RESEARCH REPORT 2017/2018

IPN · Leibniz Institute for Science and Mathematics Education
## TABLE OF CONTENTS

### PREFACE

- Central activities in the period of reporting
- Ethnic disparities right from the start?
- Relevance of structural variables and process quality for early science learning of children with and without migration background (NEPS)
- Modeling and assessing kindergarten teachers' professional competence in mathematics (WILMA)

**Perspectives for Research Line 1**
**Projects in Research Line 1**

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

- A longitudinal study of textbook effects on students' mathematics achievement during primary school
- The interplay between conceptual understanding and interest in secondary school chemistry

**Perspectives for Research Line 2**
**Projects in Research Line 2**

### PROFESSIONAL COMPETENCE

- The development of professional knowledge in mathematics and science university teacher education. Results from a longitudinal study (KeiLa)
- Student teachers' professional development. Design, research questions and exemplary results from the panel study of teacher students (PaLea)

**Perspectives for Research Line 3**
**Projects in Research Line 3**
## SCIENCE COMMUNICATION AND ENRICHMENT

1. The Kieler Forschungswerkstatt and the network of student research centers in Schleswig-Holstein 77
2. The Science Olympiads – Strengthening the international perspective and anchoring the programs in empirical evidence 79
   2.1 WinnerS – Effects of science competitions for students 79
   2.2 IBOint 85
   2.3 IJSO 2020 – Inviting talents from around the world to Germany 86
3. The Kiel Science Outreach Campus 87

Perspectives for Research Line 4 91
Projects in Research Line 4 92

## EDUCATIONAL ASSESSMENT AND EDUCATIONAL MEASUREMENT

1. Educational Assessment 100
   1.1 Estimating trends in German PISA data 2015 101
   1.2 Trend estimation and linking errors in large-scale assessments 107
2. Educational Measurement 115
   2.1 Multiple imputation of incomplete multilevel data 115
   2.2 Multiple imputation at the classroom level 117
   2.3 Multiple imputation with interaction effects and random slopes 119
   2.4 Discussion 120

Perspectives for Research Line 5 121
Projects in Research Line 5 122

## IPN DEPARTMENTS

124

## PUBLICATIONS 2017/2018

136

Publications 2017 138
Publications 2018 158
PREFACE

IPN – Successful research and knowledge transfer in times of external evaluation

In 2016, the Leibniz Institute for Science and Mathematics Education (IPN) celebrated its 50th anniversary – it was founded in 1966 as a research institute for science education. Only one year later, in 2017, the IPN underwent the external evaluation process of the Leibniz Association. In this process a group of national and international experts assessed the institute’s work of the last years and its prospects regarding future research and knowledge transfer. In their report the experts stated that the institute has been very successful with its scientific work during the last years and presents a convincing agenda for the future. The federal ministry of education and research, the federal state of Schleswig-Holstein and the remaining 15 federal states decided to continue their funding for seven additional years based on this report. Therefore, the IPN will be able to continue its work as a member of the Leibniz-Association.

The Leibniz Association is a network of 93 scientifically, legally, and economically independent research institutes and scientific infrastructure facilities in Germany. Leibniz institutes perform strategic subject-oriented research and offer scientific services which have a national impact while striving to find scientific solutions for major societal challenges.

The IPN is closely affiliated with Kiel University. The six department heads of the IPN hold full professorships at Kiel University. Future generations of teachers trained at Kiel University thus directly benefit from new insights into science and mathematics teaching and learning. The IPN and Kiel University also collaborate on a variety of joint research projects.

To advance and promote science and mathematics education through research, the IPN investigates domain-specific teaching and learning processes from a multi-level perspective. The IPN’s research approach is based on six core assumptions:

· Mathematics and science education is a central prerequisite for successful individual participation in society and successful vocational and academic careers.
· The achievements in mathematics and science education are dependent on the interplay of individual resources (antecedents) on the one hand, and in-school and out-of-school opportunity structures on the other hand.
· The nature and structure of in-school learning opportunities are the result of processes of social negotiation that occur at various levels (education systems, school supervisory authorities, schools, classes) and have considerable effects on students’ educational pathways.
- Out-of-school learning opportunities are determined mainly by family background and peers, and are much less amenable to societal influence. However, mathematics and science learning can be facilitated, for example, by out-of-school learning sites (learning laboratories, museums, etc.).
- The research on, and advancement of, mathematics and science education requires an empirical approach that – drawing on expertise in the respective disciplines – requires quantitative and qualitative research methods of the social and natural sciences and is interdisciplinary.
- Subject-based educational research across multiple disciplines requires close collaboration between the various disciplines represented at the IPN. At the same time, the increasingly complex research questions require collaboration with experts of additional disciplines through research associations.

**Five research lines: A life-span perspective on educational processes in mathematics and science**

The IPN’s research is organized in a matrix-structure with five Research Lines (rows of the matrix) that allow for research across departments and disciplines, and six departments (columns of the matrix) representing different disciplines. The Research Lines clearly demonstrate the IPN’s focus on investigating educational processes across the lifespan, starting in early childhood up through adulthood with a particular focus on teachers’ professional development.
Although the Research Lines follow their own agendas, they have theoretical and empirical overlap. For example, professional development of preschool teachers is studied in Research Line 1 (Educational Processes in Preschool Education) but calls for close cooperation with Research Line 3 (Professional Competence).

The matrix-structure of the institute is completed by six departments: Biology Education, Chemistry Education, Educational Measurement, Educational Research and Educational Psychology, Mathematics Education, and Physics Education. This organization by disciplines reflects the idea that in-school and out-of-school educational processes are domain-specific to a considerable extent, and that researchers with high expertise in the respective subject and its teaching are required to systematically investigate them. The Department of Educational Research and Educational Psychology complements this domain-specific approach by providing a generic, educational, and psychological perspective on learning and instruction research. With its expertise in statistical and methodological procedures, the Department of Educational Measurement supports the state-of-the-art research throughout the institute and conducts research in educational assessment and educational measurement. The departmental structure facilitates a high level of research quality and visibility in each discipline. It also allows that all researchers remain actively engaged in their respective reference disciplines and that this subject-specific expertise is reflected in the junior scientists’ qualifications.

The six departments collaborate within the five Research Lines specified above. Large, mainly longitudinal research projects of national significance are complemented by smaller micro-analytically based projects, often funded by the German Research Foundation (DFG) or the Federal Ministry of Education and Research (BMBF). The IPN conducts many projects that require the infrastructure of a research institution within the Leibniz Association due to their design and duration; it thus conduces to scientific progress in a manner universities cannot.

The current biennial research report covers the year of the IPN’s external evaluation and the following year. Much effort has been invested during these two years to establish and consolidate the five Research Lines that were newly introduced in 2016. We present the work of all Research Lines highlighting selected projects in each Line and hope that the readers will find the idea of different Research Lines convincing.
Cooperation within research networks

In recent years the IPN was able to significantly expand the institute’s national and international research networks. The cooperation with the local Kiel University has been extended, particularly in the area of science outreach. Together, the IPN and Kiel University established the Kiel Science Outreach Campus (KISOC) which is funded by the Leibniz Association, the federal state of Schleswig-Holstein, Kiel University, and the IPN for four years.

With regards to strategic expansion, the IPN is strongly involved in the two Leibniz Research Networks Education Research and Energy Transition. The bi- and multi-lateral cooperation established within the Leibniz Education Research Alliance will be expanded and further strengthened in the coming years.

In the field of large-scale assessment, the IPN is one of the three institutions – next to the Technical University of Munich and the German Institute for International Educational Research (DIPF) – making up the Centre for International Student Assessment (ZIB), which is funded by the BMBF and the federal states. As for the previous survey, the center was responsible for the national project management (NPM) of the Programme for International Student Assessment (PISA) 2018. In addition to the NPM, the ZIB focuses on research in educational measurement. In 2015, the ZIB received a positive evaluation and will continue its work until at least 2022.

On an international level, the IPN has initiated or intensified collaborations with renowned universities and research institutions in the Netherlands, Switzerland, Luxemburg, Denmark, England, Sweden, Norway, Israel, the United States, Australia, China, and Chile.

Gender equality and family-friendly institute

The IPN is an equal opportunity employer with a strong and committed interest in affirmative action to promote gender equality. A major aim with regards to equal opportunity is a significant increase of women in leading positions. Target numbers have been defined by the so-called cascade model in which a defined percentage of women move upwards through all academic levels. In order to achieve this important goal, the IPN carries out a variety of actions at different levels of the scientific career. The IPN has introduced three positions for independent female junior researchers (in line with the Emmy Noether Programme of the DFG) to increase the opportunities for leading female post-docs. One of the IPN’s approaches to establish equal opportunities is creating family-friendly conditions for studies, teaching, and research. The
basic certificate verifying the IPN’s family friendly work environment policies was already awarded in 2006. Since then the IPN has successfully completed the re-auditing in 2009, 2013, and 2016. The IPN is continuously working on extending childcare service. Thus, working parents receive support to progress in their research and thereby their academic careers.

**Support for the doctoral students**

The doctoral students at the IPN (65% salary level TVL E 13) are members of the IPN graduate school and participate in its structured program; the IPN graduate school was established in 2013. The program’s curriculum requires students to participate in lectures, seminars, and workshops designed to introduce them to the methodological aspects of educational research and to provide training in qualitative and quantitative research. Courses also offer instruction in univariate and multivariate statistics, with a focus on procedures used in non-experimental social research (regression and factor analyses, structural equation modeling). With regards to their own theses, the IPN’s doctoral students each receive interdisciplinary support from two mentors (usually at the post-doc level), each mentor representing a different discipline (e.g., Biology Education and Chemistry Education, or one science subject accompanied by psychology or educational science). All doctoral students also have the opportunity to spend three to six months abroad with financial support from the IPN.

**And finally our thanks**

The IPN’s research is made possible by the support of numerous funding bodies. On behalf of all IPN employees, I would like to thank them for financing our work. Our thanks also go to the IPN’s Board of Trustees and to the Scientific Advisory Board. Members of both boards have monitored our work over the past two years and provided valuable feedback and guidance. Most importantly, I would like to express our gratitude to the many children, adolescents, and adults who contributed their time and effort which allowed us to advance and promote science and mathematics education through our empirical research.

Professor Olaf Köller

*IPN Managing Director of Research*