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Situational interest in university mathematics courses: similar for real-world problems, calculations, and proofs?

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In the educational context where this study was conducted, the transition from school to university is associated with changes of the learning domain mathematics. In high school, solving real-world problems and performing calculations are dominating practices, whereas in university, the main focus is on proving. Successful learning processes are associated with appropriate prerequisites, e. g. interest. The question is which component of interest concerning which practice is important for successful processes. We developed an instrument to differentiate these facets of students' situational interest. A study with 339 first-semester students in mathematics partially confirms the expected factorial structure of this instrument. Precise information concerning learners' interest may help us to support students at this challenging transition.

Key words: Students' interest; Feeling- resp. value-related component; Mathematical practices; Transition to and across university mathematics; Teachers' and students' practices at university level.

INTRODUCTION

The transition from school into a university mathematics programme is a challenging phase for many students. Reports mentioning high dropout rates in academic study programmes with a focus on mathematics (OECD, 2010) illustrate this fact. Reasons for students' problems in the first year of university study are primarily attributed to the changes of the learning domain: while the school subject mathematics strongly relies on performing calculations and solving real-world problems, mathematics in university is presented as a scientific discipline with a focus on proving (Rach, Heinze, & Ufer, 2014). It is yet not clear which of the individual prerequisites, that students bring from school, support successful learning processes in university courses. Many researchers assume that subject-specific interest, in the sense of a person-object or a person-situation relationship, is an important learning prerequisite in general (Wigfield & Cambria, 2010). Common instruments to survey interest in mathematics are questionnaires. Mostly, these use the word "mathematics" to describe the objects of interest. At the transition from school to university, however it is not clear if students refer to school or university mathematics when reporting their interest in this questionnaires. To obtain a more differentiated insight into students' interest with a stronger relation to concrete learning situations, we develop a task-based instrument to measure students' interest concerning different mathematical practices. In this contribution, we present the conceptualisations of this instrument in detail and report results of an empirical study with 339 first-semester students that investigates the factorial structure of the instrument.

THEORETICAL BACKGROUND

In the first section, we give an overview about the motivational construct “interest” by addressing common definitions and results concerning its role in learning processes. In the second section, we summarize ideas to the objects of interest, mathematics.

Interest in mathematics learning processes

Researchers agree that interest is an important motivational variable. Its role as a learning prerequisite, a learning processes measure, and as a learning outcome has been put forward repeatedly (Rotgans & Schmidt, 2017; Sonnert & Sadler, 2015; Wigfield & Cambria, 2010). Interest is defined as a specific relationship between a person (here: a student) and an object or a situation (here: mathematics resp. mathematical practices) (Krapp, 2002; Schiefele, 2009). The objects of interests may be concrete objects, topics, or school subjects. Whereas Schiefele, Krapp, and Winteler (1992) conceptualize interest mainly as a relatively stable trait: “*Individual interest* is conceptualized as a relatively stable affective-evaluative orientation toward certain subject areas or objects” (Schiefele, 2009, pp. 198), Linnenbrink-Garcia et al. (2010, 2013), in contrast, see interest as specific to a situation: “*Situational interest* is a temporary state aroused by specific features of a situation, task, or object (e. g., vividness of a text passage)” (Schiefele, 2009, pp. 197–198). Situational interest is limited at a point of time, e. g., in a certain learning situation and may or may not develop into individual interest (Hidi & Renninger, 2006). Schiefele (2009) distinguishes between two components of interest: (1) a feeling-related component, related to fun or other positively experienced emotions, and (2) a value-related component, related to a high importance of the objects of interest for oneself (adapted from Linnenbrink-Garcia et al., 2010, 2013). Linnenbrink-Garcia and colleagues (2010, 2013) could confirm in empirical studies the two-factor structure of (maintained) situational interest and separate the two components from each other. The separation of interest in a feeling-related and a value-related component is also in line with expectancy-value models that distinguish between an intrinsic and a utility value (Eccles & Wigfield, 2002).

Several researchers assume that interest can trigger successful learning processes: interest can lead to more engagement and to an enhanced use of deeper learning strategies which then result in better learning achievement (Hidi & Renninger, 2006). However, empirical studies could not confirm this assumption for learning processes in undergraduate mathematics courses (Rach & Heinze, 2017). The conceptualisation and operationalisation of interest in mathematics may be one reason for these conflicting findings: firstly, the interest object “mathematics” changes its character at the transition from school to university. So the objects of reported interest may differ from the learning object in the first semester (see next section). Secondly, many of the used instruments measure the individual interest rather than the situational interest, although the situational interest is a more proximal variable to the specific learning situation.

Mathematical practices at the transition from school to university

In the literature (Gueudet, 2008; Engelbrecht, 2010), changes in two relevant aspects of the learning environment at this transition are described: a shift in the character of the learning domain, mathematics, and a change in the learning opportunities and their use. As interest is a person-object relationship resp. a person-situation relationship, the change of the learning domain is important for the conceptualisation of interest. The specific differences of mathematics at school and at university might vary between countries due to traditions concerning learning goals etc. The subsequent presentation refers to the situation in Germany which was analysed in empirical studies (Rach et al., 2014) and which is relevant for the empirical study we present below. Nevertheless, several of the described features might hold for other countries as well. One central goal of teaching and learning at school is to apply mathematics for solving real-world problems (CCSSI, 2010; OECD, 2016). Thus, describing realistic situations mathematically, performing computations, and applying mathematical procedures are central. On the contrary, university mathematics is usually taught as a scientific discipline based on formal definitions of concepts and formal-deductive proofs (Gueudet, 2008; Nardi, 1996). Mathematics at university is often presented in a DTP (Definition-Theorem-Proof) structure to emphasise its logical rigidity (Engelbrecht, 2010; Weber, 2015). These conclusions are mainly based on observations of lectures (Weber, 2004) or of tutorials (Nardi, 1996), interviews with involved parties (Nardi, 2008), or analyses of tasks (Gueudet, 2008). In general, mathematical tasks are often used to describe and examine learning situations and their cognitive demands (e. g., Stein & Lane, 1996).

Theoretical analyses and anecdotal evidence from students and teaching staff have described a change of the learning domain (e.g., Engelbrecht, 2010; Gueudet, 2008; Thomas & Klymchuk, 2012). However, empirical studies supporting the role of this shift and its effects on student learning are scarce. In particular, reliable evidence on the role of students' motivational variables, especially of students' interest, is scarce.

The SISMa project

The goal of the SISMa project ("Self-concept and Interest when Studying Mathematics") is to contribute evidence concerning students' interest and self-concept with regard to certain mathematical practices (Ufer, Rach & Kosiol, 2017). As a first step of the project, we developed interest and self-concept measures that focus central mathematical practices. Using these measures, the development of these variables during students' learning processes and their effect on student learning in undergraduate mathematics programmes are investigated.

In this contribution, we focus on the measurement of situational interest. We developed a questionnaire of situational interest that is based on the conceptualisation of interest as a person-object (situation) relationship, and on the assumption that interest concerning a specific task is an indicator of situational interest. Here, we follow the idea of Schukajlow and colleagues (2012) who operationalize the two

components of situational interest with the constructs enjoyment and value (see also Schukajlow & Krug, 2014). In this questionnaire, mathematics tasks are presented to students and they are asked to imagine solving this task (not to solve the task), and then to state their anticipated enjoyment and value appraisals when working on the task. For our questionnaire, we designed mathematical tasks concerning the topic derivatives that each prototypically represent one of the three practices “solving real-world problems” (resp. applying mathematics, sample item: “Using metal, you should produce a cylindrical can with a prescribed volume. For which radius is the material consumption minimal?”), “performing complex calculations” (sample item: “Let f be $f(x) = \frac{\sqrt{1+x} \cdot e^x}{4+x^2} - 1$. Calculate the extrema of the function f .”), “and “proving” (sample item: “Let $f: \mathbb{R} \rightarrow \mathbb{R}$ be a differentiable function. Show that f is continuous.”). After a pilot study (see Rach et al., 2014), we used 12 tasks. While the first and second practice are considered central in mathematical lessons at school, the last practice predominates in university courses. After reading each task, students rate their agreement to one statement concerning the feeling-related component (item: “It would be fun to me to work on this task.”) and one statement concerning the value-related component of interest (item: “Even if the task is not part of an exam, it is important to be able to solve the task.”). So in sum, situational interest is divided into six subscales – one for each component and each mathematical practice (see table 1).

	<i>Solving real-world problems, applying mathematics (4 tasks)</i>	<i>Performing complex calculations (4 tasks)</i>	<i>Proving (4 tasks)</i>
<i>Feeling related</i>	Feel Apply	Feel Calc	Feel Proof
<i>Value related</i>	Value Apply	Value Calc	Value Proof

Table 1: Two components of situational interest and three practices.

RESEARCH QUESTIONS

The aim of this contribution is to investigate the structure of students’ situational interest as measured with our instrument. To achieve this, we applied the instrument to students from a first semester mathematics course. The questions focused in this contribution address students’ reported levels of interest and the empirical structure of the questionnaire:

1. What level of feeling- and value-related situational interest do students from a first semester mathematics course report concerning the three practices?
Since prior research has shown similar trends, we expected that students would report lower interest levels for each component and practice after six weeks, compared to the first day of their studies. One reason might be that high demands in the first semester lead to a decrease in interest.
2. Is the theoretical structure of subscales, that guided their development, reflected in the factorial structure of the newly developed instruments?

We expected that the two components of situational interest, the feeling- and the value-related component, are reflected in the empirical data. Moreover, we expected that subscales concerning the three different practices can be separated from each other.

METHOD

Design and sample

We present data from two measurements, at the beginning of the first semester (T1) and in the middle of the first semester (T2). Our sample consists of 339 mathematics students (162 female) of one German university of the course “Analysis I” which is compulsory for first-semester mathematics students. In this course, mathematics is presented as a scientific discipline with a strong focus on formal concept definitions and deductive proofs. The students were enrolled in the bachelor’s programmes “mathematics” ($n = 90$), “business mathematics” ($n = 91$), or a mathematics teacher education programme for the highest attaining secondary school track in Germany ($n = 104$) – for the remaining students, we have no information about their study programme. The participation in the study was voluntary.

Instruments

The mathematical tasks were arranged in a fixed, random order. The questionnaire was submitted to the students with the following instructions: “Imagine how you solve these tasks. Do not solve the tasks, but report your agreement to the following statements”. Students rated each statement 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.

RESULTS

Table 2 shows the means, standard deviations, and Cronbach’s Alpha of the six scales at the first and second measurement point.

	Beginning of the first semester (T1)			Middle of the first semester (T2)		
	<i>N</i>	<i>M (SD)</i>	α	<i>N</i>	<i>M (SD)</i>	α
Feel Apply	323	2.22 (0.61)	.73	226	2.02 (0.67)	.76
Feel Calc	323	2.16 (0.71)	.79	230	2.01 (0.74)	.80
Feel Proof	331	2.18 (0.61)	.77	237	2.00 (0.61)	.82
Value Apply	323	2.25 (0.64)	.82	224	2.04 (0.71)	.82
Value Calc	325	2.26 (0.70)	.86	232	2.00 (0.76)	.86
Value Proof	331	2.31 (0.61)	.88	237	2.06 (0.67)	.86

Table 2: Means, standard deviations, and Cronbach’s Alpha of the interest scales. Likert scale from 0 (disagree) to 3 (agree).

Concerning all 24 items (3 practices, 4 tasks, 2 components), there are no floor or ceiling effects. Reliability analyses underpin the internal consistency of the six subscales. For T1 ($N = 323\text{--}331$), Cronbach's alpha of each scale ranges from .73 to .88, for T2 ($N = 224\text{--}237$), from .76 to .86. Indeed, students reported higher value and feeling ratings concerning all practices in the first as compared to the second measurement (cf. table 2; $t(194\text{--}197) = 5.42\text{--}6.83$; $p < .001$; $d = 0.39\text{--}0.49$; measured with students who were present at both measurements). Levels of value- and feeling-related interest were relatively similar between the three practices.

Correlation analyses (see table 3) show that, as expected, the feeling-related and value-related scales concerning each practice strongly relate to each other (Solving real-world problems: T1: $r = .55$, T2: $r = .65$, Performing complex calculations: T1: $r = .49$, T2: $r = .53$, Proving: T1: $r = .53$, T2: $r = .60$). Moreover, the three feeling-related scales ($r = .43\text{--}.60$) resp. value-related scales ($r = .59\text{--}.79$) correlate strongly. The correlations of feeling-related scales with value-related scales for different practices are moderate (T1: $r = .28\text{--}.44$, T2: $r = .31\text{--}.39$).

	Feel Apply	Feel Calc	Feel Proof	Value Apply	Value Calc	Value Proof
Feel Apply		.47	.43	.55	.31	.31
Feel Calc	.47		.60	.28	.49	.32
Feel Proof	.44	.54		.38	.44	.53
Value Apply	.65	.31	.31		.66	.68
Value Calc	.30	.53	.39	.59		.79
Value Proof	.37	.37	.60	.66	.79	

Table 3: Correlations between the interest scales. Over the diagonal T1 ($N = 334\text{--}339$), under the diagonal T2 ($N = 239\text{--}243$). All correlations significant with $p < .01$.

As some of the situational interest scales correlate strongly, we investigated whether our expected scale structure would be replicated by exploratory factor analyses. The results of Principal Component Analysis with Varimax rotation for every measurement point partially support our expected structure of our scales. For T1, results indicate four factors that explain nearly 63% of the variance. Table 4 shows the factor loadings of the items on the four identified factors.

As expected, the feeling-related items concerning each of the three practices load strongly on one of the factors two to four each. Contrary to the theoretical construction of our questionnaire, the first factor includes the value items for all three practices. Some value-related items have cross-loadings on the feeling-related scales for the same practice. For T2, the factor analysis shows similar results, with the four factors explaining 65% of the variance. Thus, it also seems to be possible to combine all value items into one value scale. This value-related scale with twelve items has an excellent reliability of $\alpha = .93$ ($N = 317$, T1) resp. $\alpha = .92$ ($N = 223$, T2).

	Factor 1	Factor 2	Factor 3	Factor 4
Feel Apply 1		.35	.36	.42
Feel Apply 2		.31		.72
Feel Apply 3			.44	.64
Feel Apply 4				.81
Feel Calc 1		.50	.41	
Feel Calc 2		.38	.67	
Feel Calc 3			.78	
Feel Calc 4		.35	.74	
Feel Proof 1		.71		
Feel Proof 2		.62		
Feel Proof 3		.65		
Feel Proof 4		.70		
Value Apply 1	.70			.44
Value Apply 2	.61			.50
Value Apply 3	.60			.56
Value Apply 4	.55			
Value Calc 1	.75			
Value Calc 2	.75		.32	
Value Calc 3	.69		.46	
Value Calc 4	.76		.35	
Value Proof 1	.73	.35		
Value Proof 2	.82			
Value Proof 3	.71	.32		
Value Proof 4	.76	.35		

Table 4: Factor loading on the four extracted factors (T1, $N = 313$). Loadings under .30 not shown. The expected loadings on a factor are bolded.

DISCUSSION

Students' interest is an important variable in successful learning processes, including the transition to university mathematics. Based on prior research, we argue that to measure students' interest validly, one requires situated, e.g. task-related, measures, to cover feeling- and value-related components of interest and to take into account the

changing role of different mathematical practices during this transition (Rach & Heinze, 2017). Contrary to the findings of Schukajlow et al. (2012), the results of our empirical study show that the relations between the feeling-related components for different practices are relatively low as compared to the respective correlations between the value-related components. This partially supports the expected six-factor model (c. f. Schiefele, 2009), and underpins the different roles the three practices play during the transition in the educational context in Germany. Beyond this, factor analyses indicate that the value-appraisals seem to be fairly consistent over all three practices and the exploratory factor analyses also allow a model assuming only one value factor over all practices. This observation applies to data from the first day of university study, but also to data collected after six weeks into the semester. After six weeks, students report across all scales lower approvals. Interestingly, even though students seem to differentiate their interest reports by practices, we find almost no differences in their mean levels of interest between the different interest scales.

Of course, the results of our study rely on students' self-reports about their anticipated situational interest in a set of specific tasks. Even though the differences between school and university mathematics have been described internationally, it might be interesting to replicate the studies in other educational systems. In future studies, the relation between the anticipated situational interest and the actual engagement in learning situations should be considered. However, Schukajlow and Krug (2014) found only slight differences in prospective and retrospective ratings of interest in working with mathematical tasks. In sum, the newly developed instrument may provide more differentiated insights into students' interest concerning different mathematical practices. Further research should investigate which facets of situational interest indeed go along with learning gain in the study entry phase. In particular, it is an open question if interest in practices that are typical for university mathematics, such as proving, are more important for learning gain than other interest facets. In the future, this instrument may help to evaluate support courses in the study entrance phase, to analyse the development of students' interest (c. f. Hidi & Renninger, 2006), and to investigate the impact of different interest facets on study success.

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