RESEARCH LINE 2

THE DEVELOPMENT OF COMPETENCES IN SCHOOL AND THEIR IMPORTANCE FOR TRANSITIONS WITHIN THE EDUCATION SYSTEM

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Mathematics and science permeate almost every aspect of modern life. For example, in order to understand the complexity of modern economics or make informed decisions about medical treatments, people need a fundamental understanding of mathematics and science. Moreover, some of the most pressing problems humanity is facing (e.g., energy crisis, climate change, or population growth) require solutions informed by a deep understanding of the underlying mathematics and science. In order to prepare scientifically literate citizens and to ensure a sufficiently large number of future mathematicians and scientists, school students need to develop a knowledge organized around the core ideas of mathematics and science and they need to be able to use this knowledge to engage in the practices of mathematics (e.g., problem solving) or science (e.g., explaining phenomena). Building such competence requires a coherent effort across multiple years of schooling – in particular during phases of transition between different stages of formal schooling (research focus 1) and beyond formal schooling (research focus 2).

Development of student competence in mathematics and science

In order to support students in developing competence in mathematics and science throughout school, more must be known about the extent to which students already meet the competences expected at the end of certain grades or grade bands, reasons for why students might not meet the expectations, and what can be done in order to better support students in their learning. The overarching research questions in this research focus are therefore:

- What competences have students developed, and to what extent, at different stages of schooling?
- Which individual and institutional factors affect the development of students' competences across grades and grade bands?
- How can students be best supported in developing competences across grades and grade bands?

RESPONSIBLE FOR RESEARCH LINE 2:
Knut Neumann (spokesperson), Ute Harms, Gabriel Nagy & Ilka Parchmann

For both mathematics and science, there is a substantial body of research that shows how students often struggle to develop the competences envisioned by standards for elementary and middle school education. Research at IPN in the period from 2017 to 2018 has accordingly focused on obtaining further insights into the individual and institutional factors that affect the development of these competences and how students can be better supported in developing them. Little, however, is known so far about the extent to which the development of these competences is affected by students' individual prerequisites (i. e., prior knowledge or general cognitive abilities) and more importantly how students' progression in development can be optimized such that students achieve the level of competence in mathematics and science envisioned in the respective standards.

In mathematics, elementary school education plays a fundamental role for providing students basic mathematical skills, such as the arithmetic skills that serve as a basis for developing more elaborate mathematical skills in middle and high school. Elementary mathematics teachers in Germany follow to a large extent the structure given by the textbook they use. Some of the textbooks even go as far as providing teachers with specific tasks aligned with a specific trajectory in developing the envisioned arithmetic skills and subsequently knowledge about core ideas of mathematics such as numbers. In order to obtain a better understanding of the influence different textbooks have for the development of student competence in elementary mathematics education, a major emphasis in mathematics education research during the research period 2017 to 2018 was to examine the effect of different textbooks as a major institutional factor in the light of students' individual (learning) prerequisites and their teachers' qualification (selected findings from this research are presented in section 1).

Although students make first contact with science in elementary school, formal schooling in the science disciplines starts with middle school. The main goal of middle school science education is to develop a fundamental knowledge about the three disciplines (i. e., biology, chemistry, and physics) organized around the core ideas of each discipline and the skills to engage in core scientific practices using their knowledge to solve problems or explain phenomena. Research in the research period 2017 to 2018 at the IPN has focused on the most central disciplinary core ideas (e. g., evolution in biology, chemical reactions in chemistry, and matter in physics) as well as on energy as a concept cutting across the three disciplines. Based on past research that has shown that students do not develop the level of knowledge expected by standards, this research has primarily focused on identifying typical progressions and examining factors affecting these progressions.

In biology education, the idea of evolution through natural selection is probably the most central concept, and it is simultaneously one of the most difficult concepts for students to understand. In particular, the principle of natural selection appears to provide a major difficulty for students at all levels, including university education. A review of the literature suggests that this is the result of neglecting the role of more abstract ideas

evovis

Tibell, L. A., & Harms, U. (2017). Biological principles and threshold concepts for understanding natural selection. *Science & Education*, *26*(7–9), 953–973.

Fiedler, D., Tröbst, S., & Harms, U. (2017). University students' conceptual knowledge of randomness and probability in the contexts of evolution and mathematics. *CBE–Life Sciences Education, 16*(2), ar38.

such as randomness, probability, and different scales in space and time. As a consequence, the project Challenging Threshold Concepts in Life Science – Enhancing Understanding of Evolution by Visualization (EvoVis) has, amongst other things, focused on the role of these abstract ideas for developing knowledge about evolution. The findings suggest that students fail to draw on abstract ideas such as randomness or probability when solving problems which would be a substantial obstacle in their learning about evolution.

DoLiS
Development of Learning in Science

In chemistry education, little is currently known about how students progress in developing knowledge around the core chemistry ideas. In order to close this gap in the current research base, the project Development of Learning in Science (DoLiS) combined a cross-sectional and longitudinal design to identify typical trajectories of students' progression in developing the envisioned competence in chemistry (selected results from this project will be presented in Section 2).

Yao, J. X., Guo, Y. Y., & Neumann, K. (2017). Refining a learning progression of energy. *International Journal of Science Education, 39*(17), 2361–2381.

One interdisciplinary effort at the IPN examining how students develop competence in science during school, is the research on energy as a disciplinary core idea and concept cutting across all science disciplines. These efforts are based on a model initially developed in the discipline of physics that describes how students develop knowledge around energy as a core idea of physics and that has been further tested and refined in the past research period. Based on this model several disciplinary studies

have been carried out to identify factors affecting students' progression from different ways of representing energy transformations and transfers to fundamentally different approaches to teaching energy. In an interdisciplinary effort, the model has been used to examine students' progression in developing knowledge about energy in all three science disciplines. The findings suggest that while students progress in developing knowledge about energy as a disciplinary core idea there is no integration taking place whatsoever. That is, while students might be able to use their disciplinary knowledge about energy, they appear to fail in using their knowledge from one domain to solve problems in another (i. e., knowledge transfer).
Overall, research in this research focus has contributed to the development of models describing students' progression in developing knowledge around the most central core ideas of mathematics and science; and identified factors that can positively affect the development of such competence as a basis for improving mathematics and science instruction.

Wernecke, U., Schütte, K., Schwanewedel, J., & Harms, U. (2018). Enhancing conceptual knowledge of energy in biology with incorrect representations. *CBE–Life Sciences Education, 17*(1), ar5.

Opitz, S. T., Neumann, K., Bernholt, S., & Harms, U. (2017). Students' energy understanding across biology, chemistry, and physics contexts. *Research in Science Education*. Advance online publication.

The role of school mathematics and science competences for post-school learning

A second major focus of Research Line 2 is the development of students' competence in the transition from school into post-school stages of learning. Two major stages of post-school learning are vocational and university training. However, students are not only educated in school for working in the fields of science, technology, engineering or mathematics (STEM). Students are also supposed to be prepared for learning more about STEM-related issues in a world increasingly driven by scientific and technological advancement. Research in this area therefore focuses both on the transition from school into vocational training and university and on democratic participation. The respective overarching research questions are:

- What role do scientific and mathematical competences as well as further individual characteristics play in the transition from school to post-school education in particular for career decisions and future learning?
- What role do the scientific and mathematical competences developed in school play for a democratic participation of students as informed citizens?

The lack of a sufficiently literate STEM workforce poses a major problem for future economic development of our society. Thus, researchers at IPN in the years 2017–2018 continued their investigations of the transitions from middle school into vocational training in STEM related fields and from high school into STEM university education. This research is crucial in order to understand how more mathematically and scientifically literate students can be recruited for a STEM career and how the transition from school into STEM-related training can be facilitated.

The project Mathematics and Science Competences in Vocational Education and Training (ManKobE) has been started in 2012 as a multi-year multi-cohort project investigating the development of students' school competences, school-related competences and vocational competences in the transition from school into vocational training. The data collection has been completed in 2017. The analyses of the extensive data are ongoing and will extend beyond the present research period. Recently completed analyses indicate that students who opted for vocational training in STEM fields show, in general, higher levels of competence in mathematics and science than students at the end of middle school normally do and that students chose the STEM field they seek training in according to their individual strengths (i.e., the field in which they are the most competent).

MαnKobE
Mathematics and Science Competencies in Vocational Education and Training

Köller, O., Nagy, G., & Retelsdorf, J. (2017). Lernausgangslagen Auszubildender in Berufen mit hohen mathematisch-naturwissenschaftlichen Anforderungen [Initial achievement of trainees in vocations with high requirements in mathematics and science]. *Unterrichtswissenschaft*, *45*(1), 5–21.

Research in this focal area of Research Line 2 has also focused on the transition from high school into university. In order to pave the way for the investigation of the development of students' competence in mathematics and science from high school into university, the project Mathematical Prerequisites of STEM Freshmen – A Delphi-Study with University Instructors (MaLeMINT) investigated, which mathematics-related knowledge and skills university instructors expect from STEM freshmen. Based on a Delphi-study, this project led to a catalogue of 140 aspects representing the consensus of the expectations of nearly 1 000 university instructors about student competence in mathematics at the end of high school – as a prerequisite for studying a STEM-related field.

In addition to research focusing on the role of students' competences in mathematics and science developed in school for the transition into tertiary education, the IPN has also begun exploring how school-based competences (in particular, the knowledge about core ideas such as energy) shape students' lives (e.g., their attitudes about energy) in scope of its participation in the Leibniz Research Alliance Energy Transition.

MaLeMINT

Altogether, this focal area comprises a broad portfolio of research providing insights into the specific role of mathematics and science competences developed in school for future learning in tertiary education as well as democratic participation as an informed citizen.

On the following pages we present central findings from two projects: a study of textbook effects on students' achievement in mathematics and a bi-national study of the development of student competence and interest in chemistry.

1 A longitudinal study of textbook effects on students' mathematics achievement during primary school

Textbooks are a frequently-used curriculum material in everyday school practice, and it is commonly assumed that they have a substantial influence on the teaching style and the content covered in classrooms. The importance of textbook effects on teaching and student learning is emphasized by the growing body of research that is conducted in this area. There is evidence that teachers frequently use textbooks as the main basis for their instruction and that there is a relationship between textbook features and teaching practices. There are only few studies investigating the effect of textbooks on the development of student competence and those show inconsistent results. In several studies textbooks represent different curricula so that the variables "textbook" and "curriculum" are confounded when investigating the effects on student achievement. This study investigates the effects of mathematics textbooks on the development of students' competence in mathematics during primary school (Grades 1 to 3) using longitudinal data. We used data of a large sample collected in a three-year longitudinal design and the examined textbooks were representing the same curriculum.

Method

This study is a re-analysis of longitudinal data comprising student information including arithmetic skills from Grade 1 and 2 as well as the students' scores of a nationwide mathematics competence test at the end of Grade 3. The data stem from an evaluation of a mathematics support program for weak students in the regular mathematics classroom. In the evaluation two groups, in which teachers received additional teaching material for low-achieving students, are compared with a control group. The participation in the support program is independent of the textbooks the teachers used and we controlled for the participation in the support program by dummy coded variables in the analyses.

The sample comprises 93 classes with 1664 students from 40 schools from rural and urban regions in a federal state of Germany. All teachers have to follow the state-wide curriculum. A textbook series for Grades 1–4, which mirrors the curriculum, is selected by each school.

The four textbooks in our sample (denoted by A, B, C, D) show specific characteristics. Textbooks A and C adopt a traditional textbook format (i.e., one book) whereas B and D consist of a set of 4–7 booklets for each grade. For each grade, textbooks A, B, and C are comparable in their didactic approach: teachers have substantial freedom to use the presented tasks, explanations, and exercises offered in the textbook; no specific learning trajectory is prescribed for students. In contrast, textbook D prescribes a linear order of booklets and of the pages within each booklet for students' individual learning. The content is structured in small steps and each problem type is dedicated 1–2 pages for practicing; connections between mathematically related topics are hardly addressed.

Data about the textbooks used by teachers were collected through a teacher questionnaire along with information on the teachers' qualification. Student data were collected at the beginning of Grade 1 using established standardized tests which assessed students' general cognitive abilities, language skills, and numerical skills (Cronbach's $\alpha = .72–.95$). Students' competence at the end of Grades 1 and 2 was measured using an arithmetic test (EAP-PV reliability: .93–.94). Student abilities were estimated based on IRT models. For each student, five plausible values were generated by fitting a latent regression model using additional variables from the teacher and the parent questionnaire aggregated to orthogonal factors. Students' competence at the end of Grade 3 was assessed in terms of the correct number of answers on the content areas 'Numbers' and 'Patterns' of the national mathematics test obtained from schools.

We used multilevel random intercept models to analyze textbook effects. First, we computed models without predictors (null models) to estimate the partition of variance between and within classes. Second, we estimated models including individual characteristics (at individual level) and class composition (at class level). We included learning prerequisites on the individual level to account for the value added in the school period and to account for individual differences between students. For all three variables, we aggregated the individual scores to class means and included them on class level to control for class composition. In the third model, we controlled for teacher qualification and the support program. Therefore, the support programs and teacher qualification (studied mathematics or not) were included as dummy coded variables. In the fourth model, we included the textbook as dummy coded variables on the class level (textbook D was specified as reference category). Scores for the learning prerequisites as well as the mathematics competence were standardized. To account for missing data on the individual learning prerequisites we utilized the FIML procedure in *Mplus* (version 7). Due to sample selection, there was no missing data for textbook and support program.

Results

van den Ham, A.-K., & Heinze, A. (2018). Does the textbook matter? Longitudinal effects of textbook choice on primary school students' achievement in mathematics. *Studies in Educational Evaluation*, *59*, 133–140.

In the unconditional multilevel model, 14 % (Grade 1), 18 % (Grade 2) and 15 % respectively 16 % (Grade 3 Number/Pattern) of the variance in student competence was located on the class level. Regarding individual characteristics at school entrance cognitive abilities and basic numerical skills showed a significant effect on the competence in mathematics at the end of Grade 1, 2 and 3, whereas language skills had a significant effect only at the end of Grade 1. The individual learning prerequisites explained between 33.6 and 40.5 % of the variance within classes.

Regarding class composition, only the cognitive abilities in Grade 2 reached the level of statistical significance. Overall, the class composition explained between 7.1 % and 26.4 % of the variance between classes. Regarding learning environment characteristics, there was a significant influence of the support program 1 on the competence in mathematics at the end of Grade 1 which disappeared when the textbook choice was included in the model. At the end of Grade 2, both support programs showed only a significant effect after including the textbook choice into the model. The teacher qualification had no significant influence on the mathematics achievement in any grade. Altogether, the inclusion of the

learning environment variables led to a small increase of the explained variance in all grades (ΔR^2 between 3.2 % and 6.8 %).
When including the dummy variables for the textbook choice into the multilevel models (Table 1), the explained variance at class level increased substantially (Grade 1: $\Delta R^2 = 11.7\%$, Grade 2: $\Delta R^2 = 20.8\%$, Grade 3: $\Delta R^2 = 19.4\%$/ 23.3 %). It turned out that textbook D had a strong negative effect on student achievement in comparison to textbook C at the end of Grade 1. At the end of Grade 2 textbook D had a strong negative effect in comparison to textbooks A, B and C. Regarding the scores of the national test at the end of Grade 3 we saw a strong negative effect of textbook D in comparison with textbooks A and C. Comparing textbooks A, B and C, the Wald Test indicated that the effect of textbook B

Table 1. Multilevel regression for individual and classroom covariates and textbook on students' competence at the end of Grade 1, 2 and 3

	Grade 1	Grade 2	Grade 3	
			Numbers	Pattern
Within level				
Cognitive abilities	.29** (.03)	.35** (.04)	.37** (.04)	.43** (.04)
Basic numerical skills	.28** (.04)	.20** (.04)	.20** (.05)	.17** (.05)
Language skills	.14** (.03)	.06 (.03)	.09* (.04)	.06 (.04)
Between level				
Cognitive abilities (mean)	.12 (.11)	.30* (.15)	.03 (.19)	.25 (.15)
Numerical skills (mean)	.11 (.10)	.14 (.12)	.12 (.16)	.08 (.16)
Language skills (mean)	–.04 (.10)	–.09(.13)	.02 (.17)	.01 (.16)
Teacher qualification	–.09 (.06)	–.07 (.07)	.00 (.10)	.03 (.10)
Support program 1	–.10 (.07)	.15* (.07)	.01 (.10)	–.09 (.10)
Support program 2	–.05 (.08)	.25** (.09)	.14 (.11)	.00 (.11)
Textbook A	.16 (.10)	.43** (.10)	.48** (.13)	.41** (0.13)
Textbook B	.14 (.09)	.20* (.09)	.17 (.11)	.03 (.10)
Textbook C	.28** (.08)	.33** (.10)	.36** (.12)	.22* (.11)
Intercept	–.03 (.08)	–.31** (.08)	–.44** (.11)	–.28* (.11)
Explained within class variance (%)	40.5 %	33.6 %	33.8 %	34.6 %
Explained between class variance (%)	32.3 %	51.7 %	33.6 %	42.5 %

Note. Standard errors are in parentheses. Variables on individual level and the output variable are standardized, cognitive abilities, numerical and language skills on class level are arithmetic means. Support program 1 and 2 are dummy variables with reference category control group, textbook A-C are dummy variables with reference category textbook D.
** $p < .01$. * $p < .05$.

differed significantly from the effect of textbook A at the end of Grade 2 and 3. Choosing textbook B as reference category in the multilevel model, we saw a significant negative effect of textbook B in comparison to textbook A (effect size Grade 2: .23, Grade 3: numbers .31/ pattern .38).

Discussion

The results of this study show a substantial effect of mathematics textbooks on students' competence in mathematics. The textbooks in our sample differ strongly in their didactic approach. In particular, textbook D, which focuses on a specific learning trajectory and highly individualized learning activities, seems to have a substantial negative impact on students' achievement. Since textbooks have an effect on teaching practice, it might happen that students use textbook D mostly individually so that they do not get sufficient feedback to overcome their misconceptions. These results bring into question whether textbook D provides adequate learning opportunities for the students. Like textbook D, textbook B is structured in different booklets (although with a different didactic approach). Since textbook B also shows a significant negative effect on student achievement in comparison to textbook A, this could imply that this booklet structure does provide inferior learning opportunities.

IPN RESEARCH GROUP // Ann-Katrin van den Ham, Aiso Heinze, Henning Sievert

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COOPERATION // Ministry of Education, Science and Cultural Affairs of the Land Schleswig-Holstein (IQSH)

HOMEPAGE // www.ipn.uni-kiel.de/de/das-ipn/abteilungen/didaktik-der-mathematik/forschung-und-projekte/mathe-macht-stark-grundschule

2 The interplay between conceptual understanding and interest in secondary school chemistry

Chemistry is a subject that is highly relevant in everyday life and aligns with many career opportunities. Research, however, has shown that substantial percentages of students lack competence in chemistry. In addition, low student interest and little perceived relevance of chemistry have been reported. However, little is known about the development of students' competence in chemistry on longer timescales and the interplay between the development of competence in chemistry and students' chemistry-related interest in the course of secondary school as well as the factors affecting this development. The project Development of Learning in Science (DoLiS) aimed, among other things, to address this research gap by examining the development and relationship between students' competence in terms of three core ideas of chemistry (i. e., chemical reaction, energy and matter) and students' interest in chemistry from Grades 5 to 12.

Method

The DoLiS project is a bi-national study carried out in Germany and Sweden (Figure 1). The DoLiS project combined a cross-sectional and a longitudinal design in order to obtain insights into the development of student competence and interest in chemistry. The analyses presented here focus on the German cohort and the first three points of measurement: In 2015, students in Grades 5 to 12 from seven different schools in Schleswig-Holstein were sampled to participate in the study. Students in Grades 5 and 9 were then followed up in three annual waves from 2016 to 2018. A total number of 3578 students participated in the study. A notable feature of the DoLiS study is that all of the tests were administered to all students, no matter whether they dropped out from chemistry courses in higher grades or not.

Students took tests assessing their general cognitive skills as well as their knowledge about three disciplinary core ideas of chemistry: chemical reaction, energy, and matter. The test construction followed a common item anchor design with both grade-specific items as well as anchor items to link the results from students in different grades. Students also completed an extensive questionnaire on their personal characteristics such as their interest and their perception of different classroom characteristics. Students' interest was measured by 28 items in seven dimensions of school science activities based on the RIASEC+N model which distinguishes between students' interest in realistic (performing given lab experiments), investigative (solving theoretical problems), artistic (em-

Grade	Cross-sectional study	Longitudinal study		
	2015	2016	2017	2018
12	126			**151**
11	514		**402**	
10	332	**527**		
9	**555**			
8	309			**288**
7	299		**414**	
6	374	**524**		
5	**614**			
Total	3123	1051	816	439

Figure 1. Design and sample composition of the DoLiS project.

phasizing linguistical and visual aspects), social (explaining something to classmates), enterprising (managing group works), conventional (organize the chemicals storage), and networking (debating with classmates) school science activities. The instrument's focus on activities within the process of doing science intends to provide a basis for comparing students' interests across longer time periods, as topics and contexts differ substantially across grades.

Students' test data from the cross-sectional study were analyzed using item response theory (IRT) in order to account for the matrix design of the test. Based on a one-dimensional multi-group generalized partial credit model (MG-GPCM), with students' grade (from 5 to 12) as grouping variable, weighted likelihood estimates (WLE) representing students' knowledge about the disciplinary core ideas of chemistry were extracted for further analysis (WLE reliability: .78). Estimates of the different measurement waves were linked based on a generalization of log-mean-mean linking in accordance with Haberman (2009).

To examine construct validity of the RIASEC+N model, confirmatory factor analysis (CFA) models with a maximum likelihood estimator were estimated, indicating a good fit to the data (χ^2 = 1458.187, p < .001, df = 67, CFI = .938, TLI = .922, RMSEA = .058, SRMR = .047). After deleting one item per dimension, the investigation of internal consistency as an estimate of reliability for all latent variables showed acceptable to excellent Cronbach's alpha values (α = .67–.87). In addition, measurement invariance was tested to ensure that the items measure the same theoretical construct across all grades and measurement waves.

Results

Students' knowledge about the three disciplinary core ideas of chemistry – chemical reactions, matter and energy – was found to increase from Grade 6 to 12, with large effect sizes for the grade transition from Grade 6 to 7 (Cohen's $d = 0.84$), a middle-sized effect for the transition from Grade 8 to 9 ($d = 0.73$) and small effects from Grade 7 to 8 ($d = 0.43$), Grade 9 to 10 ($d = 0.35$) and Grade 10 to 11 ($d = 0.19$). Students' interest in school science activities, on the contrary, followed the pattern known from many studies, declining from grade to grade with a substantial drop in all seven dimensions about every two years ($d = [0.05, 0.32]$).
With regard to the interplay between students' knowledge about core chemistry ideas and interest in school science activities across grades, latent correlations between students' knowledge and interest were found to increase with grade. However, the correlations differ substantially across interest dimensions and grades, revealing two major patterns (Figure 2). First, students' interests in realistic, artistic, and conventional activities show only weak correlations to students' conceptual understanding, while, second, the correlations between students' knowledge and students' interests in investigative, social, enterprising, and networking activities increases from lower to higher grades.

Höft, L., Bernholt, S., Blankenburg, J., & Winberg, M. (2018). Knowing more about things you care less about: Cross-sectional analysis of the opposing trend and interplay between conceptual understanding and interest in secondary school chemistry. *Journal of Research in Science Teaching*. Advance online publication.

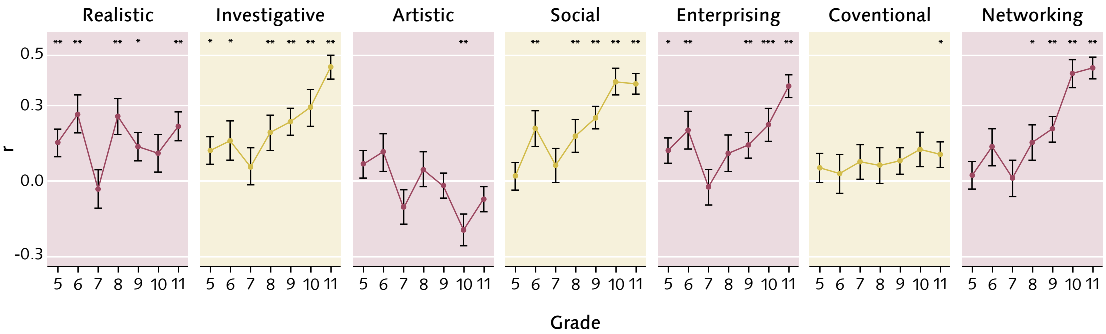

Figure 2. Latent correlations between students' knowledge (WLE parameter of the MG-GPCM) and students' interest in school science activities according to the RIASEC+N model (MIMIC approach). Correlation coefficients were tested to be significantly different from 0 (* $p < .05$. ** $p < .01$. *** $p < .001$).

These findings are largely confirmed by the analysis of the longitudinal cohort. Here, we applied bivariate latent cross-lagged models (CLM) to analyze the interplay between interest in a specific school science activity and conceptual understanding for students transitioning from Grade 9 to 11, controlling for gender differences, age and general intelligence. The fit indices (CFI > .936, TLI > .911, RMSEA < .037, SRMR < .061) provided support for the CLMs for all seven dimensions of students' interest in school science activities (Figure 3).

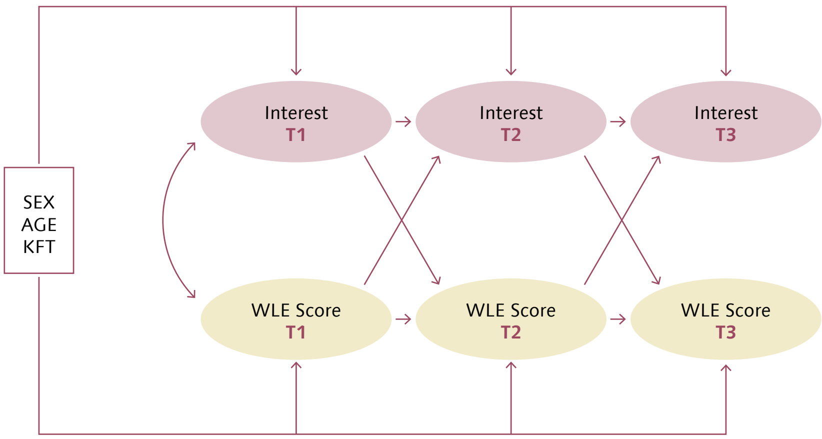

Figure 3. Bivariate cross-lagged model used to analyze the relation between students' interest in school science activities and their knowledge about core chemistry ideas (WLE), while controlling for students' sex, age, and general cognitive abilities (KFT).

Both the interest variables and students' knowledge were considerably stable over time, as indicated by moderate to high autoregressive effects for these variables (β = [.44, .66], p < .01). Moreover, there were significant positive correlations between interest and knowledge (r = [.13, .31], p < .05) at Grade 9 (T1), except for the artistic and conventional activities. With regard to cross-lagged effects between interest and knowledge, meaningful patterns of significant cross-paths emerged only for the investigative and the networking dimensions, i. e., three out of four cross-paths were significant for these two dimensions, indicating a reciprocal relationship between students' knowledge and their interest only in these two dimensions. No or only single cross-paths were significant for the other dimensions of students' interest in school science activities.

Discussion

Overall, the results of both the cross-sectional as well as the longitudinal analysis indicate a general increase in students' knowledge about core chemistry ideas and a decline in students' interest for all school science activities across grades. Despite these opposing trends, the interplay between students' knowledge and interest differs across the seven dimensions. In the cross-sectional analysis, small- to middle-sized positive relations, increasing from Grade 7 to 12, were found between students' knowledge and their interest in investigative, social, enterprising, and networking activities. When contrasting these findings to the results of the longitudinal data from students transitioning from Grade 9 to 11, the interplay between knowledge and interest seems to be even more restricted. Here, we only observed systematic cross-lagged relations between students' interest in investigative and networking school science activities and their knowledge, but no meaningful connections for students' interests in social and enterprising activities to their knowledge about core chemistry ideas.

To our perception, the investigative and networking dimensions of the RIASEC+N model reflect activities that seem to be associated with cognitive activation (e. g., involving cognitive conflict or problem-solving) and the application of knowledge. Activities associated with the communication of knowledge (i. e., the social and enterprising dimensions) showed substantial correlations to knowledge in higher grades as well. However, these activities that emphasize group work characterized by expert-novice relations between the students seem to play a minor role with regard to the reciprocal relation on the individual level. Hence, students' interests in scientific activities that are cognitively demanding drives knowledge development. Simultaneously, knowledge contributes to interest development in these kinds of activities. Consequently, investigative and networking activities could represent convenient starting points for fostering both students' knowledge and interest.

Bernholt, S., & Höft, L. I. (2017). Wahlmotive beim Übergang in die Profiloberstufe: Gemeinsamkeiten und Unterschiede zwischen den Profilbereichen [Choice motives at the transition to upper secondary profiles]. *Schulmanagement, 2017*(6), 29–32.

Future analyses will also cover the fourth measurement point which was collected in 2018. In addition, other constructs like students' epistemic beliefs, motivation, and classroom perceptions will be included. Besides developmental patterns across grades, a central goal is to better understand students' decision processes for choosing or dropping out from chemistry when transitioning to upper secondary school.

Finally, findings from Germany and Sweden will be contrasted in order to further identify similarities and differences between both countries. Furthermore, the close cooperation to the participating schools in this study is currently leading to a follow-up project. Here, results from the DoLiS project are used as a starting point to develop teaching materials and strategies in order to foster interest and learning in chemistry in school.

IPN RESEARCH GROUP // Andrea Bernholt, Sascha Bernholt, Sabrina Bruns, Lars Höft, Ilka Parchmann

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HOMEPAGE // www.ipn.uni-kiel.de/en/research/projects/dolis

Perspectives for Research Line 2

In the future, work in Research Line 2 will continue to explore the factors affecting the development of student competence in mathematics and science in school and the role these competences play for their learning beyond school. In addition to research focusing on further refinement of the developed models of student competence and research on optimization of students' learning trajectories based on these models, a major aim of this research line is further transfer of existing results into practice and continued research into how students can be best supported in developing the level of competence in mathematics and science envisioned in the standards. One way existing research results will be transferred is through further research on understanding the role of mathematics textbooks in relation to teachers' professional competence (in close collaboration with Research Line 3). Future work in the area of competence development includes research on students' learning about energy as a disciplinary core idea and cross-cutting concept. One planned project in this area aims to explore the extent to which curricular units organized around students' developing understanding of energy as a disciplinary core idea in physics will support a coherent, cumulative development of competence in science. Another major effort involves sharing developed instructional and curricular material through an open educational resources (OER) platform through which teachers from across Germany can access these materials and adopt and adapt them for their own instruction.

To continue investigating the role of students' competence in mathematics and science for future learning in and beyond school, we plan a project to examine the role of the competence in mathematics (in particular students' mathematical skills) and science (in particular students' knowledge about the core ideas of science) for students' choice of a profile in upper secondary level (i. e., high school) and their continued learning in upper secondary level up to the freshman year at university. We also plan further analyses of the extensive ManKobE data set, in particular of the factors predicting students' development of professional competence in their respective vocational fields. Finally, we plan to expand the research on the role of students' competence in mathematics and science for understanding and making informed decisions about mathematics- and science-related issues in their everyday lives.

Projects in Research Line 2:

Project // Homepage	**Conditions for successful tutoring: A reanalysis of LAU and KESS data (GeliNU) // www.ipn.uni-kiel.de/en/research/projects/gelinu/**
Funded by	German Research Foundation (DFG)
Term	2017 – 2019
Departments involved	Educational Research and Educational Psychology
Staff (IPN)	Karin Guill, Olaf Köller, Melike Ömeroğulları
Cooperation partners	

Project	**Physics instruction based on core concepts: Cumulatively building competence in physics using the energy concept (energy_transfer)**
Funded by	German Research Foundation (DFG)
Term	2018 – 2021
Departments involved	Physics Education
Staff (IPN)	Julian A. Fischer, Daniel Laumann, Knut Neumann, Jeffrey Nordine
Cooperation partners	Gottfried Wilhelm Leibniz University of Hannover // University of Duisburg-Essen // Westermann Gruppe

Project // Homepage	**Using eye movement modeling examples as an instructional tool in organic chemistry (EYE-OC) // www.ipn.uni-kiel.de/en/research/projectlist/eye-oc**
Funded by	German Research Foundation (DFG)
Term	2017 – 2020
Departments involved	Chemistry Education
Staff (IPN)	Sascha Bernholt, Marc Rodemer
Cooperation partners	Justus Liebig University Gießen // University of Northern Colorado

Project // Homepage	**Challenging threshold concepts in life science – Enhancing understanding of evolution by visualization (EvoVis) // www.ipn.uni-kiel.de/en/research/projects/evovis**
Funded by	The Swedish Research Council (Vetenskapsrådet)
Term	2013 – ongoing
Departments involved	Biology Education
Staff (IPN)	Daniela Fiedler, Ute Harms
Cooperation partners	University of Linköping

Project // Homepage	**Development of learning in science (DoLiS) // www.ipn.uni-kiel.de/en/research/projects/dolis**
Funded by	The Swedish Research Council (Vetenskapsrådet)
Term	2014 – 2017
Departments involved	Chemistry Education, Educational Research and Educational Psychology
Staff (IPN)	Andrea Bernholt, Sascha Bernholt, Sabrina Bruns, Lars Höft, Ilka Parchmann
Cooperation partners	Department of Science and Mathematics Education (Umeå University)

Project // Homepage	**Exploring learning in various approaches to teaching energy (ELeVATE) // www.ipn.uni-kiel.de/en/the-ipn/departments/physics-education/projects/elevate**
Funded by	National Science Foundation
Term	2014 – 2019
Departments involved	Physics Education
Staff (IPN)	Marcus Kubsch, Knut Neumann, Jeffrey Nordine
Cooperation partners	Michigan State University // Weizmann Institute of Science

Project // Homepage	**Fostering knowledge about energy in biological, interdisciplinary, and social contexts (EnergyBio) // www.ipn.uni-kiel.de/en/research/projects/energybio**
Funded by	Leibniz Association, German Federal Environmental Foundation (DBU)
Term	2012 – ongoing
Departments involved	Biology Education
Staff (IPN)	Ute Harms, Hanno Michel, Dirk Mittenzwei, Sebastian Opitz, Ulrike Wernecke
Cooperation partners	Förderverein Klimakommune Saerbeck e.V. // Leibniz Research Alliance "Energy Transition"

Project // Homepage	**Mathematics and science competences in vocational education and training (ManKobE) //** **www.ipn.uni-kiel.de/de/forschung/projekte/mankobe**
Funded by	Leibniz Association
Term	2012 – 2017
Departments involved	Biology Education, Chemistry Education, Educational Measurement, Educational Research and Educational Psychology, Mathematics Education, Physics Education
Staff (IPN)	Sascha Bernholt, Julian Etzel, Ute Harms, Aiso Heinze, Robert von Hering, Olaf Köller, Gabriel Nagy, Knut Neumann, Ilka Parchmann
Cooperation partners	Institute for Educational Quality Improvement, Berlin // University of Duisburg-Essen // University of Stuttgart // University of Wuppertal

Project // Homepage	**College for interdisciplinary educational research (CIDER) // www.ciderweb.org**
Funded by	Federal Ministry of Education and Research (BMBF), Jacobs Foundation, Leibniz Association
Term	2016 – 2019
Departments involved	Educational Research and Educational Psychology
Staff (IPN)	Olaf Köller, Janina Roloff-Bruchmann
Cooperation partners	Berlin Social Science Center, WZB // Centre for European Economic Research, ZEW // German Institute for Economic Research, DIW Berlin // German Institute for International Educational Research, DIPF // Leibniz Education Research Network, LERN // Leibniz Institute for the Social Science, GESIS

Project // Homepage	**Perspectives on the labor market with science and mathematics // www.panama-project.eu**
Funded by	EU / Interreg 5a
Term	2015 – 2019
Departments involved	Chemistry Education, Mathematics Education
Staff (IPN)	Aiso Heinze, Stefanie Herzog, Anke Lindmeier, Frank Lüthjohann, Birte Niebuhr, Marc Wilken
Cooperation partners	Syddansk University Odense

Project	**The soilbox**
Funded by	The Ministry for Energy Transition, Agriculture, Environment, Nature and Digitalization (MELUND) in the Framework of the European Innovation Partnership Schleswig-Holstein (EIP)
Term	2018 – 2021
Departments involved	Biology Education
Staff (IPN)	Marc Eckhardt, Ute Harms
Cooperation partners	Maschinenring Dithmarschen // University of Applied Sciences Kiel

Project // Homepage	**Berlin study (BERLIN) // www.ipn.uni-kiel.de/en/research/projects/berlin-survey**
Funded by	Jacobs Foundation
Term	2014 – 2018
Departments involved	Educational Research and Educational Psychology
Staff (IPN)	Olaf Köller, Michael Leucht, Gabriel Nagy
Cooperation partners	German Institute for International Educational Research, DIPF // Max Planck Institute for Human Development

Project // Homepage	**Knowledge and decision making on animal research (TUBE) //** **www.ipn.uni-kiel.de/en/research/projects/tube**
Funded by	Joachim Herz Foundation
Term	2017 – ongoing
Departments involved	Biology Education
Staff (IPN)	Carola Garrecht, Ute Harms
Cooperation partners	Understanding Animal research – A Science Information Initiative

Project // Homepage	**Mathematical learning prerequisites for the STEM studies – A delphi study (MaLeMINT) //** **www.ipn.uni-kiel.de/de/das-ipn/abteilungen/didaktik-der-mathematik/forschung-undprojekte/malemint**
Funded by	Deutsche Telekom Stiftung
Term	2015 – ongoing
Departments involved	Mathematics Education
Staff (IPN)	Aiso Heinze, Irene Neumann, Christoph Pigge
Cooperation partners	

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Project	**Learning Processes, Educational Careers, and Psychosocial Development in Adolescence and Young Adulthood Study (BIJU)**
Funded by	Max Planck Institute for Human Development (MPI), German Institute for International Educational Research (DIPF)
Term	1991–2019
Departments involved	Educational Research and Educational Psychology
Staff (IPN)	Olaf Köller
Cooperation partners	German Institute for International Educational Research, DIPF // Hamburg University // Max Planck Institute for Human Development

Project // Homepage	**Research group on "individual developmental trajectories and institutional contexts across the lifespan" // www.dipf.de/en/research/current-projects/individual-developmental-trajectories-and-institutional-contexts-across-the-lifespan**
Funded by	German Institute for International Educational Research (DIPF)
Term	2016–2021
Departments involved	Educational Research and Educational Psychology
Staff (IPN)	Olaf Köller
Cooperation partners	German Institute for International Educational Research, DIPF

Project // Homepage	**Assessment of learners' views about scientific inquiry – Germany (VASI-G) // www.ipn.uni-kiel.de/en/research/projects/vasi**
Funded by	
Term	2015–ongoing
Departments involved	Biology Education, Mathematics Education, Physics Education
Staff (IPN)	Kerstin Kremer, Irene Neumann, Frauke Voitle
Cooperation partners	Illinois Institute of Technology)

Project // Homepage	**Evaluation of the mathematics primary school support program (MMS Primary School) // www.ipn.uni-kiel.de/en/the-ipn/departments/mathematics-education/forschung-und-projekte/mms-primary-school**
Funded by	
Term	2013–ongoing
Departments involved	Mathematics Education
Staff (IPN)	Ann-Katrin van den Ham, Aiso Heinze, Henning Sievert
Cooperation partners	Institute for Quality Development at Schools in Schleswig-Holstein (IQSH)

Project	**Fields in energy learning in the lower secondary level (FiEldS)**
Funded by	
Term	2018–ongoing
Departments involved	Physics Education
Staff (IPN)	Kristin Fiedler, Knut Neumann, Jeffrey Nordine
Cooperation partners	Weizman Institute of Science

Project // Homepage	**Learning with multiple representations (LeMuR) // www.ipn.uni-kiel.de/en/research/projects/lemur**
Funded by	
Term	2015–ongoing
Departments involved	Biology Education, Educational Research and Educational Psychology
Staff (IPN)	Lara Magnus, Kerstin Schütte
Cooperation partners	Humboldt-Universität zu Berlin

Project // Homepage	**Nature of science and physics learning // www.ipn.uni-kiel.de/de/das-ipn/abteilungen/didaktik-der-physik/projekte/nature-of-science-und-physiklernen**
Funded by	
Term	2014–2018
Departments involved	Physics Education
Staff (IPN)	Hanno Michel, Irene Neumann
Cooperation partners	Universiy of Cyprus

Project // Homepage	**Primary school students' competence in length estimation: exploring the intercultural validity of an estimation competence model by contrasting the educational systems of taiwan and germany (TAIGER) //** **www.ipn.uni-kiel.de/de/das-ipn/abteilungen/didaktik-der-mathematik/forschung-und-projekte/taiger**
Funded by	
Term	2016 – ongoing
Departments involved	Mathematics Education
Staff (IPN)	Aiso Heinze, Jessica Hoth
Cooperation partners	University of Lüneburg // University of Taipei

Project // Homepage	**Sustainability-oriented consumer intention in adolescents (NOKIJ) //** **www.ipn.uni-kiel.de/en/research/projectlist/nokij**
Funded by	
Term	2016 – ongoing
Departments involved	Biology Education
Staff (IPN)	Deidre Bauer, Kerstin Kremer
Cooperation partners	University of Applied Sciences of North-West Switzerland