found that variables assessed close to exams or to the time of dropout are stronger predictors than variables assessed at the beginning of students' programmes (cf. Schiefele et al., 2007; Bengmark et al., 2017). The results of the study at hand draw a less clear picture. Only in the case of satisfaction, students' beliefs in the middle of the term were clear stronger predictors than the beliefs at the beginning of the term. In contrast, for dropout the beliefs at the beginning of the term were stronger. The latter result can be seen as a hint that early identifying students at risk to drop out could be possible.

5.2. *Limitations and strength*

Limitations of the study at hand lie within the used sample as well as the instruments. The sample consists only of students from one university. However, by including three consecutive cohorts it is at least ensured that the results do not heavily depend on the specifics of one single lecture course and the characteristics of a specific lecturer. Students' data were assessed during lectures. Therefore, students who do not regularly attend the courses might not be represented in the data. By applying multiple imputation missing data was handled so that data of students who only participated at one measurement point could be included in the analysis and the bias of the sample could be reduced. With regard to the used instrument, the rather low reliability of the static beliefs scale (especially at T1) has to be taken into account. However, the results concerning static beliefs and students' achievement are in line with previous findings which are an indicator that the results are still trustworthy. Nevertheless, the used instrument was not specifically designed to assess beliefs during the transition. An instrument taking into account the context of transition and the specifics of university mathematics might enable more detailed insights.

A particular strength of the study is that different criteria for a successful transition were used which enabled a more differentiated perspective of the impact of beliefs during this crucial phase in students' mathematics programmes.

5.3. *Implications and outlook*

As argued before, university mathematics has static as well as dynamic aspects. Given that dynamic beliefs turned out to be beneficial with regard to all analysed criteria whereas static beliefs had a negative impact, it seems that coping with the dynamic aspects of university mathematics is crucial for a successful transition. Therefore, holding on to static beliefs during the transition can be seen as beliefs-overhang in the sense of Daskalogianni and Simpson (2001). Unfortunately, static beliefs turned out to remain rather stable during the transition (Table 2) whereas dynamic beliefs slightly decreased. Potential didactical actions with the aim to support students with a successful transition should pay attention to fostering dynamic beliefs.

Ideally, students' dynamic beliefs should be fostered already during school so that students begin their studies of mathematics with favourable beliefs. Unfortunately, schematic tasks are frequently used in school (Jordan et al., 2008; OECD, 2020). Instead, complex problem-solving tasks with multiple solutions could be used more often to stress the process character of mathematics. Furthermore, dynamic beliefs should be fostered in undergraduate courses as well to prevent a decrease of dynamic beliefs (cf. Kolter et al., 2016). As discussed before, during lectures mathematics is often presented as a finished system while the process behind the formal proofs remains in the background. Instead, the proving processes could be set in the focus during lectures. However, more research in this direction is needed to understand how dynamic beliefs can be fostered during lectures. In particular, studies linking the actual characteristics of the lectures and students' beliefs development could enable valuable insights.

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