The relation between interests and grades: Path analyses in primary school age

Jutta von Maurice, Tobias Dörfler, Cordula Artelt

Abstract Within the school context substantial correlations between interests and grades are well documented, but the causal ordering still remains unclear. The paper examines how the relation between interests and grades over several measurement waves in elementary school age can be characterized, whether gender differences in the pattern of effects can be shown, and whether the effects are school-subject-specific. The present analysis follows N = 1.199 students in the 3rd Grade over a year and a half. It can be shown that grading determines the level of future interests but not vice versa. Thereby, the pattern of results concerning interests and grades is similar for boys and girls. The effects of grades on subsequent interests are mostly school-subject-specific.

Keywords: Interests Elementary school students Academic achievement Path analysis Grade level

1. Theoretical background

Interests in school subjects are related to academic achievement. Referring to an often cited meta-analysis conducted by Schiefele, Krapp, and Winteler (1992), an overall correlation of r = .30 between interests and academic achievement can be assumed – varying slightly between the subjects under investigation and the indicators for achievement used. Since empirical evidence concerning the causal order of effects is largely missing, this study highlights the relation between subject-specific interests and grades – as an indicator of academic achievement – in elementary school from a longitudinal perspective.

1.1. Relations between interests and academic achievement

From a t heoretical point of view, interests can be regarded as an important determinant of academic achievement: higher interests can lead to academic engagement, typically associated with positive affect and persistent engagement in related tasks, which in turn can lead to learning gains and condense in improved achievement test scores or school grades. Borrowing theoretical conceptualizations from the literature on academic self-concepts, this kind of unidirectional effect of interests on academic achievement can be described as self-enhancement model (see Calsyn & Kenny, 1977, for self-concept and achievement).

However, a different conceptualization of the relation between interest and academic achievement stems from the idea that learning gains lead to better test results or grades and to other forms of positive feedback, which might in turn foster the perception of self-efficacy and promote the development of corresponding interests (see Köller, Baumert, & Schnabel, 2001; Lent, Brown, & Hackett, 1994). The unidirectional effect of achievement on interests refers to the skill-development model (Calsyn & Kenny, 1977), which was also formulated in the discussion of the relation between interests and self-concept.

Dealing with the self-enhancement- and the skill-development-models, Marsh (1990, 1993) formulated an alternative reciprocal effects model (see also Green, Nelson, Martin, & Marsh, 2006; Marsh & Yeung, 1997), which includes effects from self-concept to subsequent achievement as well as reverse effects from achievement to self-concept.

There is a lot of discussion and empirical research about the causal interrelation between self-concept and achievement, giving support to the reciprocal effects model (e.g., the meta-analysis by Valentine, DuBois, & Cooper, 2004). In interest research – compared to self-concept research – there has been much less activity aiming at the causal interrelations with achievement. As described above, effects from interests to achievement as well as effects from achievement to subsequent interests are well justified from a theoretical point of view. The empirical evidence about the causal ordering of school subject interests and school achievement – measured by achievement tests as rather objective indicators of competence or by grades which might be more important for self-perception of competence – is still limited. Meaningful empirical analyses dealing with causal effects between interests in school subjects and indicators of academic achievement require longitudinal data with sufficient sample sizes (see e.g., Köller, Trautwein, Lüdtke, & Baumert, 2006; Marsh, 1990). In 1998 Schiefele complained that most studies were cross-sectional and that so little well-founded evidence concerning causal relations was available. This picture is currently changing, as longitudinal data are more and more available. Based

Accepted Author’s Manuscript. This article was published in:
International Journal of Educational Research (2014) 64:1-11. DOI: 10.1016/j.ijer.2013.09.011

The research presented within this paper was supported by a grant (AR 301/9-1) of the German Research Foundation (DFG).

on the data of the BIJU study (Bildungsverläufe und psychosoziale Entwicklung im Jugendalter; Learning Processes, Educational Careers, and Psychosocial Development in Adolescence and Young Adulthood), Köller et al. (2006) integrated self-concept, interests, course choices, grades, and achievement test scores in mathematics in a complex model. In a sample of students in Grade 10 and 12 they found a positive effect of interests on gains in achievement tests. Marsh, Trautwein, Lüdtke, Köller, and Baumert (2005) referred to BIJU-data of a younger cohort (two measurement points in Grade 7) and data of TIMSS (Third International Mathematics and Science Study; Grades 7 and 8). Using structural equation models that integrated self-concept, interests, grades, and achievement test scores, for none of the two studies effects from interests on subsequent achievement could be proven, nor vice versa.

When Marsh et al. (2005) reduced the model to interests and grades in supplemental analyses they showed that the effect of interests at time 1 on grades at time 2 is higher than the effect of grades at time 1 on interests at time 2, but the effects still remain quite small. Besides, there are more studies that show effects of achievement on interests. Baumert, Schnabel, and Lehrke (1998) reanalyzed several studies on students' achievement and interest in mathematics. Thereby they showed that – controlling for prior competence level – interest in mathematics had no causal effect on subsequent achievement test scores (for grades weak but significant effects can be shown), whereas achievement had a stronger effect on interest development. However, also reciprocal effects were demonstrated in the 1990s. A study by Yoon, Eccles, and Wigfield (1996) found hints for a weak reciprocal relation between intrinsic value (defined as interests and liking) and academic achievement (grades and teacher performance rating of the students) over a two-year-period in a sample of sixth graders for mathematics. Also, Marsh and Yeung (1997) confirmed the reciprocal effects model for mathematics, science and English.

Altogether, the empirical results for the causal ordering of interests and achievement are still somewhat heterogeneous (see also Marsh & Yeung, 1997). So far there has been mixed evidence concerning either the interests-to-achievement model or the achievement-to-interests model or the model of reciprocal effects between interests and achievement.

1.2. Effect of age on the relation between interests and achievement

Looking at the literature on self-concept and achievement in more detail, it also seems worthwhile for modeling the relation between interest and achievement to take into account the idea of a changing relationship over time. Köller et al. (2001) discussed the idea that the direction of effects between self-concept and achievement may vary depending on the developmental stage of the subjects under study. Depending on the age of the respondents as well as on the corresponding contexts (esp. the amount of opportunities for self-regulated learning activities given in the context), the causal effects might change over time (for the developmental perspective see also Guay, Marsh, & Boivin, 2003; Marsh, 2003). ''To summarize, the developmental perspective suggests that young children have very positive self-concepts that may appear to be biased in relation to external indicators of self-concept but that these very high self-concepts tend to become less positive and more differentiated as they grow older. In addition, it appears that this developmental pattern may lead to a skill-development effect for younger children, but as children's self-concept becomes more closely aligned with external indicators, a reciprocal-effects model may be obtained'' (Guay et al., 2003, p. 126). Corresponding to the developmental perspective, Skaalvik and Hagtvet (1990) found evidence for reciprocal effects in higher school grades but evidence for the skill-development model in lower grades. In the study conducted by Guay et al. (2003) the reciprocal effects model fits best in three different age cohorts (starting in Grades 2, 3, and 4).

A similar developmental pattern can be considered for the relation between interests and achievement. In their formulation of a four-phase model of interest development Hidi and Renninger (2006) distinguished two stages of early situational interests – which are mainly externally supported – from two stages of later individual interests – which are, to a higher degree, self-generated and based on self-regulated activity. A changing pattern between interests and achievement was demonstrated by Köller et al. (2001) on the basis of BIJU-data. Findings from structural equation modeling show effects from the results of a standardized achievement test in mathematics in Grade 7 on interest in Grade 10 (but not from interestin Grade 7 to achievement in Grade 10) but reverse effects from interest in Grade 10 to achievement in Grade 12 (but not from achievement in Grade 10 to interest in Grade 12). This kind of result can also be regarded as an indication for the importance of the specific context. Interests can have an effect on subsequent achievement in higher school classes, because especially in this context students have opportunities to engage in interest-based learning activities. By contrast, it can be assumed that the highly structured school system in lower secondary school years lacks such opportunities (see also Kunter, Baumert, & Köller, 2007). For choice-related activities the secondary school level thus seems to be a more fruitful context. Indeed, most studies focus on secondary school and disregard ongoing processes in elementary school. However, the elementary school years, especially Grades 3 and 4, are a crucial time period for German students since in most German federal states the decision for a secondary school track has to be made after Grade 4. Thus, this period of time is of special importance as the decision of school tracking affects children's future school career. Despite the critical importance of elementary school age for interest development and the crucial role of elementary school grades for secondary school track decisions, only limited research exists on causal effects concerning this age group (Guay et al., 2003). It remains unclear whether the results from self-concept research – a shift from the skill-development model to the reciprocal effects model (see also Marsh, 2003) – can also be assumed for the causal ordering of the reciprocal effects interests and achievement. Some preliminary conclusion can be drawn from the research by Dotterer, McHale, and Crouter (2009). In their research the authors were focusing on interests and grades in a variety of academic subjects starting at an age from about 7 for a 9-year period up to the age of 18 years. Among other research questions the links between interests in school subjects and grades were studied. As one major result, they found that declines in academic interests were related to declines in academic performance.

1.3. *Effects of gender on the relation between interests and achievement*

Gender effects related to school subjects are well documented in the literature. Mathematics is an example of a typically male subject, whereas German is typically female (see e.g., Baumert & Köller, 1998). There is a large body of international research on gender differences in mathematics (see also Geary, 1996; Hosenfeld, Köller, & Baumert, 1999; Johnson, 1996). Leaving results of differences between countries and improvements in the last decades unconsidered, mathematics can still be described as a ''typically male'' subject (for Germany see also Köller & Klieme, 2000). Compared to the results in mathematics, studies dealing with native language (English or German) are sparse. Explanations for gender differences in interests are manifold (see e.g., Baumert & Köller, 1998).

Whereas gender differences in school subject interests and academic achievement are well documented, the question whether the order of effects between interests and achievement varies between boys and girls and whether the paths between both constructs in their longitudinal development are the same in both groups has not been the focus of scientific interest. According to the findings of Yoon et al. (1996) the effects of feedback given via grades might work differently for boys and for girls. Moreover, following the argument given by Marsh (1989) in the context of self-concept research, different causal relations might result from differential, sex-stereotyped socialization patterns (see also Eccles, Wigfield, Harold, & Blumenfeld, 1993). However, empirical research is still limited (see also Krapp, 2000; Marsh et al., 2005). One of the few exceptions is the analysis of a 9-year longitudinal data set by Dotterer et al. (2009). As mentioned above, they found declines in academic interests as being related to declines in academic achievement (measured by grades). This link was stronger for girls than for boys. As a consequence, the authors recommended detailed analyses for boys and girls in this area of research. Köller, Daniels, Schnabel, and Baumert (2000) showed separable effects of self-concepts and interest in mathematics in Grade 10 regarding course selection in mathematics in Grade 12. The effects are described as identical for boys and girls. Marsh et al. (2005) also identified comparable causal models (gender-invariance for causal paths, not for level-effects) in the relation of academic self-concept, interests, and achievement test scores (see also Schilling, Sparfeldt, & Rost, 2006, for the gender invariant relations between self-concept and achievement, as well as Marsh & Yeung, 1998, for gender invariance in a complex model including grades, tests, academic self-concept, affect, and coursework selection). By contrast, Yoon et al. (1996) disclosed gender differences in the pattern of causal relations (see also the early research done by Calsyn & Kenny, 1977).

1.4. *Subject-specificity of the relation between interests and achievement*

Most studies dealing with the order of effects between self-concept, interests, and achievement focus on one single school subject (e.g., Yoon et al., 1996 focusing on mathematics) or even use calculated sum scores from different domains. In self- concept research it is well-known that – alongside external comparisons with peers – also internal comparisons of students between different subjects are important for individual self-concept development (internal/ external frame of reference model by Marsh, 1986). In their analyses Dotterer et al. (2009), for example, used a mean value of grades in English, mathematics, science, and social studies on the one hand and a factor value calculated on the basis of interests in reading, writing, language, arts, mathematics, and science on the other hand. Some empirical studies analyzed more than one domain but the analyses are normally done separately, even though the different results are brought together in the interpretation (see Marsh & Yeung, 1997). One remarkable example of this kind of study is the comparison of the relations between academic self-concept and academic achievement in mathematics, science, and English from Marsh and Yeung (1997). They were able to demonstrate reciprocal effects. While the effect sizes from achievement to subsequent self-concept were comparable in all three subjects, there were substantial differences concerning the opposite effect from academic self- concept to subsequent achievement. These effects were stronger in mathematics than in science and especially in English. Studies like this show that the causal effects between interests and academic achievement may vary between subjects (see also Gottfried, Fleming, & Gottfried, 2001).

However, in order to gain a more complete picture of the mechanisms at work, a comparison between separately conducted causal models regarding several subjects is insufficient (see also Marsh & Yeung, 1998) – the simultaneous inclusion of two or more subjects is required: it is possible that the order of effects between interests in school subjects and achievement are subject-specific (this means that the relation between interests and achievement in one subject is independent of the other subject). If, however, school subjects are compared, also contrast effects (increase of interests in school subjects if achievement in other subjects are low) or assimilation effects (better achievement in whichever subject fosters academic engagement and interests on a general level) might be found (see e.g., Marsh & Yeung, 1998; Pohlmann, Möller, & Streblow, 2006; Schilling, Sparfeldt, & Rost, 2004). These effects are missed when only one subject domain is taken into account. Within an extension of the internal/external frame of reference model Möller, Streblow, Pohlmann, and Köller (2006) were able to show that contrast effects from achievement (measured by grades) in one subject to self-concept in another subject are likely to occur, particularly so when markedly different subjects (such as mathematics and German as a native language) are taken into account (see also Möller, Retelsdorf, Köller, & Marsh, 2011). For the more similar school subjects mathematics and physics assimilation effects and for German (as native language) and English (as foreign language) no effects at all have been found for the paths from achievement to self-concept (see also Schilling et al., 2004). In general, theoretical discussions about the role of different school subjects for interest-achievement-relation are still sparse and empirical results are missing.

1.5. Research questions

In the analyses presented in this paper the complex interplay between school-subject-specific interests and achievement (as measured by grades) in Grades 3 and 4 of elementary school is examined. The analyses include two largely different school subjects – mathematics as a ‘‘typically male’’ domain and German as a ‘‘typically female’’ school subject.

When looking at the relation between school-subject-specific interests and grades over time, three aspects are of special importance:

- First, we examine how the order of effects of school-subject-specific interests and grades in elementary school age develop over time. It is of special importance whether unidirectional or reciprocal effects between subject-specific interests and grades are found in elementary school age.
- Second, it is examined whether significant gender differences in the pattern of effects can be disclosed. Our aim is not focused on the well-documented effect of gender on the level of interests and grades but on the potentially different relations between interests and grades for boys and girls over time.
- Third, it is tested whether the effects are subject-specific. We especially want to find out whether the relation between grades and interest in mathematics (German) is influenced by the achievement level in German (mathematics) or whether subject-specific effects are independent of other school subjects.

By answering the three research questions described above we want to contribute to a better understanding of the causal relation between school-subject-specific interests and grades in elementary school. Our significance level is set at .01.

2. Method

2.1. Design and participants

In this longitudinal study, data were assessed within the framework of the interdisciplinary BiKS research group (Bildungsprozesse, Kompetenzentwicklung und Formation von Selektionsentscheidungen im Vor- und Grundschulalter; Educational Processes, Competence Development and Selection Decisions in Pre- and Elementary School Age; see von Maurice et al., 2007), which is funded by the German Research Foundation and consists of eight research projects sharing data of two large longitudinal panel studies. The panel that is referred to in this paper started with students from the third year of elementary school and followed the students with a total of three measurement points until the end of elementary school. Starting in Grade 5 the participating students attended different school tracks in consideration of their individual competencies and parental assistance. Within our analysis of elementary school students, we used data from the first measurement point in the second term of Grade 3 (T1), the second measurement point in the first term of Grade 4 (T2), and the third measurement point in the second term of Grade 4 (T3).

Our study included a total sample of 1.199 elementary school students from 78 classes (from 43 different elementary schools) in Grade 3 at measurement point T1. The average age at T1 was 111.16 months (SD = 5.79) – corresponding to an age of 9 years and 3 months. The sample consists of 603 boys (50.3%) and 596 girls (49.7%). 806 (67.2%) students were native German, whereas 302 (25.2%) had a migration background (at least one parent not born in Germany); 91 (7.6%) did not give any information about their migration background. The sociodemographic background was defined by the HISEI (Highest International Socio-Economic Index of Occupational Status within the family; see Ganzeboom, Graaf, Treiman, & Leeuw, 1992); the HISEI had a mean of 50.64 (SD = 16.40).

2.2. Measures

In order to investigate the relation between interests and grades, data from students as well as their parents and teachers participating in the BiKS-Study were used. The data were taken from different data sources: some information (age and sex) was collected during the sampling procedure (agreement consent form) and is available for the total sample of 1.199 students at T1. The student questionnaire (interest scores) was filled in by 1.151 students at T1 (96.0%), 1.071 students at T2 (89.3%) and 1.004 students at T3 (83.7%). The sociodemographic data (migration background, sociodemographic background) were taken from the parents' questionnaire at T1 (CATI; 1.099 valid interviews; 91.7%). Grades as a measure of students' academic achievement were taken from the teachers' individual description of students in their classes. Here, 1.119 valid descriptions were delivered at T1 (93.3%), 1.037 cases at T2 (86.5%) and 940 cases at T3 (78.4%). Missing data were handled by implementing the SPSS package for missing data imputation. We used multiple imputations with a sophisticated background model to impute the data and got m = 5 data sets that were subsequently entered in M*plus* 7 for the following analyses.

2.2.1. School-subject-related interests

Students' interests were assessed by a questionnaire incorporating four items concerning mathematics and four items concerning German. The items were taken from the BIJU study (see Baumert et al., 1996; Köller, 1998). The item construction of this instrument is based on an educational-psychological theory of interest (Hidi & Renninger, 2006; Krapp, 2000), taking value-oriented and emotional features as well as the self-intentionality of interest-based activities into account. Items asked, for instance, ''How much do you look forward to the next lesson in mathematics'' and had to be answered on a 5-point Likert- type scale ranging from 1 (not at all) to 5 (very much). The interest scores in mathematics and German were calculated as the mean of the four corresponding items. Internal consistencies by Cronbach's alpha turned out to be very satisfying at all points of measurement and vary between .82 and .87 (mathematics: αT1 = .86, αT2 = .84 and αT3 = .87; German: αT1 = .86, αT2 = .82 and αT3 = .86).

2.2.2. Grades

Teachers were asked to give information on their students' grades in the school subjects mathematics and German as they were registered in the school reports at the end of each term. School grades in Germany are labeled as numerical values and range from 1 (best grade, i.e., ''very good'') to 6 (worst grade, i.e., ''very poor or failed'').

3. Results

3.1. Descriptive statistics

Descriptive data and correlations were computed using M*plus* 7 on the basis of m = 5 imputed data sets. Table 1 displays means and standard deviations of all used measures separated for boys and girls.

First, the results indicate that school performance differs significantly (at the defined significance level of .01) between boys and girls: boys get better grades in mathematics than girls (lower mean because grade 1 is the best grade), whereas girls get better grades in German than boys. This applies for all measurement points. Second, according to the effects concerning grades, boys are more interested in mathematics than girls, and girls, on the contrary, describe themselves as being more interested in German than boys. Table 2 shows the correlations between all used measures regarding both sexes.

It can be observed that half-year rank order stability as well as one-year rank order stability for school grades in mathematics (range between r = .71 and r = .82) and German (range between r = .75 and r = .85), with no major differences between sexes (maximum z-value for maths = -.72, not significant; maximum z-value for German = 2.23, not significant), are very high. By contrast, also interests in mathematics (range between r = .42 and r = .61) and in German (range between r = .41 and r = .59) show moderate rank order stability without significant differences between sexes (maximum z-value for maths = .93, not significant; maximum z-value for German = -1.27, not significant). Correlations between the grades in mathematics and German across time vary between r = .59 and r = .70 with no significant difference between boys and girls (maximum z-value = -2.17, not significant). Thus, school performance in mathematics and German is moderately correlated at one point of measurement and across measurement points. Finally, contrary to school performance only low correlations of interest scores regarding mathematics and German as a subject can be found at one measurement point and very low to even no correlations across the time (range between r = .02 and r = .29). Differences between boys and girls are small and not significant (maximum z-value = -2.36, not significant). On a descriptive level, an interesting pattern between interests and grades can be observed: whereas interests and grades concerning the same subject covary negatively (thus, pointing to a positive association between students' performance and interests in the same subject), the correlation between interests and grades concerning different subjects are in most cases only very low. Path analyses are conducted to investigate causal effects between grades and interest scores including sex as a grouping factor.

Table 1: Descriptive statistics for grades and interest measures separated for boys and girls.

	Boys *(N = 603)*		Girls *(N = 596)*		*t*-Test	
	M	SD	*M*	SD	*t*	df
Grade math T1a	2.36	.93	2.52	.97	-2.92	1197
Grade math T2a	2.45	.91	2.61	.95	-2.98	1197
Grade math T3a	2.58	1.01	2.80	1.02	-3.75	1197
Grade German T1a	2.78	.94	2.50	.86	5.38	1197
Grade German T2a	2.76	.95	2.44	.88	6.05	1197
Grade German T3a	2.87	.95	2.58	.89	5.45	1197
Interest math T1b	4.17	1.05	3.62	1.17	8.57	1197
Interest math T2b	4.14	.97	3.68	1.02	8.04	1197
Interest math T3b	3.92	1.17	3.51	1.10	6.25	1197
Interest German T1b	3.22	1.22	3.69	1.08	-7.06	1197
Interest German T2b	3.37	1.09	3.87	.90	-8.66	1197
Interest German T3b	3.25	1.17	3.68	1.01	-6.21	1197

Note: German grades are coded: 1 = best grade, 6 = worst grade; T1, T2, T3 = measurement point 1, 2 or 3; suffixes a and b = temporal order of questionnaires;
N = number of students; *t* = t-value; df = degrees of freedom.

Table 2: Manifest correlations of grades and interest measures for both groups (boys/girls).

		Pearson correlations (boys/girls)										
		1	2	3	4	5	6	7	8	9	10	11
1	Grade math T1a	–										
2	Grade math T2a	.82/.81	–									
3	Grade math T3a	.71/.73	.75/.75	–								
4	Grade German T1a	.63/.70	.63/.63	.59/.62	–							
5	Grade German T2a	.66/.66	.68/.65	.62/.63	.85/.81	–						
6	Grade German T3a	.64/.68	.66/.65	.66/.68	.76/.75	.79/.79	–					
7	Interest math T1b	-.22/-.21	-.18/-.21	-.16/-.15	-.01/-.06	-.01/.02	.02/.02	–				
8	Interest math T2b	-.23/-.20	-.22/-.22	-.20/-.23	-.06/-.07	-.04/-.05	-.02/-.07	.53/.49	–			
9	Interest math T3b	-.24/-.26	-.25/-.29	-.29/-.35	-.10/-.17	-.09/-.14	-.09/-.15	.42/.42	.58/.61	–		
10	Interest German T1b	.01/.00	.02/.00	.03/-.04	-.14/-.18	-.10/-.12	-.08/-.09	.15/.28	.02/.09	.08/.15	–	
11	Interest German T2b	-.00/-.05	.03/-.03	.03/-.04	-.20/-.22	-.13/-.17	-.10/-.14	.10/.20	.11/.23	.04/.16	.54/.59	–
12	Interest German T3b	-.02/-.08	-.01/-.06	.04/-.04	-.17/-.19	-.15/-.20	-.11/-.20	.12/.15	.09/.17	.29/.28	.41/.42	.55/.57

Note: German grades are coded: 1 = best grade, 6 = worst grade; T1, T2, T3 = measurement point 1, 2 or 3; suffixes a and b = temporal order of questionnaires;
$N_{boys} = 603$, $N_{girls} = 596$.

3.2. Path analyses

Path analyses examine the predictive association between two (or more) variables over time. Therefore, each variable is regressed onto its own lagged measure to determine the autoregressive paths and additionally onto lagged measures of other variables to estimate the directionality of effects between different measures. M*plus* 7 (Muthén & Muthén , 1998–2012) was used as a tool to analyze the pattern of correlations between grades and school subject interests. Missing data were handled by using the multiple imputation package in the SPSS estimation option, which allows the inclusion of participants with partially missing data and the use of all available information in the analyses (Lüdtke, Robitzsch, Trautwein, & Köller, 2007; Muthén & Muthén , 1998–2012). The hierarchical structure of the data was handled by using the type = complex option of M*plus* 7. The ordering of variables is based on the temporal ordering of data collection in the formulated models. As school grades were based on the previous school reports, they were posited to precede the interest scores; the temporal order is referred to by the suffixes a and b added to the measurement points 1, 2 and 3. Two major model groups can be distinguished: on the one hand focusing on the interest in mathematics as a subject, on the other hand looking at the interest in German as a subject. Models are respectively labeled as *mathematics or German.* Since differential effects can be assumed for gender, multiple group analyses were conducted with sex as grouping variable. According to theoretical assumptions and preliminary analyses on empirical data, four nested models were compared: *model 1* with no invariance constraints (=all parameters can be distinct for both sexes), *model 2* with invariant structural weights between boys and girls (= regression weights in the path model are set to be equal for boys and girls), *model 3* assuming invariant intercepts between sexes (=intercept (means) for boys and girls are constrained to the same), and finally *model 4* with invariant structural weights plus invariant intercepts (means) between boys and girls in the sample which is the addition of the restrictions in models 2 and 3.

Table 3: Goodness of fit statistics for the multiple group (boys/girls) comparison for the interest in mathematics (models M1–M4).

Invariance constraints for both groups[a]	χ^2	df	χ^2/df	RMSEA	SRMR	CFI
M1: None (totally free)	24.887	16	1.555	.030	.010	.998
M2: Invariance of structural weights	39.083	35	1.117	.014	.022	.999
M3: Invariance of intercepts	133.219	25	5.329	.085	.044	.979
M4: Invariance of structural weights and intercepts	236.853	44	5.383	.085	.076	.963

Note: χ^2 = Chi-square; df = degrees of freedom; RMSEA = root mean square error of approximation;
SRMR = standardized root mean square residual;
CFI = comparative fit index.
[a] Parameters are constrained to be equal for both groups (boys/girls).

Table 4: Goodness of fit statistics for the multiple group (boys/girls) comparison for the interest in German (models G1–G4).

Invariance constraints for both groups[a]	χ^2	df	χ2/df	RMSEA	SRMR	CFI
G1: None (totally free)	31.666	16	1.979	.040	.012	.997
G2: Invariance of structural weights	42.734	35	1.221	.018	.025	.998
G3: Invariance of intercepts	134.655	25	5.386	.085	.051	.978
G4: Invariance of structural weights and intercepts	237.318	44	5.394	.085	.076	.961

Note: χ^2 = Chi-square; df = degrees of freedom; RMSEA = root mean square error of approximation;
SRMR = standardized root mean square residual;
CFI = comparative fit index.
[a] Parameters are constrained to be equal for both groups (boys/girls).

From theoretical assumptions and according to our descriptive data (see Table 1) model 2 is most likely because it accepts different levels of grades and interest scores but expects invariant regression weights for the paths of interest. To underpin this, all models were evaluated by common fit parameters (Hu & Bentler, 1998; Hu & Bentler, 1999). The four models are quite similar in mathematics and German. Model comparisons indicate the equality of an unconstrained model 1 and model 2 where structural weights are constrained to be equivalent for boys and girls. Thus, gender-specific paths are not evident and the more restricted model 2 is favored for mathematics as well as German. Goodness of fit indices for all alternative models are reported in Table 3 (mathematics interest) and Table 4 (German interest).

Descriptive data indicated differences in mean grades as well as mean interest levels of boys and girls (see Table 1). Thus, constrained models 3 and 4 were tested to show that an unconstrained model with free estimates of intercepts fits the data better in case of both subjects. Model 2 showed the most satisfactory fit indices as already assumed.

In summary, model comparison analyzing interest in mathematics indicates the equality of models 1 and 2 ($\Delta\chi^2$ = 14.196, df = 19, not significant), whereas models 3 and 4 differ significantly from model 1 (model 3: $\Delta\chi^2$ = 108.332, df = 9, $p \leq .01$; model 4: $\Delta\chi^2$ = 211.966, df = 28, $p \leq .01$) and consequently from model 2. Model comparison for analyzing interest in the subject German indicates the equality of model 1 and 2 ($\Delta\chi^2$ = 11.068, df = 19, not significant), whereas model 3 and 4 differ significantly from model 1 (model 3: $\Delta\chi^2$ = 102.989, df = 9, $p \leq .01$; model 4: $\Delta\chi^2$ = 205.652, df = 28, $p \leq .01$) and consequently from model 2.

For both subjects model 2 has to be preferred as it indicates that different levels of school grades and interest scores between both sexes are evident. The overall fit (see Tables 3 and 4) of model 2 (M2) regarding the interest in mathematics is satisfactory (χ^2 = 39.083, df = 35, not significant; RMSEA = .014; SRMR = .022; CFI = .999). Fit statistics of model 2 concerning German interest (G2) are convincing

(χ^2 = 42.734, df = 35, not significant; RMSEA = .018; SRMR = .025; CFI = .998) as well. The results of the path analyses will be discussed on the estimated coefficients of models M2 and G2. Standardized parameter estimates are displayed in Figs. 1 and 2.

For clarity purposes, covariances between grades in mathematics and German are not displayed in the model, neither at each measurement point nor across time. To give an impression of the highly correlated measures, Table 2 provides the observed correlation coefficients of the relevant variables at all measurement points T1 to T3. When those covariances are neglected, the model fit decreases considerably, but the path coefficients remain unaltered.

The estimates in model M2 can be described as follows: at the given significance level of .01, interest in mathematics (Fig. 1) can be predicted by the lagged grades in mathematics, whereas grades are not predicted by prior interests. Better grades in mathematics lead to higher interest in this subject. The paths from the grades in mathematics and German at T1a to the mathematics interest scores at T1b are both significant but with an opposite sign: whereas good grades in mathematics (low scores) covary with high mathematics interest scores, the effect of German is reverse (and lower in the amount): low grades in German (high scores) covary with high interest scores in mathematics. However, the significant paths from the first measure of both grades to the first measure of mathematics interest reflect a correlation pattern only because there is no preceding measure of interest. The two remaining significant paths from grades in mathematics to interest in mathematics represent subject-specific effects in the autoregressive model. Here, the effect of grades in mathematics to the subsequent measure of interest in the subject mathematics is significant in addition to the effects of prior interest levels, whereas – after controlling for prior grades – there is no significant effect of interests on grades. Finally, there is also one significant path from interest in mathematics at T1b to grades in German at T2a which has a positive sign. Higher interests in mathematics lead to lower grades in German.

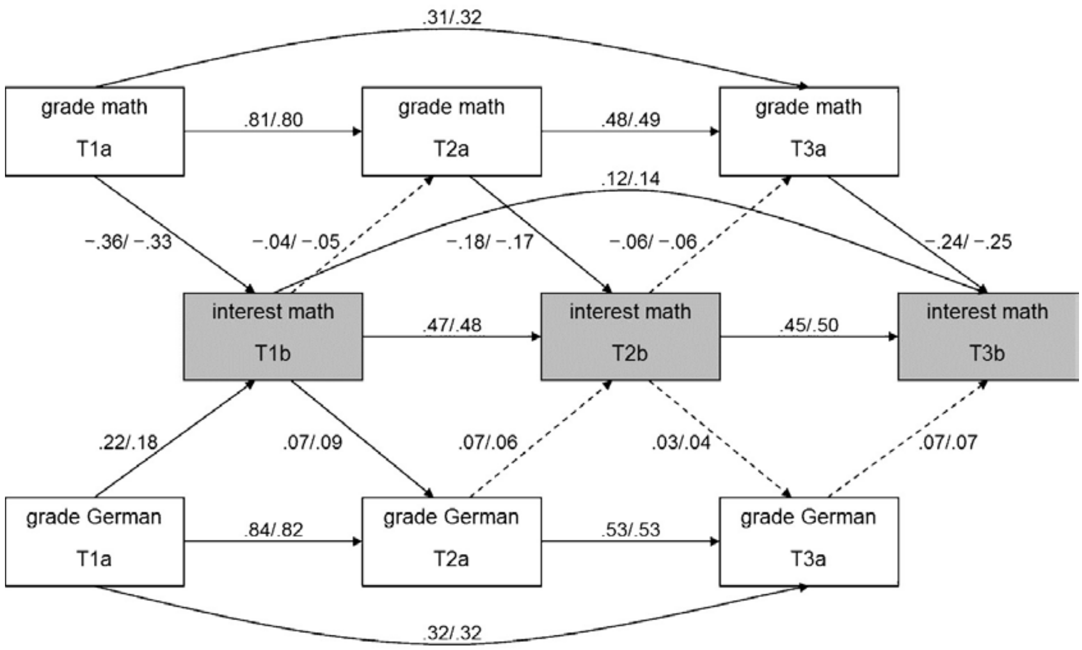

Fig. 1. Autoregressive cross-lagged panel model for interest in mathematics (model M2) with reciprocal effects of school grades in mathematics and German. Coefficients are standardized beta weights (boys/girls) with solid lines for effects significant at the significance level of .01 and broken lines for nonsignificant effects. The temporal order for all measures is referred to by the suffixes a and b added to the measurement points T1, T2 and T3. Estimates between mathematics and German grades are not shown.

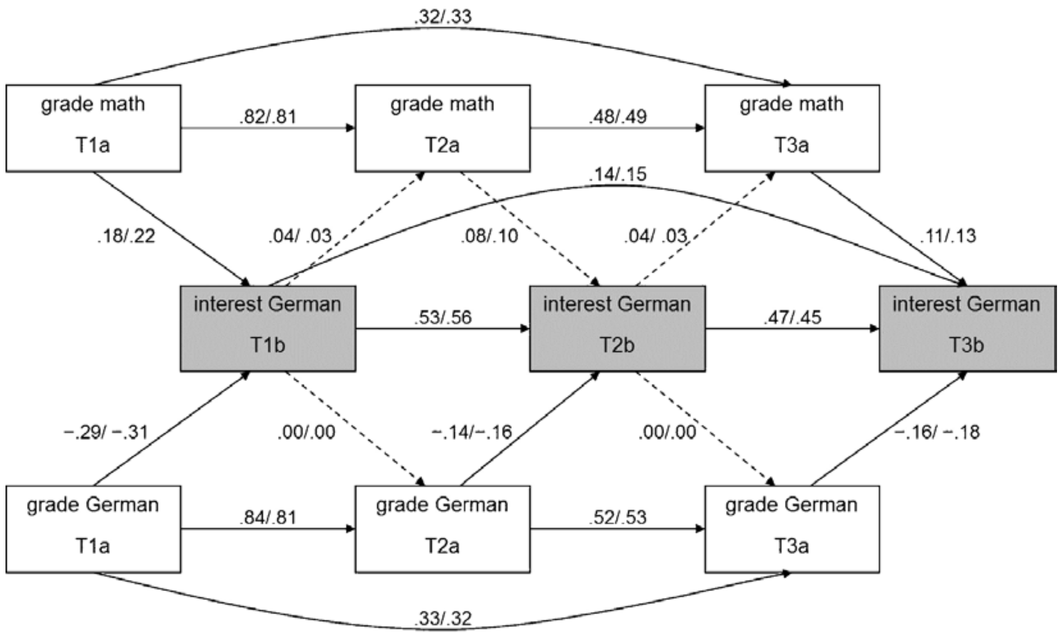

Fig. 2. Autoregressive cross-lagged panel model for interest in German (model G2) with reciprocal effects of school grades in mathematics and German. Coefficients are standardized beta weights (boys/girls) with solid lines for effects significant at the significance level of .01 and broken lines for nonsignificant effects. The temporal order for all measures is referred to by the suffixes a and b added to the measurement points T1, T2 and T3. Estimates between mathematics and German grades are not shown.

The model G2 in German duplicates the results in mathematics in nearly all aspects: interest in German (Fig. 2) can significantly be predicted by grades in German – again in addition to prior interest level. German interest instead does not predict grades. Contrary to model M2, German interests at T3b can additionally be predicted by prior grades in mathematics at T3a; the positive sign shows that bad grades in mathematics are predictive for higher subsequent interests in the German language (but the coefficient stays rather low).

For both models M2 and G2 it can be declared that the implementation of correlations between grades in German and mathematics over time as well as indirect paths from T1a to T3a do not change cross-lag paths but increase model fits considerably. Consequently, the interpretation of the results will be identical with or without those paths.

To summarize the results of the analyses conducted it can be retained that: first, grades show larger rank order stability over time than do interest scores in both subjects for both sexes. Grades in mathematics predict interests in mathematics and grades in German predict interests in German in the one year and a half period of time. The effects between the subjects are small and – if at all – they show a tendency to be regarded as contrast effects. Despite the huge sex effect on the grades and the level of interests in mathematics and German, the structural patterns are largely comparable for boys and girls.

4. Discussion

4.1. Summary and interpretation

Up to now there has been a lack of evidence regarding the order of effects of interests and grades in elementary school. Yet, especially this age is crucial for the manifestation and maintenance of future individual interests as well as for school careers in secondary school. The interplay between both measures from a longitudinal perspective is an important issue of educational research. Thus, the research aims of the present study were threefold.

First, we examined the relationship between subject-specific interests and grades of two different school subjects. Emerging from the literature review there is an inconsistent pattern concerning this interplay: the existence of a reciprocal relation of both measures is reported as well as unidirectional pathways. Therefore, we asked how interests and grades are associated. Second, we investigated how gender contributes to the relationship between interests and grades. It was assumed that gender indeed leads to different interest and grade levels but not to different path coefficients in the pattern between interest scores and grades. Third, we contrasted the relationship of interests and grades for two different school subjects (mathematics and German). This research aim concerned the question whether the relationship of interests and grades was subject-specific. We supposed larger path coefficients within one school subject compared to coefficients between subjects.

Our data confirmed a unidirectional association between interests and grades in elementary school age as it was found by Baumert et al. (1998). The relationship can be described as follows: within the teaching subjects mathematics and German, feedback in terms of grades is a significant predictor of subsequent subject-specific interests. The reverse path coefficients from interests to grades are lower and insignificant. Thus, grading in school determines future interest levels, but not vice versa. It is argued that the achievement feedback given by teachers' grades does enhance interests in younger ages. Even though interests have no direct effect on school achievement during elementary school, we cannot be sure in our study if and when a reversion of the trend from grades to interests in secondary school occurs – which would be in line with the model of interest development formulated by Hidi and Renninger (2006). Consequently, if interests can be developed in elementary school and early secondary school, this might be a powerful investment for achievement gains in high school and beyond. Only if this proves to be true, interests evidentially become a strong predictor of competence development (Marsh et al., 2005). Our results are of both theoretical and practical significance. The reason why the focus on interests and grades is so important is because many other predictors of school achievement (e.g., cognitive abilities or socioeconomics of the family) are hardly modifiable. Interests instead are comparatively easy to foster by curricular or instructional interventions. Beyond the mentioned positive aspects underlying a self-enhancement model of development the link between interests and grades (or other indicators of school achievement) should not only be treated as a positive relation, whereas good grades benefit the development of interests. Also, destructive effects of poor grades and negative feedback on interest development should be taken into consideration (see Dotterer et al., 2009).

The findings on gender differences are twofold. We found substantial differences between boys and girls with reference to their levels of interests and grading, but not to path coefficients. Considering our results, boys are more interested in mathematics than girls and have better grades. Girls show higher interest in German and have better grades in this subject. The path coefficients for boys and girls reflecting the relationship between interests and grades are similar in extent and direction. Thus, the investigated developmental processes seem to be equivalent for both sexes – at least in elementary school age. Our results strongly support the sex-invariant developmental model found, for example, by Köller et al. (2000), Marsh et al. (2005), and Marsh and Yeung (1998). A differential effect between sexes might only occur if longer time spans are considered – as done in the 9-year longitudinal study by Dotterer et al. (2009).

Our results revealed subject-specific effects between interests and grades in the two subjects under investigation. Interest in mathematics is promoted by grades in mathematics at every measurement point and interest for German as a subject are influenced by grades in German. In both subjects better grades (1 = best possible grade) are coincident with higher interest scores. By contrast, grades of the contrary domain have a lower impact on interests and path coefficients, moreover, always have an opposite algebraic sign. Contrast effects for highly different subjects were reported earlier; despite even one significant (but low) path estimate the contrast effects presented can be best described as tendency. These findings can be explained in light of the internal/external frame of reference model (Marsh, 1986), pointing to dimensional comparisons between two distinctly different school subjects. Further research is needed to clarify the causal relations between interests and grades, also by including more than two subjects – varying in their degree of similarity (see also the extended internal/external frame of reference model by Möller et al., 2011).

4.2. Strengths and limitations of the study

The present study has several important theoretical and methodological strengths. First, we investigated the common development of subject-specific interests and grades longitudinally of 1.199 students. Grades were assessed by teacher ratings a few months before interest scores were obtained. This design allows causal interpretations concerning the ordering of interests and grades. Second, our longitudinal study includes two quite distinct subjects which provide information about contrast effects in terms of interest development. Furthermore, our focus on elementary school age supports an understanding of the development of interest because most studies can be found within the secondary education sector. Additional questions are still unsolved and should be addressed in further studies. It is still unclear to what extent potentially moderating variables (e.g., academic self-concept) contribute to the relationship of interests and grades. Most available studies follow up self-concept and school achievement but do not include subject-specific interest scores. More elaborated research would help to understand the complex set of motivational and performance-based measures in school. The interplay between motivational variables, such as interests and school achievement, still needs further empirical research. The effects of prior grades on interests might be stronger than the effects of standardized tests on interests, because school grades are a more salient source of feedback than test scores. Therefore, it would be helpful to include both achievement indicators – grades and achievement test scores – in a longitudinal model simultaneously. In this context,observing various subjects simultaneously over longer time spans will be an ambitious but promising approach.

References

Baumert, J., & Köller, O. (1998). Interest research in secondary level II: An overview. In L. Hoffmann, A. Krapp, K. A. Renninger, & J. Baumert (Eds.), *Interest and learning. Proceedings of the Seeon conference on interest and gender* (pp. 241–256). Kiel: Institut für die Pädagogik der Naturwissenschaften.

Baumert, J., Roeder, P. M., Gruehn, S., Heyn, S., Köller, O., Rimmele, R., et al. (1996). Bildungsverläufe und psychosoziale Entwicklung im Jugendalter (BIJU). In K.-P. Treumann, G. Neubauer, R. Mü ller, & J. Abel (Eds.), *Methoden und Anwendungen empirischer pädagogischer Forschung* (pp. 170–180). Münster/New York: Waxmann.

Baumert, J., Schnabel, K., & Lehrke, M. (1998). Learning math in school: Does interest really matter? In L. Hoffmann, A. Krapp, K. A. Renninger, & J. Baumert (Eds.), *Interest and learning. Proceedings of the Seeon conference on interest and gender* (pp. 327–336). Kiel: Institut für die Pädagogik der Naturwissenschaften. Calsyn, R. J., & Kenny, D. A. (1977). Self-concept of ability and perceived evaluation of others: Cause or effect of academic achievement? *Journal of Educational Psychology, 69*, 136–145 http://dx.doi.org/10.1037/0022-0663.69.2.136

Dotterer, A. M., McHale, S. M., & Crouter, A. C. (2009). The development and correlates of academic interests from childhood through adolescence. *Journal of Educational Psychology, 101*, 509–519 http://dx.doi.org/10.1037/a0013987

Eccles, J., Wigfield, A., Harold, R. D., & Blumenfeld, P. (1993). Age and gender differences in children' self- and task perceptions during elementary school. *Child Development, 64*, 830–847.

Ganzeboom, H. B. G., Graaf, P. M. de, Treiman, D. J., & Leeuw, J. de (1992). A standard international socio-economic index of occupational status. *Social Science Research21(1-56.)* http://dx.doi.org/10.1016/0049-089X(92)90017-B

Geary, D. C. (1996). Sexual selection and sex differences in mathematical abilities. *Behavioral and Brain Sciences, 19*, 229–247 http://dx.doi.org/10.1016/1041-6080(95)90003-9

Gottfried, A. E., Fleming, J. S., & Gottfried, A. W. (2001). Continuity of academic intrinsic motivation from childhood through late adolescence: A longitudinal study. *Journal of Educational Psychology, 93*, 3–13 http://dx.doi.org/10.1037/0022-0663.93.1.3

Green, J., Nelson, G., Martin, A. J., & Marsh, H. W. (2006). The causal ordering of self-concept and academic motivation and its effect on academic achievement. *International Education Journal, 7*, 534–546.

Guay, F., Marsh, H. W., & Boivin, M. (2003). Academic self-concept and academic achievement: Developmental perspectives on their causal ordering. *Journal of Educational Psychology, 95*, 124–136 http://dx.doi.org/10.1037/0022-0663.95.1.124

Hidi, S., & Renninger, K. A. (2006). The four-phase model of interest development. *Educational Psychologist, 41*, 111–127 http://dx.doi.org/10.1207/ s15326985ep4102_4

Hosenfeld, I., Köller, O., & Baumert, J. (1999). Why sex differences in mathematics achievement disappear in German secondary schools: A reanalysis of the German TIMSS-data. *Studies in Educational Evaluation, 25*, 143–161 http://dx.doi.org/10.1016/S0191-491X(99)00018-8

Hu, L. T., & Bentler, P. M. (1998). Fit indices in covariance structure modeling: Sensitivity to underparameterized model misspecification. *Psychological Methods, 3*, 424–453 http://dx.doi.org/10.1037/1082-989X.3.4.424

Hu, L., & Bentler, P. M. (1999). Cutoff criteria for fit indexes in covariance structure analysis: Conventional criteria versus new alternatives. *Structural Equation Modeling, 6*, 1–55 http://dx.doi.org/10.1080/10705519909540118

Johnson, S. (1996). The contribution of large-scale assessment programmes to research on gender differences. *Educational Research and Evaluation, 2*, 25–49 http:// dx.doi.org/10.1080/1380361960020102

Köller, O. (1998). *Zielorientierungen und schulisches Lernen*. Münster: Waxmann.

Köller, O., Baumert, J., & Schnabel, K. (2001). Does interest matter? The relationship between academic interest and achievement in mathematics. *Journal for Research in Mathematics Education, 32*, 448–470.

Köller, O., Daniels, Z., Schnabel, K. U., & Baumert, J. (2000). Kurswahlen von Mädchen und Jungen im Fach Mathematik: Zur Rolle von fachspezifischem Selbstkonzept und Interesse. *Zeitschrift für Pädagogische Psychologie, 14*, 26–37 http://dx.doi.org/10.1024//1010-0652.14.1.26

Köller, O., & Klieme, E. (2000). Geschlechtsdifferenzen in den mathematisch-naturwissenschaftlichen Leistungen. In Baumert, J., Bos, W., & Lehmann, R. H. (Eds.) *Dritte internationale Mathematik- und Naturwissenschaftsstudie: Mathematische und naturwissenschaftliche Bildung am Ende der*

Schullaufbahn pp. 373–404). (Vol. II Opladen: Leske + Budrich.

Köller, O., Trautwein, U., Lüdtke, O., & Baumert, J. (2006). Zum Zusammenspiel von schulischer Leistung, Selbstkonzept und Interesse in der gymnasialen Oberstufe. *Zeitschrift für Pädagogische Psychologie, 20*, 27–39 http://dx.doi.org/10.1024/1010-0652.20.12.27

Krapp, A. (2000). Interest and human development during adolescence: An educational-psychological approach. In J. Heckhausen (Ed.), *Motivational psychology of human development* (pp. 109–128). London: Elsevier.

Kunter, M., Baumert, J., & Köller, O. (2007). Effective classroom management and the development of subject-related interest. *Learning and Instruction, 17*, 494–509 http://dx.doi.org/10.1016/j.learninstruc.2007.09.002

Lent, R. W., Brown, S. D., & Hackett, G. (1994). Toward a unifying social cognitive theory of career and academic interest, choice, and performance. *Journal of Vocational Behavior, 45*, 79–122 http://dx.doi.org/10.1006/jvbe.1994.1027

Lüdtke, O., Robitzsch, A., Trautwein, U., & Köller, O. (2007). Umgang mit fehlenden Werten in der psychologischen Forschung: Probleme und Lösungen. *Psychologische Rundschau, 58*, 103–117 http://dx.doi.org/10.1026/0033-3042.58.2.103

Marsh, H. W. (1986). Verbal and math self-concepts: An internal/external frame of reference model. *American Educational Research Journal, 23*, 129–149. Marsh, H. W. (1989). Sex differences in the development of verbal and mathematics constructs: The high school and beyond study. *American Educational Research Journal, 26*, 191–225.

Marsh, H. W. (1990). Causal ordering of academic self-concept and academic achievement: A multiwave, longitudinal panel analysis. *Journal of Educational Psychology, 82*, 646–656 http://dx.doi.org/10.1037/0022-0663.82.4.646

Marsh, H. W. (1993). Academic self-concept: Theory, measurement, and research. In J. Suls (Ed.), *Psychological perspectives on the self: Vol. 4. The self in social perspective* (pp. 59–98). Hillsdale, NJ: L. Erlbaum.

Marsh, H. W. (2003, November). *A reciprocal effects model of the causal ordering of academic self-concept and achievement.* Paper presented at NZARE AARE, New Zealand: Auckland. Retrieved from https://www.aare.edu.au/03pap/mar03755.pdf.

Marsh, H. W., Trautwein, U., Lüdtke, O., Köller, O., & Baumert, J. (2005). Academic self-concept, interest, grades, and standardized test scores: Reciprocal effects models of causal ordering. *Child Development, 76*, 397–416 http://dx.doi.org/10.1111/j.1467-8624.2005.00853.x

Marsh, H. W., & Yeung, A. S. (1997). Causal effects of academic self-concept on academic achievement: Structural equation models of longitudinal data. *Journal of Educational Psychology, 89*, 41–54 http://dx.doi.org/10.1037/0022-0663.89.1.41

Marsh, H. W., & Yeung, A. S. (1998). Longitudinal structural equation models of academic self-concept and achievement: Gender differences in the development of math and English constructs. *American Educational Research Journal, 35*, 705–738 http://dx.doi.org/10.3102/00028312035004705

Möller, J., Retelsdorf, J., Köller, O., & Marsh, H. W. (2011). The reciprocal I/E model: An integration of models of relations between academic achievement and self- concept. *American Educational Research Journal, 48*, 1315–1346.

Möller, J., Streblow, L., Pohlmann, B., & Köller, O. (2006). An extension to the internal/external frame of reference model to two verbal and numerical domains. *European Journal of Psychology of Education, 21*, 467–487 http://dx.doi.org/10.1007/BF03173515

Muthén , L. K., & Muthén , B. O. (1998–2012). *Mplus user's guide* (4th ed.). Los Angeles, CA: Muthén & Muthén

Pohlmann, B., Möller, J., & Streblow, L. (2006). Zur Bedeutung dimensionaler Aufwärts- und Abwärtsvergleiche. *Zeitschrift für Pädagogische Psychologie, 20*, 19–25 http://dx.doi.org/10.1024/1010-0652.20.12.19

Schiefele, U. (1998). Individual interest and learning– What we know and what we do not know. In L. Hoffmann, A. Krapp, K. A. Renninger, & J. Baumert (Eds.), *Interest and learning. Proceedings of the Seeon conference on interest and gender* (pp. 91–104). Kiel: Institut fü r die Pädagogik der Naturwissenschaften.

Schiefele, U., Krapp, A., & Winteler, A. (1992). Interest as a predictor of academic achievement: A meta-analysis of research. In K. A. Renninger, S. Hidi, & A. Krapp (Eds.), *The role of interest in learning and development* (pp. 183–212). Hillsdale, NJ: Erlbaum.

Schilling, S. R., Sparfeldt, J. R., & Rost, D. H. (2004). Wie generell ist das Modell? Analysen zum Geltungsbereich des Internal/External Frame of Reference-Modells. *Zeitschrift für Pädagogische Psychologie, 18*, 221–230 http://dx.doi.org/10.1024/1010-0652.18.34.221

Schilling, S. R., Sparfeldt, J. R., & Rost, D. H. (2006). Facetten schulischen Selbstkonzepts: Welchen Unterschied macht das Geschlecht? *Zeitschrift für Pädagogische Psychologie, 20*, 9–18 http://dx.doi.org/10.1024/1010-0652.20.12.9

Skaalvik, E. M., & Hagtvet, K. A. (1990). Academic achievement and self-concept: An analysis of causal predominance in a developmental perspective. *Journal of Personality and Social Psychology, 58*, 292–307 http://dx.doi.org/10.1037/0022-3514.58.2.292

Valentine, J. C., DuBois, D. L., & Cooper, H. (2004). The relation between self-beliefs and academic achievement: A meta-analytic review. *Educational Psychologist, 39*, 111–133 http://dx.doi.org/10.1207/s15326985ep3902_3

von Maurice, J., Artelt, C., Blossfeld, H.-P., Faust, G., Roßbach, H.-G., & Weinert, S. (2007). *Bildungsprozesse, Kompetenzentwicklung und Formation von Selektionsentscheidungen im Vor- und Grundschulalter: Überblick über die Erhebungen in den Längsschnitten BiKS-3-8 und BiKS-8-12 in den ersten beiden Projektjahren. PsyDok (Online)* 2007/1008. Retrieved from http://psydok.sulb.uni-saarland.de/volltexte/2007/1008/pdf/online_version.pdf.

Yoon, K. S., Eccles, J. S., & Wigfield, A. (1996, April). *Self-concept of ability, value, and academic achievement: A test of causal relations*. Paper presented at the annual meeting of the American Educational Research Association, New York. Retrieved from http://www.rcgd.isr.umich.edu/garp/articles/eccles96o.pdf.