THE MATHEMATICAL BELIEFS AND INTEREST DEVELOPMENT OF PRE-SERVICE PRIMARY TEACHERS

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We investigated the development of interest in mathematics of pre-service primary teachers (N=62) during the transition from school to university using longitudinal data and examined whether their beliefs about the nature of mathematics explained their future interest. One main result is that although high correlations between dynamic beliefs (the process and utility aspects of mathematics) and interest were found in each of three surveys, dynamic beliefs did not predict future interest (in addition to prior interest). Instead of dynamic beliefs, formalism beliefs formed an additional significant predictor of future interest.

THE SECONDARY-TERTIARY TRANSITION

The transition to university brings many changes and is often perceived as a stressful endeavour (Gueudet, 2008). Many students feel that mathematics has changed without being able to handle this new form of mathematics. A fundamental change refers to what Tall (2008) calls the formal world. Definitions, logic, and proofs are new to most students, whereas calculations now play a minor role. In particular, dealing with proofs is difficult for students and may negatively impact their interest in mathematics. Consequently, many students lose interest during the transition (Rach & Heinze, 2017). Interest and beliefs may be helpful concepts to understand the psychological side of this transition. In particular, analysing their relationship may help understanding why some students struggle more than others.

We focus on primary teacher education that has some commonalities with secondary teacher education like the new role of formalism and proof. Mathematics in primary teacher education is less formal than in secondary teacher education. Unlike in school, however, even the primary teachers' mathematics courses emphasise argumentation and reasoning not only in the lectures but also in the homework. This work completes earlier analyses presented at PME (Liebendörfer et al., 2014).

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INTEREST AND BELIEFS

We use Krapp's (2005) interest concept, in which interest is defined as a motivational person-object relationship, which is rather stable over time. Interest is specific to a person, but, unlike other motivational concepts, it is also specific to a (mental) object which, in our case, is mathematics. Interest has a cognitive component, which refers to a high personal value, and an emotional component related to positive affect.

Interest has gained importance as a predictor of good learning processes, such as the use of deep learning strategies, effort, and good learning outcomes, as can be shown across various disciplines and settings (Krapp et al., 1992; Köller et al., 2001). Pre-service primary teachers have reported low interest in mathematics. In a study by Abel (1996), pre-service primary teachers' interest scores (N=171) were about one standard deviation (SD) below the theoretical mean of the scale and considerably lower than the interest scores of pre-service secondary teachers (N=36) who had opted for mathematics as the subject of their future teaching careers. Whereas in higher secondary teacher education, interest declines during the transition (Rach & Heinze, 2017), this is not the case in lower secondary teacher courses that focus less on formalism (Liebendörfer & Schukajlow, 2017).

We use Grigutsch et al.'s (1998) concept of beliefs on the nature of mathematics that distinguishes four dimensions: The process aspect describes mathematics as a vivid field of trial and discovery. The utility aspect emphasises the usefulness of mathematics in everyday life. The formalism aspect characterises mathematics by logic, proof, and abstraction. Finally, the toolbox aspect describes mathematics as the application of routine skills, formulae, and standard procedures (see also Table 1). The first two aspects are rather dynamic whereas the last two aspects reflect a rather static view on mathematics.

Dynamic beliefs are often favoured over static beliefs because they emphasise opportunities for learning and improvement. They are further positively correlated with students' interest, whereas toolbox beliefs are negatively correlated (Baumert et al., 2000). Beliefs generally affect the way we experience and deal with new mathematics. In particular, improper beliefs may be seen as one reason for the decline of interest during the transition (Daskalogianni & Simpson, 2001) and beliefs that fit to the new mathematics students are presented may help them taking interest (Liebendörfer & Schukajlow, 2017). Thus, the static formalism beliefs may also be important for students' interest development during the transition as they may help them understanding new elements like the role of axioms and definitions.

RESEARCH QUESTIONS AND DESIGN

Our main aim is to describe how pre-service primary teachers' interest in mathematics develops in the first semesters at university and whether beliefs about the nature of mathematics may explain this development.

RQ1: How is pre-service primary teachers' interest connected to their beliefs?

RQ2: How do interest and beliefs change during the first year at university?

RQ3: Do beliefs serve as a predictor of future interest?

Design of the Study

We used data from the KLIMAGS-project (Blum, Biehler, & Hochmuth, 2014) collected at Kassel University. There, mathematics courses are compulsory for all pre-service primary teachers. The data were collected in the first (T1) and last lectures (T2) of a course on arithmetic during the students' first semester. The third survey was collected at the end of a course on geometry (T3) during the students' second semester in which they also took a course on the didactics of arithmetic. These paper-and-pencil surveys were collected over two consecutive years to gain a reasonable sample size. The sample consisted of N=62 pre-service primary teachers who participated at all three time points, 57 of whom were female. They were on average 21.75 years old (SD 5.06) and all but two were first-year students.

Scale	Items	Example	α (T1-T3)
Interest in Mathematics	6	I am not interested in mathematics. (reverse scoring)	.74 / .81 /.78
Utility Beliefs	4	Mathematics is helpful for solving everyday tasks and problems.	.79 / .74 /.71
Process Beliefs	4	Mathematics thrives on inspiration and new ideas.	.80/ .80 /.74
Formalism Beliefs	7	Clarity, accuracy, and uniqueness are features of mathematics.	.63 / .68 /.76
Toolbox Beliefs	5	Mathematics is a collection of procedures and rules that specify exactly how to solve tasks.	.47 /.46 /.50

Table 1: Scales and their reliabilities

To measure interest and beliefs, well-tested Likert scales were taken from other projects and were modified slightly if needed (words were adjusted; e.g. "university" instead of "school"). To measure interest, we used Rheinberg & Wendland's (2000) scale; to measure beliefs, we took Grigutsch et al.'s (1998) scales from the COACTIV (Baumert et al., 2009) version with a 6-point format

(1=not at all, 6=exactly). Reliabilities (Cronbachs α) ranged from poor to good, see Table 1. In particular, the toolbox scale had a low reliability. For the sake of completeness, we included this scale; however, results concerning toolbox beliefs should be handled cautiously.

RESULTS

We analysed data from a subgroup of the first-year pre-service primary teachers; namely, those who answered all three surveys. Using Levene's tests and t-tests to compare the variances and means of the reported constructs, we found no differences between this subgroup and students who missed one of the three tests and had thus been excluded from further analyses ($p>.10$ in each case). The means (SDs in parentheses) of the different constructs are displayed in Table 2. We found that the interest values were below the theoretical mean of the scale (3.5).

	T1	T2	T3
Interest in Mathematics	3.36 (0.83)	3.07 (0.92)	3.15 (0.80)
Beliefs: Utility Aspect	4.59 (0.79)	4.03 (0.88)	4.35 (0.75)
Beliefs: Process Aspect	4.27 (0.91)	3.99 (0.95)	4.13 (0.88)
Beliefs: Formalism Aspect	4.21 (0.65)	4.29 (0.68)	4.26 (0.66)
Beliefs: Toolbox Aspect	4.12 (0.66)	4.13 (0.64)	3.93 (0.61)

Table 2: Means and standard deviations of interest and beliefs

For RQ1, we found significant correlations between interest and both dynamic beliefs and toolbox beliefs on each survey. However, there were no statistically significant correlations between interest and formalism beliefs. The correlations between interest and the different aspects of belief are displayed in Table 3 for each time point.

Correlation between interest and …	T1		T2		T3	
	r	p	r	p	r	p
… Beliefs: Utility Aspect	**.46**	**<.001**	**.50**	**<.001**	**.47**	**<.001**
… Beliefs: Process Aspect	**.52**	**<.001**	**.52**	**<.001**	**.50**	**<.001**
… Beliefs: Formalism Aspect	-.10	.444	-.11	.393	.04	.758
… Beliefs: Toolbox Aspect	-.13	.308	**-.28**	**.026**	**-.31**	**.013**

RQ2 asks for the development of interest and beliefs. Interest was a stable construct in our study. Correlations were .66 (both T1-T2 and T2-T3) and .60 (T1-T3). The beliefs were also rather stable; correlations ranged from .44 to .59 (T1-T2) and .37 to .43 (T1-T3). The changes in mean scores of both interest and beliefs can be derived from Table 2.

	Between T1 and T2			Between T2 and T3		
	p	t(df=61)	d	p	t(df=61)	d
Interest in Mathematics	**.003**	**3.14**	**.33**	.423	-0.81	.09
Beliefs: Utility Aspect	**<.001**	**5.95**	**.67**	**.003**	**-3.08**	**.39**
Beliefs: Process Aspect	**.006**	**2.85**	**.30**	.227	-1.22	.15
Beliefs: Formalism Aspect	.249	-1.17	.12	.706	0.38	.04
Beliefs: Toolbox Aspect	.744	-0.33	.12	**.017**	**2.45**	**.32**

Table 4: Significance values, t-values, and effect sizes

Results of paired samples t-test for these differences and the effect sizes (Cohen's d) are shown in Table 4. There was a considerable decline in interest as well as in dynamic beliefs during the first semester, followed by a slight recovery in the second semester. Static beliefs were less affected; only toolbox beliefs decreased in the second semester.

	Effect on interest at T2			Effect on interest at T3		
	β	p	R^2	β	p	R^2
Pre-Interest	**.615**	**<.001**	.47	**.666**	**<.001**	.50
Beliefs: Utility Aspect	.149	.297		-.088	.444	
Beliefs: Process Aspect	.093	.462		-.089	.410	
Beliefs: Formalism Aspect	-.168	.326		**.292**	**.013**	
Beliefs: Toolbox Aspect	.168	.310		-.094	.464	

Table 5: Results of linear regressions.

RQ3 was to investigate, whether beliefs could predict students' future interest. We calculated a linear regression and took interest and beliefs at T1 and T2 as independent variables to predict interest values at T2 and T3 respectively. In a simple linear regression using interest values only, the explained variance of the dependent variable (R^2) was .44 at T2 and .43 at T3. Including beliefs increased the R^2 to .47 and .50 for T2 and T3, respectively (cf. Table 5). The additional variance in interest explained by beliefs was rather low and not significant in the first semester. In the second semester, formalism beliefs explained an additional 7% of the variance in future interest.

DISCUSSION

Answers to the Research Questions

In terms of their general level, the students in our study had little interest in mathematics. This result compares to other findings and fits the idea that primary teachers often have a stronger pedagogical than content-specific (e.g. mathematical) interest (Abel, 1996). In addition, at Kassel University, mathematics courses were compulsory for pre-service primary teachers.

The answer to RQ1 is that the correlations between beliefs and interest during secondary school were positive for the two dynamic aspects (utility, process) and negative for formalism beliefs. The correlations of interest and beliefs even appeared to be slightly higher than those reported by Baumert et al. (2000). The answer to RQ2 for the development of beliefs and the interest in mathematics of pre-service primary teachers over the first year at university is threefold. For interest and dynamic beliefs, a strong decline was followed by a weak recovery. Toolbox beliefs decreased in the second semester, whereas formalism beliefs were constant. To answer RQ3, modelling the influence of interest and beliefs on future interest surprisingly revealed no effect of dynamic beliefs but a significant positive influence of formalism beliefs.

How can this development and the predictive power of beliefs be explained? Students' loss of interest is similar to the loss of interest reported for future higher secondary teachers (Liebendörfer, 2018; Rach & Heinze, 2017). An important reason for their loss of interest lies in the restrictions in students' self-determination. Formal mathematics requires competencies in handling symbols and working with definitions, that cause students problems in solving their tasks and it may even become difficult to understand the task itself. In such situations, competence and autonomy are hard to perceive (Daskalogianni & Simpson, 2001; Liebendörfer, 2018); however, they are necessary for a positive interest development (Krapp, 2005). Students who share a more formal view on mathematics may better handle the "formal world" (e.g. proving theorems) at this point and see its elegance and use. The changes in the second semester might then be an adaption of the students to the new situation. Our data thus underline the idea that beliefs that fit the mathematics addressed in future may help taking interest (Schukajlow & Liebendörfer, 2017).

Strengths, Limitations and Practical Implications

One strength of our study is the longitudinal sample that revealed differences between correlations and predictors. One limitation is that it is possible that more interested students have a greater willingness to participate in the testing thus affecting the results. We should further mention that our study could not cover students' prior knowledge, performance, and other motivational factors, which most likely interact with interest and its development.

Our results shed some new light on interventions, which mainly focus on dynamic beliefs (e.g., Grootenboer, 2008). Formalism beliefs should not be seen as something obstructive but can also help students take an interest in mathematics.

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