DEPARTMENT OF BIOLOGY EDUCATION

The Department of Biology Education at the IPN conducts empirical research on teaching and learning biology in school and in out-of-school settings over the lifespan. Most projects can be related to four core research foci. The first focus deals with conceptual and inquiry learning in school biology (cf. Research Line 2), with particular emphasis on evolution (EvoVis) and energy (EnergyBio). The studies focus on conditions and instructional strategies that support students in learning these highly abstract and complex concepts. Furthermore, the department investigates conceptual understanding and non-cognitive student's characteristics as predictors of learning in the context of sustainable development (NOKIJ, EnergyBio). A further area of work in this focus pertains to epistemology. Essential components for this area include students' learning progressions in inquiry during their school career (VASI) and the role of epistemic beliefs.

The department's second research focus is on teacher professionalization (cf. Research Line 3). In cooperation with other IPN departments prospective biology teachers' development is investigated in a longitudinal design (KeiLa). Of particular research interest is the development of procedural pedagogical content knowledge in biology teacher education. A simulated classroom for teaching evolutionary biology is designed, tested, and applied for intervention studies (ProSim).

Research foci three and four go beyond formal school education focusing on students' competitions in biology and science communication in the life sciences (cf. Research Line 4). Focus three addresses questions concerning the validity of the instruments used to assess students' accomplishments in the International Biology Olympiad (IBO; IBOint), and how participation in the IBO affects participants' interest in biology and science (WinnerS). The science communication projects in focus four concentrate on the biodiversity concept (KiSOC, Wtimpact) as well as on health and medical topics (KiSOC, CRC 1182).

Finally, the life:lab of the Kieler Forschungswerkstatt provides a considerable amount of service and support for schools.

Benninghaus, J. C., Kremer, K., & Sprenger, S. (2018). Assessing high-school students' conceptions of global water consumption and sustainability. *International Research in Geographical and Environmental Education, 27*(3), *250–266.*

Harms, U., & Bertsch, U. (2018). Energy, photosynthesis, and respiration. In K. Kampourakis, & M. Reiss (Eds.), *Teaching biology in schools. Global research, issues, and trends* (pp. 139–152). London: Routledge.

Wernecke, U., Schwanewedel, J., & Harms, U. (2018). Metaphors describing energy transfer through ecosystems: Helpful or misleading? *Science Education, 102*(1), 178–194.

DEPARTMENT OF CHEMISTRY EDUCATION

The department of chemistry education at IPN combines empirical research with the development of educational practice. Foci have been set on student learning, both in school and in out-of-school learning environments, and on teacher professionalization. A new perspective has been added by the Kiel Science Outreach Campus (KISOC), focusing on science communication and communicators and interfacing with science education. All levels from preschool up to tertiary education are addressed.

On the preschool level and in Research Line 1, influences of learning environments on basic science knowledge and interests are investigated. At the same time we analyze professional competences of pre-school teachers and their relation to children's learning.

The longitudinal study of the project DoLiS has become the backbone of the departmental work in Research Line 2. Investigating students' progression with regard to conceptual understanding and interest has been combined with analyses on their choices and further learning processes in professional environments (cf. projects ManKobE, PANaMa) and on university level (cf. project EYE-OC). Qualitative observations and interviews currently provide a deeper foundation for further teacher training measures, e.g. by better understanding effects of contexts on motivation. Media are incorporated both as analytical and as learning tools, such as tablets, eye-tracking, and combinations of hands-on experiments and simulations, and form a link to Research Line 4.

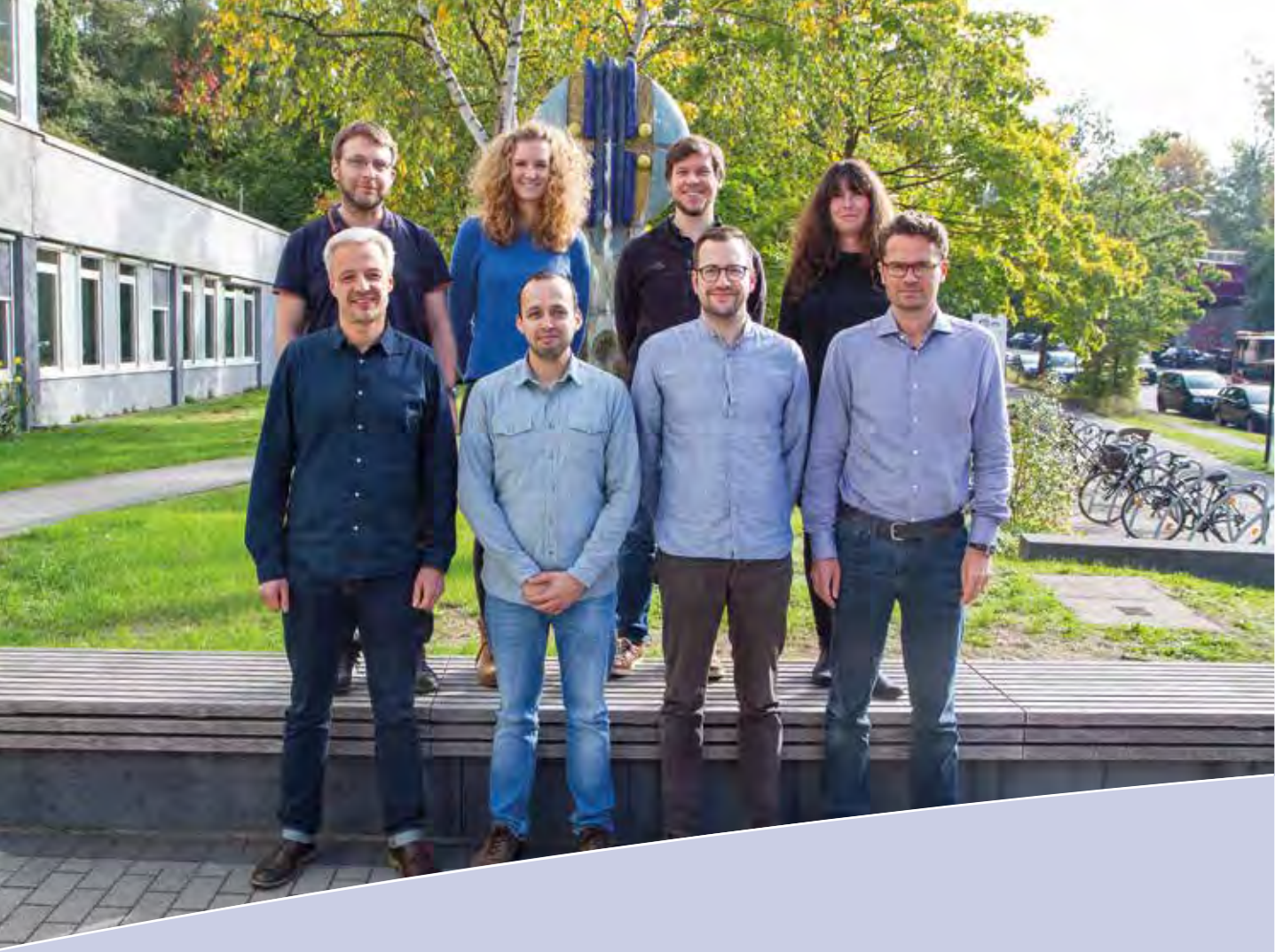
Related to school learning, the department continuously develops and investigates competitive and non-competitive enrichment programs aiming to strengthen students' understanding of the nature of science and science careers. The accompanying research is built around the IPN project WinnerS and analyzes conditions, effects and side-effects of participating in enrichment activities. The two chemistry related Science Olympiads and the Kieler Forschungswerkstatt provide the main environments for research and outreach; the student research center network of Schleswig-Holstein (SFZ-SH) has been added to this field in 2017.

In the Leibniz Science Campus KiSOC several studies are carried out with regard to chemistry and material science, forming new cooperations with researchers at Kiel University and beyond. Objects of design-based research projects are media approaches (simulations, immersive videos, text genres) as well as communicator trainings.

Meschede, N., Fiebranz, A., Möller, K., & Steffensky, M. (2017). Teachers' professional vision, pedagogical content knowledge and beliefs: On its relation and differences between pre-service and in-service teachers. *Teaching and Teacher Education, 66,* 158–170.

Höffler, T. N., Bonin, V., & Parchmann, I. (2017). Science vs. sports: Motivation and self-concepts of participants in different school competitions. *International Journal of Science and Mathematics Education, 15*(5), 817–836.

Podschuweit, S., & Bernholt, S. (2018). Composition-effects of context-based learning opportunities on students' understanding of energy. *Research in Science Education, 48*(4), 717–752.



DEPARTMENT OF EDUCATIONAL MEASUREMENT

The Department of Educational Measurement was established as an independent department of the IPN in 2015 and includes a team of educational researchers, psychometricians, and psychologists. In its research the department addresses statistical and methodological challenges in educational research and large-scale assessment studies. The primary focus is on three research topics: First, data structures in educational research often have a multilevel structure (e.g., students nested within schools). Multilevel modeling techniques that deal with these data structures are further improved and evaluated using simulation studies. A special focus is on the evaluation of the potential of alternative estimation approaches such as Bayesian approaches in problematic data constellations (e.g., small sample sizes). Second, competences and other educational constructs are often assessed using complex measurement designs. Psychometric latent variable models are evaluated that take into account the complexities of these designs (e.g., item context effects) when assessing differences between groups or modeling longitudinal change. Third, missing data represent a pervasive problem in educational research. For example, it is often the case that students do no respond to all items in a questionnaire or even refuse to participate in a study. Different approaches (multiple imputation, structural equation modeling) for dealing with missing data are compared and recommendations for research practice provided on the basis of comprehensive simulation studies. In addition, statistical software is developed that allows for an easy implementation of the different strategies for handling missing data. The department was complemented by the independent junior research group "Personality development in educational contexts" (Dr. Jenny Wagner) which used innovative longitudinal designs and methods to better understand developmental processes across the lifespan in educational contexts. Since 2018 Jenny Wagner is Professor of Educational Psychology and Personality Development at the University of Hamburg. Finally, the department contributes to the IPN graduate school offering workshops for doctoral candidates that are also accessible for more advanced colleagues.

Lüdtke, O., Robitzsch, A., & Wagner, J. (2018). More stable estimation of the STARTS model: A Bayesian approach using Markov Chain Monte Carlo techniques. *Psychological Methods, 23*(3), 570–593.

Nagy, G., Nagengast, B., Frey, A., Becker, M., & Rose, N. (2018). A multilevel study of position effects in PISA achievement tests: Student- and school-level predictors in the German tracked school system. *Assessment in Education: Principles, Policy & Practice.* Advance online publication.

DEPARTMENT OF EDUCATIONAL RESEARCH AND EDUCATIONAL PSYCHOLOGY

The Department of Educational Research and Educational Psychology focusses on empirical research on teaching and learning from an institutional and psychological perspective. Most activities can be classified according to three core research foci. The first research focus is on cognitive, psychosocial, and health characteristics of (prospective) teachers which also affects teachers' professional behavior and student outcomes. The department's second research focus is on students' academic development and its individual and contextual prerequisites. We use longitudinal designs to investigate how student characteristics like family and social background, cognitive abilities, or motivation affect individual development in different academic contexts such as school track, class composition, or vocational trainings particularly during transitions (cf. e. g., Research Line 2). The third focus has a strong infrastructural character combining scientific service with research in educational assessment. Research-based services refer on the one hand to the IPN's engagement in international large-scale assessments like the Programme for International Student Assessment (PISA), Trends in International Mathematics and Science Study (TIMSS), and International Computer and Information Literacy Study (ICILS), and on the other hand to test development in the context of the German National Educational Panel Study (NEPS). Research in educational assessment focusses on questions concerning the validity of tests and their interpretation. Psychometrically, the projects particularly focus on the comparability of mathematics and science tests from different national and international large-scale assessments. In addition, experimental studies, some employing eye-tracking methodology, are conducted to better understand information processing while students work on multiple-choice (MC) items. New methodological projects have also recently been initiated on techniques of machine coding of student essays.

Guill, K., Lüdtke, O. & Köller, O. (2017). Academic tracking is related to gains in students' intelligence over four years: Evidence from a propensity score matching study. *Learning and Instruction, 47,* 43–52.

Lindner, M. A., Lüdtke, O., Grund, S. & Köller, O. (2017). The merits of representational pictures in educational assessment: Evidence for cognitive and motivational effects in a time-on-task analysis. *Contemporary Educational Psychology, 51,* 482–492.

Schöber, C., Schütte, K., Köller, O., McElvany, N. & Gebauer, M. M. (2018). Reciprocal effects between self-efficacy and achievement in mathematics and reading. *Learning and Individual Differences, 63,* 1–11.

DEPARTMENT OF MATHEMATICS EDUCATION

The Department of Mathematics Education investigates the prerequisites, conditions, processes, and results of mathematics education as well as its interrelations with the learning in other science- and engineering-related domains. It examines mathematics-related educational processes across the lifespan from preschool to university education. The main research foci are the development of student competence in mathematics and the professional competence of mathematics teachers.

Current research projects address the mathematical competence development in elementary school as well as the transition from secondary school to university. In an ongoing longitudinal study with 130 elementary school classes we are investigating the role of individual learning prerequisites at the time of school enrollment, mathematics curriculum topics, and environmental conditions like mathematics textbooks for children's development in mathematics during elementary education. Research on the transition from school to university focuses on the characterization of mathematical learning prerequisites university instructors expect from freshmen in STEM programs. Based on the findings of a Delphi study with approx. 1000 university instructors, the requirements of the universities are compared with intended educational goals of German high schools.

The department's current research on teachers' professional competence addresses two aspects. First, we are undertaking research on preservice teachers' subject-specific knowledge formation. Using a three-dimensional model distinguishing scientific content knowledge, school-related content knowledge, and pedagogical content knowledge, we analyze pre-service teachers' knowledge development during mathematics teacher education at university. This study is based on a longitudinal data set from the IPN study KeiLa. Second, we investigate the subject-specific nature of competences of teachers who were educated to teach the two subjects mathematics and economics. Using data on professional knowledge as well as on teachers' ability to master challenging teaching demands in mathematics and economics lessons, we examine intraindividual relations of mathematics- and economics-specific components of teacher competence.

Heinze, A., Arend, J., Grüßing, M., & Lipowsky, F. (2018). Instructional approaches to foster third graders' adaptive use of strategies: An experimental study on the effects of two learning environments on multi-digit addition and subtraction. *Instructional Science, 46*(6), 869–891.

Rach, S., & Heinze, A. (2017). The transition from school to university in mathematics: Which influence do school-related variables have? *International Journal of Science and Mathematics Education, 15*(7), 1343–1363.

Tröbst, S. A., Kleickmann, T., Heinze, A., Bernholt, A., Rink, R., & Kunter, M. (2018). Teacher knowledge experiment: Testing mechanisms underlying the formation of pre-service elementary school teachers' pedagogical content knowledge concerning fractions and fractional arithmetic. *Journal of Educational Psychology, 110*(8), 1049–1065.

DEPARTMENT OF PHYSICS EDUCATION

In 2017–2018, research in the Department of Physics Education focused on fostering student competence in physics, the development and effects of physics teachers' professional competence, and the effects of extracurricular activities on supporting student engagement and learning in physics.

Theory suggests that the foundation of any competence is a knowledge organized around the core concepts of the respective domain. Past research conducted by the Department has generated extensive insights into how students develop a well-connected knowledge organized around the core concept of energy. While research in 2017–2018 continued to explore the effects of different approaches to teaching energy on this development, researchers have also worked with practitioners to implement findings into the teaching and learning of physics in school.

Neumann, K. & Weßnigk, S. (Eds.) (2018). Energieerhaltung und Energieentwertung [Energie conservation and degradation] [Special issue]. *Naturwissenschaften im Unterricht – Physik, 29*(164).

Much research has concentrated on learning how to best foster the development of a knowledge base organized around the core concepts of physics (or science). Little research, however, has shown that such competence indeed prepares students for future learning. In 2017–2018 the Department has intensified its efforts in exploring the role of student competence in physics for future learning beyond school – in particular, in with respect to the extent of which student physics competence developed in middle school prepares them for future learning in vocational training.

Frank, C., Härtig, H., & Neumann, K. (2017). Schulisch erworbene Kompetenzen als Voraussetzung für berufliches Wissen gewerblich-technischer Auszubildender [Competences acquired in general education as a precondition for occupation-related knowledge of Industrial-technical trainees]. *Unterrichtswissenschaft, 45*(1), 22–35.

Recently, research in the Department has tested and extended a developmental model of teacher professional competence that specifies the relationship between key dimensions of teacher knowledge, motivation, beliefs, and experiences in school. In 2017–2018, this research focused on the interdependency of motivational-affective and knowledge-related aspects of teacher competence. The findings contribute to a broader understanding of the functions of different aspects of professional competence and how to best develop them in teacher education.

Keller, M. M., Neumann, K., & Fischer, H. E. (2017). The impact of teacher pedagogical content knowledge and motivation on students' achievement and interest: Investigating physics classrooms. *Journal of Research in Science Teaching, 54*(5), 586–614.

To examine the effects of extracurricular activities on student engagement and learning in physics, the department continued to investigate the factors affecting young women's engagement in physics enrichment programs such as the Physics Olympiad and to develop interventions to stabilize or even increase their engagement. In the coming years, the department will extend its work in the respective research lines and continue its collaborations with partners in Germany and throughout the world to advance physics learning in both formal and informal settings.