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Review

A decade of educational research with the German National Educational Panel Study: A systematic review[☆]Timo Gnams^{a,*} , Tanja Kutscher^a , Marie-Ann Sengewald^{a,b} ^a Leibniz Institute for Educational Trajectories, Germany^b Department of Psychology, Friedrich-Alexander-University Erlangen-Nuremberg, Germany

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ABSTRACT

Educational large-scale assessments (LSAs) are indispensable for empirical research on educational systems and academic achievement. The German National Educational Panel Study (NEPS) stands out among LSAs due to its unique longitudinal, multi-cohort design embedded within a multilevel assessment context. By following six distinct cohorts from early childhood through adulthood, the NEPS enables analyses of educational processes and competence development across the entire life course. Despite its extensive use over the past decade, little is known about the scope and scholarly impact of studies analyzing NEPS data. This systematic review of 625 peer-reviewed journal articles published between 2013 and 2024 assessed the academic use, thematic focus, and contribution to international educational research of studies based on NEPS data. The findings revealed a NEPS-related research output that is comparable to major international LSAs. Studies with NEPS data contributed high-impact articles across psychology, education, and sociology, addressing topics such as early cognitive development, educational inequalities, personality and motivation, and school-to-work transitions. Additionally, the dataset has informed research on higher education, adult learning, and career development. Still, the review identified several underexplored areas that underscore the continued potential of the NEPS as a popular data source for longitudinal and contextualized educational research.

Over the past few decades, educational large-scale assessments (LSAs) have emerged as indispensable tools for evaluating the performance of educational systems and analyzing academic outcomes across the globe (Hernández-Torrano & Courtney, 2021; Kutscher et al., 2024). Typically implemented at a national level, LSAs are designed to cover entire age cohorts or grade levels to provide systematic, empirical data on educational achievement and its correlates across diverse contexts such as home environments, institutional learning settings, and geographical regions. The primary objective of LSAs is to support evidence-informed educational policy and reform by monitoring educational trends and identifying systemic strengths and areas in need of improvement. In addition to informing policy, LSAs also have become an essential data source for academic research in diverse fields including psychology, sociology, and economics (e.g., Brunner et al., 2024; Hanushek et al., 2019; Nennstiel, 2023) because they offer access to large, representative data with standardized achievement measures in key domains such as reading, mathematics, and science, which are often considered essential for successful societal participation (Weinert et al., 2019). Consequently, research using data from LSAs is

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prominently featured in the academic literature in different disciplines (see [Maehler et al., 2025](#); [Mejía-Rodríguez et al., 2026](#); [Stiff et al., 2023](#); [Veletić et al., 2024](#); [Zheng et al., 2024](#)).

While international LSAs such as the *Programme for International Student Assessment* (PISA), *Progress in International Reading Literacy Study* (PIRLS), or *Programme for the International Assessment of Adult Competencies* (PIAAC) are designed for cross-national comparisons, many countries also conduct national or regional assessments tailored to their specific educational systems (e.g., [Carrasco et al., 2023](#)). In the United States, for example, the *National Assessment of Educational Progress* (NAEP) provides regular assessments of students in Grades 4, 8, and 12 across various subjects. Unlike international LSAs, NAEP offers detailed disaggregated results by state, demographic group, and other contextual variables, thus providing a granular view on the U.S. education system which is often unavailable in international assessments. In Germany, the *National Educational Panel Study* (NEPS) serves a similar role as a national LSA ([Blossfeld et al., 2019](#)). A unique feature of the study, however, is its longitudinal, multi-cohort design including representative samples, embedded in a multi-perspective context (e.g., including students, teachers, parents, and school principals). This allows tracing individual competence development across the life course to analyze educational trajectories from early childhood through adulthood. The breadth and interdisciplinary appeal of the NEPS have made it a popular data source for empirical research on the German educational system for over a decade ([Artelt & Sixt, 2023](#)).

Given the growing relevance of NEPS data for educational research, it is time to take stock of how it has been used since the inception of the study. Accordingly, this systematic review aims to provide a comprehensive summary of research trends that have emerged from analyses using NEPS data. In addition, it seeks to identify potential gaps in the existing literature to highlight areas where the full potential of the NEPS has yet to be realized.

1. The role of international LSAs in educational research

International LSAs have become an attractive resource for educational researchers around the world for several reasons (e.g., [Ertl et al., 2020](#); [Hernández-Torrano & Courtney, 2021](#)). The breadth, quality, and accessibility of the data they provide make them an inexpensive alternative to primary data collection to examine individuals' knowledge, skills, and learning outcomes. One of the key strengths of LSAs lies in their use of representative samples, in contrast to the small, often non-random convenience samples that still dominate much of educational research ([Doebel & Frank, 2024](#)). This often enhances the external validity and generalizability of research findings ([Wild et al., 2022](#)). Another advantage of LSAs is their ability to include and represent hard-to-reach or marginalized subpopulations such as students with a migrant background, those with special educational needs, or individuals from socioeconomically disadvantaged groups, which are sometimes underrepresented in conventional research ([Rad et al., 2018](#)). Furthermore, LSAs typically connect data from multiple sources, such as students, educators, and parents, which support contextualized analyses that consider the complex interplay between individual, institutional, and systemic factors in shaping educational outcomes. Finally, the large samples with comprehensive contextual information that are typically collected in LSAs allow researchers to apply advanced statistical methods that more accurately reflect the peculiarities of real-life data structures ([Kutscher et al., 2024](#)).

Accordingly, data from international LSAs has seen growing use in academic educational research. Among these, PISA stands out as the most influential, having generated over 900 peer-reviewed articles with secondary data analysis between 1991 and 2021 ([Zheng et al., 2024](#)). Other LSAs such as PIRLS ([Stiff et al., 2023](#)), PIAAC ([Maehler et al., 2025](#)), and the *Teaching and Learning International Survey* (TALIS; [Veletić et al., 2024](#)) have also made substantial contributions to the literature, each resulting in over 200 to 300 peer-reviewed publications, although they have comparatively shorter operational histories. Despite their differences in scope and scale, systematic reviews of the publication output for these LSAs have revealed two consistent trends. First, there is a steady increase in the number of publications per year over time, reflecting a growing recognition of the value of LSA data in the global research community. Second, Germany consistently emerges as one of the leading contributors, both as a subject of investigation and in terms of authorship. For example, German researchers rank second only to those from the United States in terms of contributions to PISA-related publications ([Zheng et al., 2024](#)). Regarding research based on PIAAC ([Maehler et al., 2025](#)) and PIRLS ([Stiff et al., 2023](#)) they even lead the field. This strong engagement with LSAs in Germany reflects a broader policy shift since the early 2000s, spurred in part by the country's unexpectedly low performance in early PISA cycles. In response, German educational policy began to place greater emphasis on empirical educational research as a basis of evidence-informed decision-making ([Zapp & Powell, 2016](#)). Since then, Germany has not only become a regular participant in multiple international LSAs but has also introduced a series of educational initiatives (see [Martens & Niemann, 2013](#); [Neumann et al., 2010](#)), including the establishment of a national LSA that is specifically targeted at the German educational system.

2. The National Educational Panel Study

The NEPS ([Blossfeld et al., 2019](#)) is a longitudinal LSA designed to investigate educational processes and outcomes across the life span within the German population. Its multi-cohort sequence design comprises six starting cohorts¹ that represent key phases of the educational life course (see [Fig. 1](#)): (1) newborns, (2) kindergarten-aged children, (3) students in Grade 5, (4) students in Grade 9, (5) first-year university students, and (6) adults. Each cohort consists of a representative sample (totaling over 60,000 individuals) that is repeatedly observed over time ([Artelt & Sixt, 2023](#)). These observations are embedded in a multi-perspective context to

¹ Data for a seventh starting cohort focusing on students in Grade 5 are available since May 2025 but are not considered further because no publications have yet been produced based on this dataset.

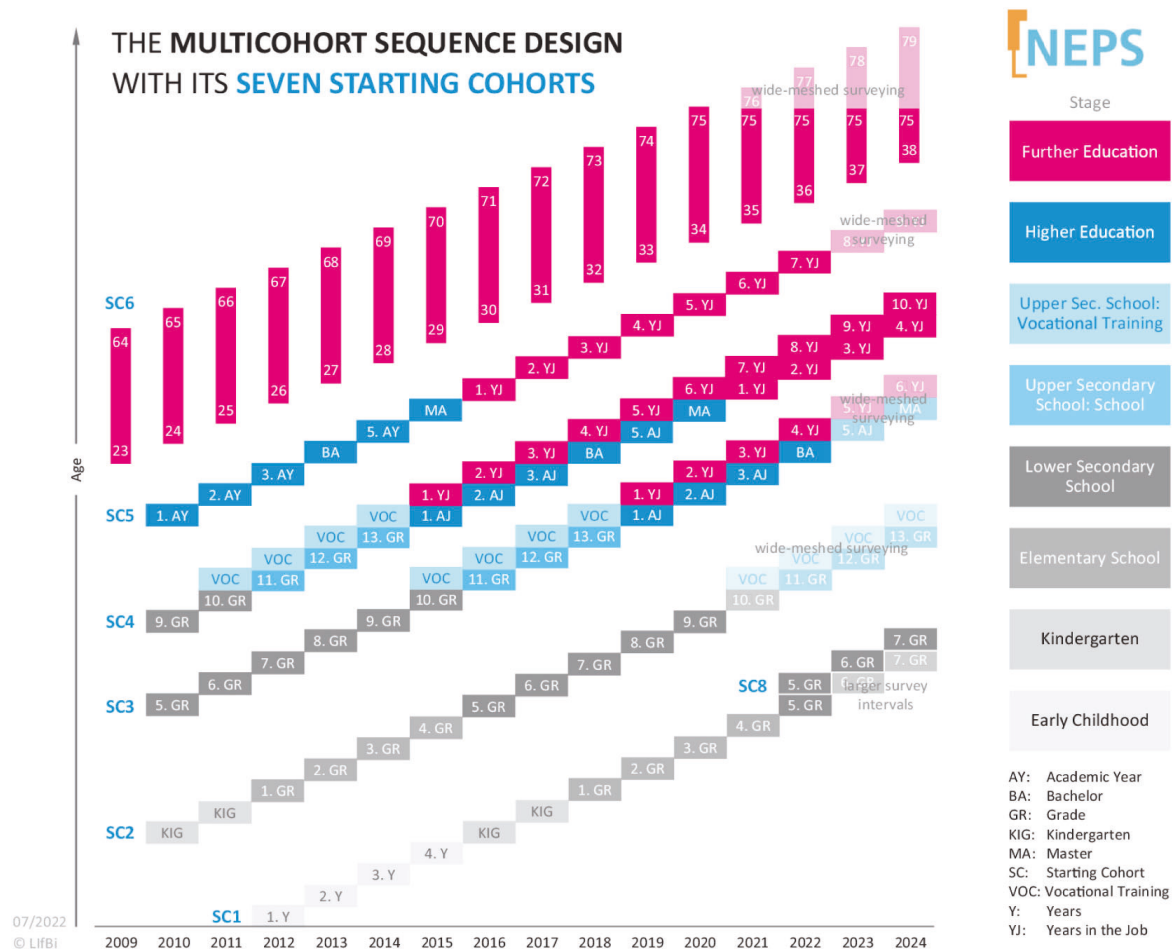


Fig. 1. Multi-Cohort Sequence Design of the National Educational Panel Study

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comprehensively capture the manifold influences shaping educational processes. Accordingly, in the younger cohorts, data from children and adolescents is supplemented by reports from parents and educators. Additionally, all starting cohorts are linked to administrative register data to enhance the survey data with contextual employment and geographic information (Bachbauer et al., 2022). The design of the NEPS enables researchers to examine both age-specific educational experiences and broader life course processes with comprehensive contextual information, making the NEPS a unique resource for both national and comparative international educational research on educational participation, achievement, and inequality in Germany.

Central to the NEPS is the repeated measurement of domain-specific cognitive competencies. Similar to other LSAs (Hernández-Torrano & Courtney, 2021), these are viewed not merely as a form of accumulated knowledge but as the functional ability to apply knowledge meaningfully in real-life contexts, thus emphasizing the relevance of skills for participation in society, the labor market, and lifelong learning (Weinert et al., 2019).

Across all starting cohorts, the NEPS includes assessments in 27 cognitive domains (see Supplement A). However, only four of them (reading comprehension, mathematical competence, scientific literacy, and information and communication technology [ICT] literacy) are measured systematically and longitudinally in all starting cohorts. Other domains such as executive functioning in early childhood (Attig et al., 2023) or spelling in lower secondary education (Thums et al., 2023) are assessed, albeit repeatedly, only during developmentally relevant periods. In addition, domain-general cognitive abilities such as reasoning skills or perceptual speed are typically measured at the beginning of each cohort to provide baseline assessments of general intellectual capacity.

The cognitive assessments are designed to capture both *inter*-individual and *intra*-individual development over time. Unlike (repeated) cross-sectional LSAs, the longitudinal nature of the NEPS also facilitates the examination of competence growth, its roots and outcomes, and causal mechanisms over time (e.g., Biazoli Jr et al., 2024; VanderWeele et al., 2020). By linking cognitive measurements to extensive contextual and background information such as demographic variables (e.g., socioeconomic status, migrant background), psychological constructs (e.g., self-efficacy, Big Five personality traits), context characteristics (e.g., of teachers or schools), and biographical data (e.g., employment histories, participation in further education), the NEPS offers diverse opportunities for exploring the determinants, trajectories, and consequences of competence development throughout the life course. Access to the data is granted free of charge to researchers agreeing to comply with established ethical and data protection regulations (Fuß & Wenzig, 2019). Consequently, for more than a decade, the NEPS has played an indispensable role for investigating educational processes and outcomes in Germany (Artelt & Sixt, 2023; Blossfeld et al., 2019).

3. Objectives

The primary goal of this study is to examine how data from the NEPS has been used by the scientific community over the past decade. Accordingly, the systematic review of publications with NEPS data pursues two main research aims:

First, we seek to evaluate the performance and impact of the NEPS as a data source for educational research, with a particular focus on studies involving cognitive competencies, studies relying on contextual information, and studies addressing methodological developments. This includes an analysis of the research output across academic disciplines in comparison to international LSAs to highlight the contribution of the NEPS for contemporary educational research. Second, we aim to identify key research themes by assessing the use of different cognitive domains and mapping the main topics addressed in the existing literature. This thematic analysis will highlight prominent research streams as well as underexplored areas that have not yet fully made use of the analytic potential provided by the NEPS.

The present review complements previous systematic analyses conducted for international LSAs such as PISA (Zheng et al., 2024), PIRLS (Stiff et al., 2023), PIAAC (Maehler et al., 2025), TALIS (Veletić et al., 2024), the *International Civic and Citizenship Education Study* (ICCS; Myoung & Liou, 2022), and the *International Computer and Information Literacy Study* (ICILS; Mejía-Rodríguez et al., 2026) which have summarized research trends based on their respective datasets. By situating the NEPS within this broader context, the present study aims to contribute to a more comprehensive understanding of how the NEPS informs educational research and to encourage researchers who are less familiar with the study to capitalize on its potential.

4. Method

4.1. Bibliometric database

4.1.1. Search and screening process

The bibliometric database was derived from the NEPS bibliography which represents an interdisciplinary compilation of publications on conceptual and methodological frameworks of the NEPS, empirical analyses of NEPS data, policy documents referring to the NEPS, and perspectives on educational research referencing the NEPS. The database provides comprehensive coverage of NEPS-related

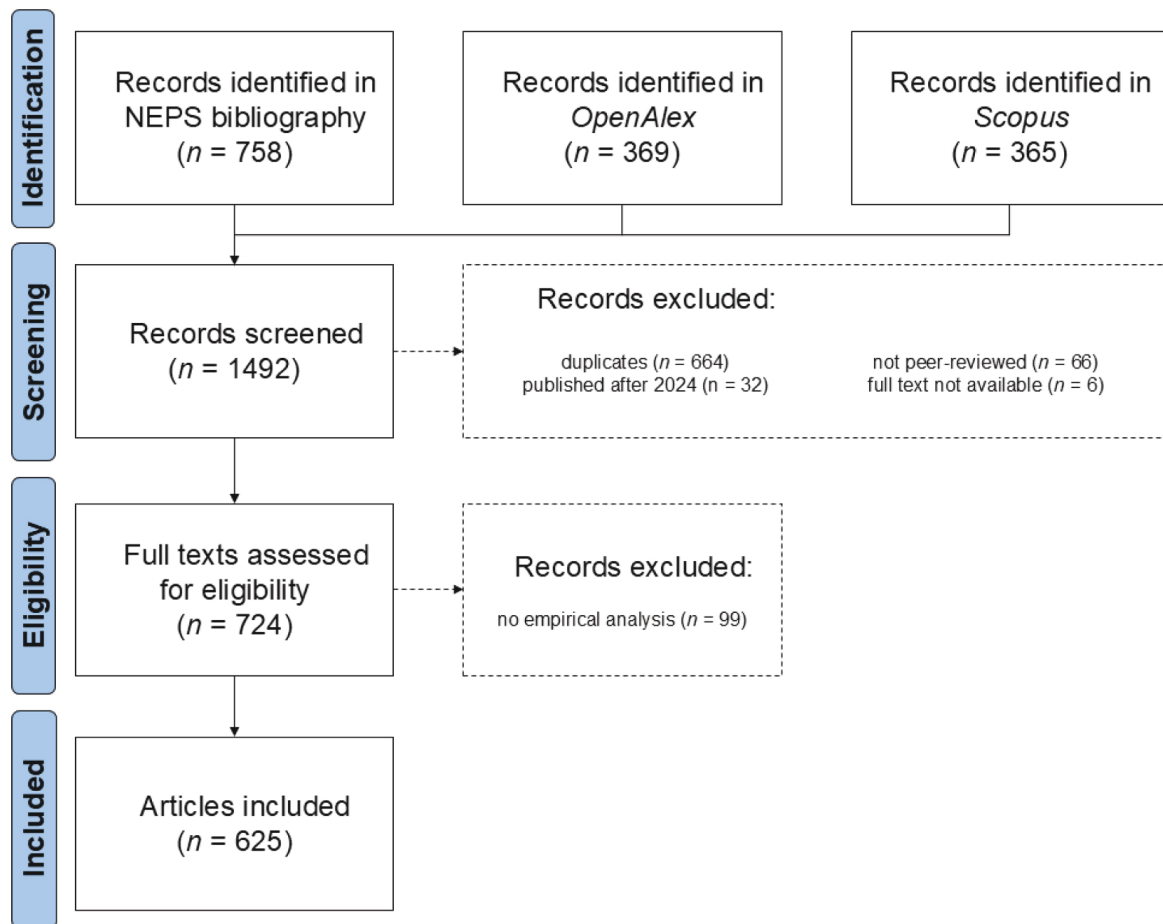


Fig. 2. Flow diagram of search and screening process for articles analyzing NEPS Data
 Note. NEPS = National Educational Panel Study.

publications and is continuously updated in several ways: (a) Researchers using NEPS data are contractually required to report all resulting publications and, thus, provide records of relevant articles. (b) Intermittent surveys among registered users for NEPS data access also query about unreported publications derived from NEPS data. (c) Additional publications are annually identified by Google searches for articles referencing NEPS datasets. As a result, the database offers a highly comprehensive record of publications using NEPS data. All publications that were included in the NEPS bibliography in February 2025 were collected. The database was augmented in March 2025 by a search in the multidisciplinary bibliographic database *OpenAlex* (Priem et al., 2022) with the *openalexR* software (Version 2.0.0; Aria et al., 2024) using the search string “National Educational Panel Study”. The database provides similar coverage of English language publications as commercial databases (Culbert et al., 2025) but covers more journals, particularly published in languages other than English, as compared to, for example, *Web of Science* or *Scopus* (Céspedes et al., 2025). Finally, in April 2025 a comparable search using an identical search string was conducted in *Scopus* (see Supplement B for further details).

A publication was eligible for inclusion in the review if it met the following criteria: (a) It reported an empirical analysis of data provided in the scientific use files of the NEPS. Descriptions of the NEPS without an empirical component or studies based on data from unpublished pilot studies for the NEPS were excluded. (b) It was published in a peer-reviewed journal. Working papers, technical reports, dissertations, book chapters, and other forms of gray literature were excluded. Similarly, articles published without peer-review (e.g., editorials) were not considered. This ensured a consistent quality standard and maintained comparability with prior reviews of large-scale assessment research. (c) It was published no later than 2024. Advance online publications without a final record of publication were excluded. (d) The full text of the article could be retrieved. No restrictions were placed on the language or topic of the publication.

The search resulted in 1492 potentially relevant publications for the review. All records were initially screened by the first author. To ensure reliability, all excluded records were independently re-screened by the second author which resulted in the identification of four articles that have been erroneously excluded and were subsequently retained. Of the 1492 identified records, 664 duplicates were removed. A further 32 publications were excluded because they were published after 2024 (primarily advance online publications), and 66 were excluded for not meeting the peer-review criterion. Additionally, full texts could not be retrieved for six articles, which were therefore excluded. The remaining 724 articles underwent full-text assessment. Of these, 99 were excluded because they did not report an empirical analysis of NEPS data. This process resulted in a final sample of 625 articles that met all inclusion criteria and were thus considered in the review. The full flow chart describing the identification and screening process for eligible articles is provided in Fig. 2.

4.1.2. Coding procedure

The bibliographic information (i.e., title, journal, publication year) was provided in the bibliographic database. In addition, a coding manual (available in the online repository) was used to extract the author-provided abstract and keywords, the country of the authors' affiliations, and the language of the publication from each article. In addition, it was coded which of the six NEPS cohorts were used to address the research questions. Then, for each of the 27 cognitive domains assessed in the NEPS (see Supplement A) it was coded whether the respective domain was included in the analysis reported in the publication. Finally, it was coded whether the article had primarily a methodological focus including (1) survey methodological aspects on sampling and data collection (e.g., sampling weights, incentives, attrition, assessment modes, interviewer effects), (2) the development or evaluation of measurement instruments (e.g., item construction, test adaptation, psychometric modeling, scaling, linking), or (3) statistical procedures for substantive research (e.g., accounting for threats to causal inference, modeling time differences, correction for clustered or incomplete data structure). Based on the coded information the articles were classified into three groups (a) articles reporting cognitive analyses (i.e., for which at least one of the 27 cognitive domains were used in the analyses): without a methodological focus, (b) articles without cognitive analyses and without a methodological focus (i.e., analyses that used the contextual information without any of the cognitive domains), and (c) articles with a methodological focus.

The articles were coded by the first author. In addition, 20 articles with cognitive analyses, without cognitive analyses, and with a methodological focus, that is, 60 articles in total representing about 10% of the bibliometric database, were randomly selected and variables referring to the cohort and competence domains were coded a second time by the third author. Additionally, the focus of all methodological articles was also coded a second time. The interrater reliabilities were calculated as Fleiss's (1971) κ . Because several variables referred to rather rare events (e.g., competence domains that were infrequently used), a prevalence-adjusted version of κ was used (Byrt et al., 1993). The respective reliabilities of the coded variables were rather large and varied between 0.79 and 1.00 ($Mdn = 1.00$). Inconsistencies were resolved by the first author.

4.1.3. Retrieval of metadata

For each article included in the bibliographic database, the major research field (i.e., education, psychology, sociology, other), the most recent journal impact factor (JIF) for the year 2024, and the field-weighted quartile of the respective JIF were retrieved from the *Web of Science*. In addition, the field-weighted citation index (FWCI) was retrieved for each article from *OpenAlex*. The FWCI represents the number of citations received within three years of publication divided by the average number of citations of articles in a field within the same time period. Thus, a value of 1 indicates that an article received a similar number of citations as the average article, while values greater than 1 reflect a larger impact of an article. The calculation of the FWCI was limited to articles published in or prior to 2022.

4.2. Analytical procedure

Major topics addressed with NEPS data were identified using a topic modeling approach that leverages transformer-based embeddings and clustering techniques to extract coherent topics from the title, abstract, and keywords of each article. The procedure as implemented in *BERTopic* (Version 0.17.0; Grootendorst, 2022) follows several steps:

First, the input text corpus is converted into high-dimensional numerical representations using the pre-trained transformer-based language model SPECTER 2 (Singh et al., 2023) which was specifically trained on scientific abstracts. These embeddings capture semantic relationships between words and documents. Second, the high-dimensional embeddings are reduced using uniform manifold approximation and projection (Healy & McInnes, 2024) to improve computational efficiency and clustering performance. This step preserves local structures in the data while reducing noise. Third, hierarchical density-based spatial clustering of applications with noise (HDBSCAN; McInnes et al. 2017), an unsupervised clustering technique that detects areas of higher semantic density in the meaning space, is applied to the reduced embeddings to identify major topics in the corpus texts. Finally, for each identified cluster, a term frequency inverse document frequency (TF-IDF; see Qaiser & Ali, 2018) statistic is used to identify representative words for each topic that distinguish them from other topics. TF-IDF is commonly used in computational linguistics to increase the weight given to specific words while smoothing out the importance of very common words (e.g., grammatical terms). This methodology enables *BERTopic* to extract interpretable topics from diverse textual datasets. The representative words for each topic were then used to derive a coherent label and description. The conceptual structure of the identified topics was further examined using word clouds of the most prominent author-provided keywords of the articles within a topic.

To evaluate the quality of the identified topics, two complementary metrics were calculated. Topic diversity measured the distinctiveness of the topics from each other based on the uniqueness of the representative words. Values closer to 1 indicate that topics are largely non-overlapping, whereas values closer to 0 suggested substantial redundancy. Semantic coherence assessed how frequently the representative words for each topic co-occurred in the abstracts. High coherence approaching 1 indicates that words defining a topic tend to appear together in the same abstracts, while low coherence near 0 suggests that the representative words may be less related.

The analyses were conducted in R (R Core Team, 2025) with its interface to Python (Version 3.12) provided by the *reticulate* package (Ushey et al., 2025). Semantic coherence was calculated using the *gensim* library (Version 4.4.0; Radim & Sojka, 2010). The full data cannot be publicly shared because the analyzed abstracts are protected by copyright. However, the references to the analyzed articles and the analysis code are available at <https://osf.io/vh8t5/>.

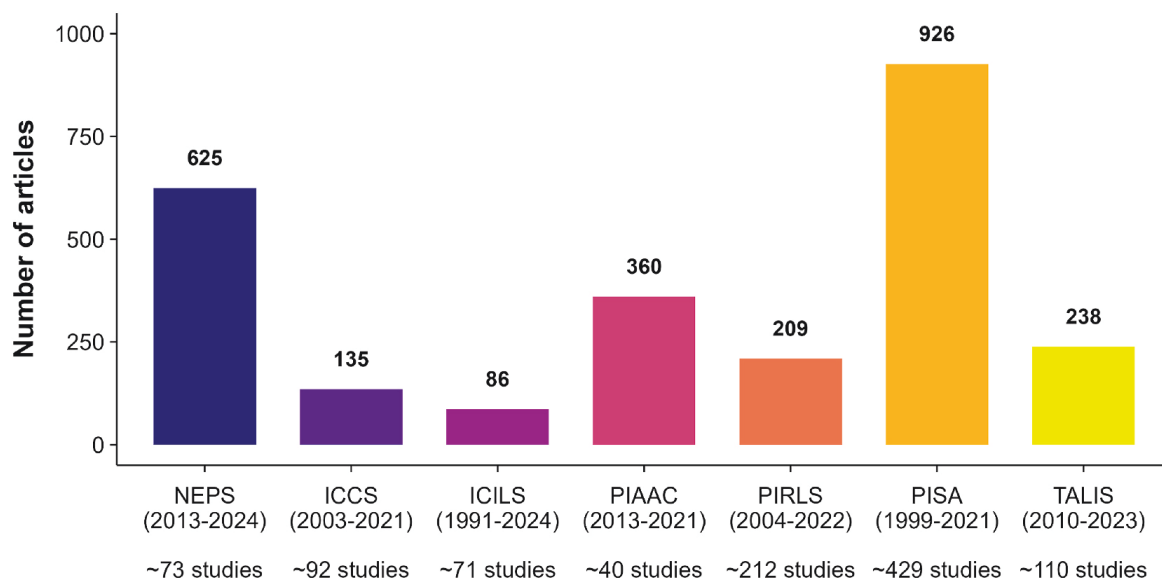


Fig. 3. Number of Articles by Large-Scale Assessment

Note. NEPS = National Educational Panel Study; ICCS = International Civic and Citizenship Education Study (Myoung & Liou, 2022); ICILS = International Computer and Information Literacy Study (Mejía-Rodríguez et al., 2026); PIAAC = Programme for the International Assessment of Adult Competencies (Maehler et al., 2025); PIRLS = Progress in International Reading Literacy Study (Stiff et al., 2023); PISA = Programme for International Student Assessment (Zheng et al., 2024); TALIS = Teaching and Learning International Survey (Veletić et al., 2024). The number of studies in the international large-scale assessments refers to the number of countries by cycle assessments, while, for the NEPS, it gives the number of waves by cohort assessments. The values refer to the number of peer-reviewed publications with secondary data analysis in English-language journals; for NEPS and PIAAC also German-language publications are considered.

5. Results

5.1. Characteristics of NEPS publications

Between 2013 and 2024, NEPS data has been used in 625 peer-reviewed publications. To put this number into perspective, Fig. 3 compares the publication output of the NEPS with six major international LSAs for which systematic reviews have reported the number of peer-reviewed articles with secondary data analysis. As expected, PISA as the longest-running and most extensive study generated the highest number of publications, exceeding 900 articles between 1991 and 2021 (Zheng et al., 2024). Despite its national scope and shorter operational period, NEPS has already reached about two-thirds of PISA's research output. Moreover, NEPS has outpaced other large-scale assessments including ICCS (Myoung & Liou, 2022), ICILS (Mejía-Rodríguez et al., 2026), PIAAC (Maehler et al., 2025), PIRLS (Stiff et al., 2023), and TALIS (Veletić et al., 2024).

The number of NEPS-based publications steadily increased following the release of the first scientific use file, reaching a plateau in 2020 (see Fig. 4). Since then, about 80 to 90 empirical articles have been published annually using NEPS data. These findings highlight that NEPS has been and still is a major data source in educational research with a contribution at least comparable to many international LSAs. However, these comparisons should be interpreted with caution, as the systematic reviews for the different LSAs differed in their search strategies inclusion criteria, and time frames adopted, which by limits the direct comparability of the reported publication numbers.

5.2. Prestige and impact

Although nearly 90% of authors publishing with NEPS data were affiliated with German institutions, only 20% of the corresponding publications were written in German (see Fig. 5). This indicates that the majority of the publications addressed an international audience. The primary research fields of these publications, as classified in *Web of Science*, were distributed relatively evenly across education, psychology, and sociology. In addition, several journals targeted more specialized areas such as economics or demography. However, this categorization should be considered a rather rough classification because it is often a matter of opinion if an article addresses a topic in, for example, education or educational psychology.

Although the JIF does not inform about the importance of an individual article, it can serve as an indicator of prestige because high-JIF journals are often held in high regard within a research field. About 17% of articles were published in journals not currently indexed in the *Web of Science*, most of which were in German-language journals targeting a national readership. However, as shown in Fig. 5, nearly two-thirds of NEPS-based articles were published in journals with above-average JIFs, with over one-third even in journals falling in the top quartile. This suggests that most publications using NEPS data contribute to academic outlets with a high prestige.

The most important journals of NEPS-related research are summarized in Table 1. As expected, most articles were published in *Zeitschrift für Erziehungswissenschaften* (38 articles) which represents the core outlet for the dissemination of research on the German educational system and specifically targets a national audience. The second and third most important journals targeted an international audience in sociology, *European Sociological Review* (27 articles), and psychology, *Frontiers in Psychology* (23 articles). Also, the remaining journals among the ten most prevalent publication outlets primarily targeted an international audience, underscoring the relevance of NEPS-related research for the global educational research community.

The impact of the articles reporting on NEPS data was assessed with the FWCI where a value of 1 represents the average citation performance for an article within its field. Fig. 5 shows that over three-quarters of articles received more citations than the field average, with about 51% of them accumulating more than three times the average number of citations, thus having an exceptionally high impact. These findings underscore the pronounced influence of NEPS-based articles in advancing educational research and informing the international research community.

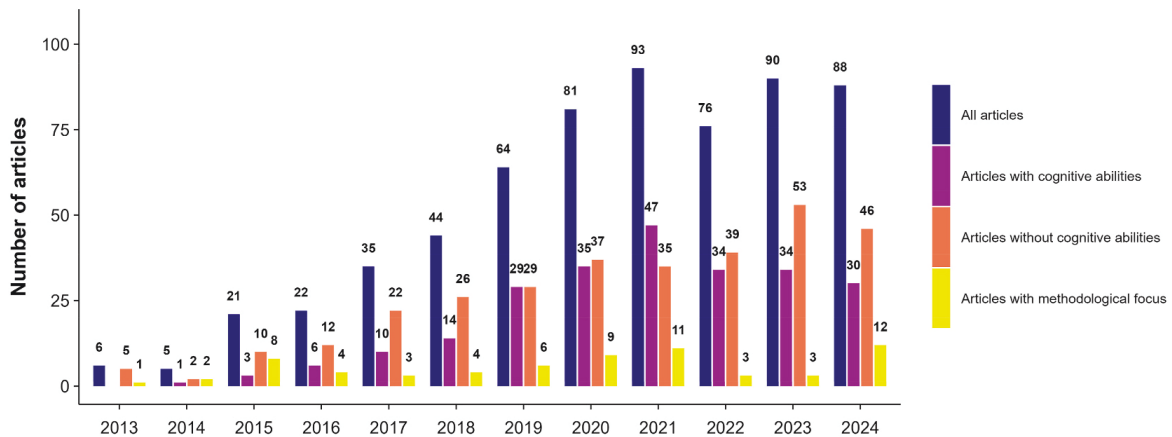


Fig. 4. Number of Articles using NEPS Data by Publication Year.

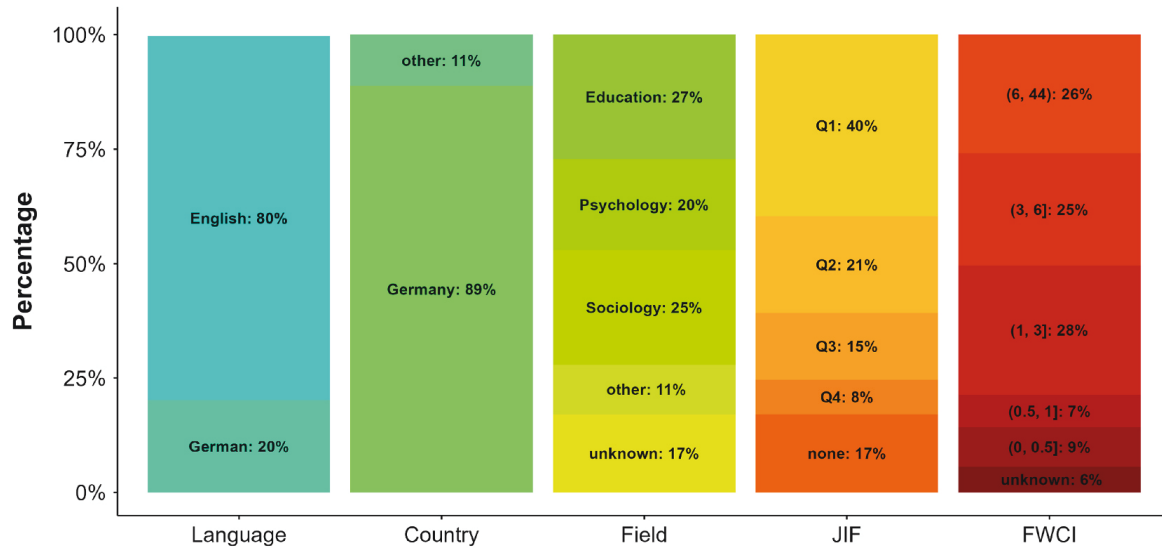


Fig. 5. Percentage of Articles using NEPS Data by Prestige

Note. Language = Publication language; Country = Country of authors' affiliations. Field = Major field from *Web of Science*. JIF = Quartile of the field-weighted journal impact factor from *Web of Science*. FWCI = Field-weighted citation index from *OpenAlex*. The distribution of the FWCI excluded articles published later than 2022, while the remaining information is based on the full bibliometric database.

Table 1

Core journals for NEPS-related research.

Journal	Number of articles	Number of citations	JIF	Range of publication years
Zeitschrift für Erziehungswissenschaften	38	129	Q3	2013-2024
European Sociological Review	27	261	Q1	2015-2024
Frontiers in Psychology	23	257	Q1	2016-2022
Research in Social Stratification and Mobility	18	172	Q2	2016-2024
Kölner Zeitschrift für Soziologie und Sozialpsychologie	18	130	Q3	2015-2022
Journal of Educational Research Online	18	79	Q4	2013-2023
Frontiers in Education	10	78	Q2	2020-2024
Empirical Research in Vocational Education and Training	10	40	Q1	2017-2024
PLOS ONE	9	117	Q2	2016-2024
Soziale Welt	9	21	Q3	2016-2023

Note. JIF = Quartile of the field-weighted journal impact factor from *Web of Science*. Number of citations from *OpenAlex* within three years since publication excluded articles published later than 2022.

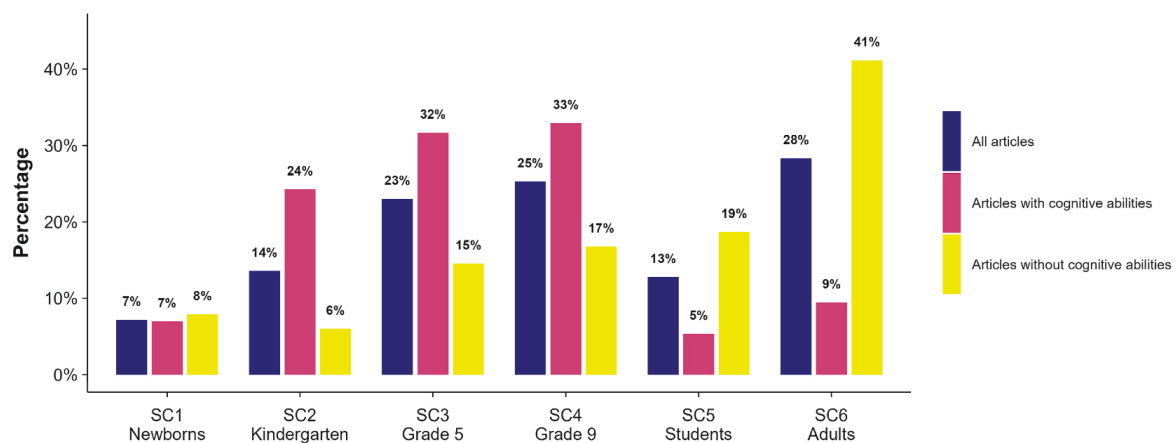


Fig. 6. Percentage of Articles using NEPS Data by Cohort

Note. SC = Starting cohort. Percentages refer to the distribution within each group. The percentages for each group do not sum to 100 because a given article may analyze multiple cohorts.

5.3. Research topics addressed with NEPS data

The available articles were grouped into three distinct categories with (a) articles analyzing cognitive abilities, (b) articles on contextual information without a cognitive analysis, and (c) articles with a methodological focus. Major topics were identified independently in the two former groups using a topic modeling approach, while the last group included too few articles and were, thus, analyzed qualitatively.

5.3.1. Research on Cognitive Abilities Using NEPS data

Research on cognitive abilities based on NEPS data was the focus of 243 articles, representing 39.0% of the bibliometric database. These primarily focused on the school cohorts with students in primary and secondary education, while research on adults was less prevalent (see Fig. 6). About 8% of these studies analyzed multiple starting cohorts. As shown in Fig. 7, most of these studies examined reading and mathematical competencies, which accounted for approximately 28% and 30% of all articles on cognitive abilities, respectively. Other domain-specific competencies like scientific literacy (7%), ICT literacy (6%), and listening comprehension (10%) received comparatively less attention. In addition, a significant portion of research (16%) focused on basic reasoning abilities as indicators of general cognitive functioning. More narrow cognitive abilities such as young children's executive functioning, students' spelling proficiency, and foreign language skills were addressed only occasionally.

The topic modeling analysis identified ten major research themes based on NEPS data (see Table 2) which are illustrated in Fig. 8 using the most prominent author-provided keywords. The topics were rather distinct (topic diversity: 0.86) and exhibited moderate semantic coherence of 0.58, indicating interpretable topics.

Early cognitive development. A substantial body of research focused on early cognitive abilities from preschool through primary school. These studies explored trajectories and predictors of mathematics, science, and vocabulary development in childhood (see Fig. 8), often emphasizing the role of early cognitive skills (Olaru et al., 2022; Seitz & Weinert, 2022) or self-regulation abilities (Doshi et al., 2024; Quis et al., 2021). Particular attention was given to the influence of home environments (Linberg, Lehl, & Weinert, 2020; Zhao & Gibson, 2023) and institutional settings (Ghirardi et al., 2023; Kähler et al., 2020) in supporting children's skill development.

Reading development. A prominent area of research was the development of reading comprehension, especially during secondary education. Numerous studies examined motivational (Miyamoto, 2024; Miyamoto et al., 2018), cognitive (Gnambis & Lockl, 2023; Jindra et al., 2022), and meta-cognitive (Edossa et al., 2023; Heyne et al., 2023) factors that support reading development. Additional work investigated the role of leisure activities (Locher & Pfost, 2020; Thums et al., 2021) and teaching practices (Attig et al., 2024) in fostering students' reading skills.

Linguistic abilities of migrants. Another theme centered on multilingualism among immigrant students (see Fig. 8) which showed how the acquisition and maintenance of minority language can impact educational achievement (Edele et al., 2018; Novita et al., 2022; Seuring et al., 2020). Further research addressed the role of bilingual educators and their teaching practices in shaping students' educational outcomes (Höckel, 2024).

ICT literacy development. A small but growing body of research focused on predictors explaining individual differences in and the growth of ICT literacy. These studies highlighted how motivational factors, patterns of technology use, and students' background characteristics contribute to the development of digital skills during adolescence (Gnambis, 2021; Hübner et al., 2023; Senkbeil, 2022) and adulthood (Wicht, Reder, & Lechner, 2021).

Personality and achievement. Numerous studies explored the relationship between academic performance and personality traits (see Fig. 8). Many of them focused on the Big Five of personality and revealed domain- and school track-specific associations with achievement outcomes (Brandt et al., 2020; Israel et al., 2019). Other work examined grading practices by analyzing the complex interplay between personality, teacher-assigned grades, and cognitive competencies (Roemer et al., 2022; Westphal et al., 2021).

Self-concept and achievement. Several studies investigated how self-concept and interests impacted students' competence

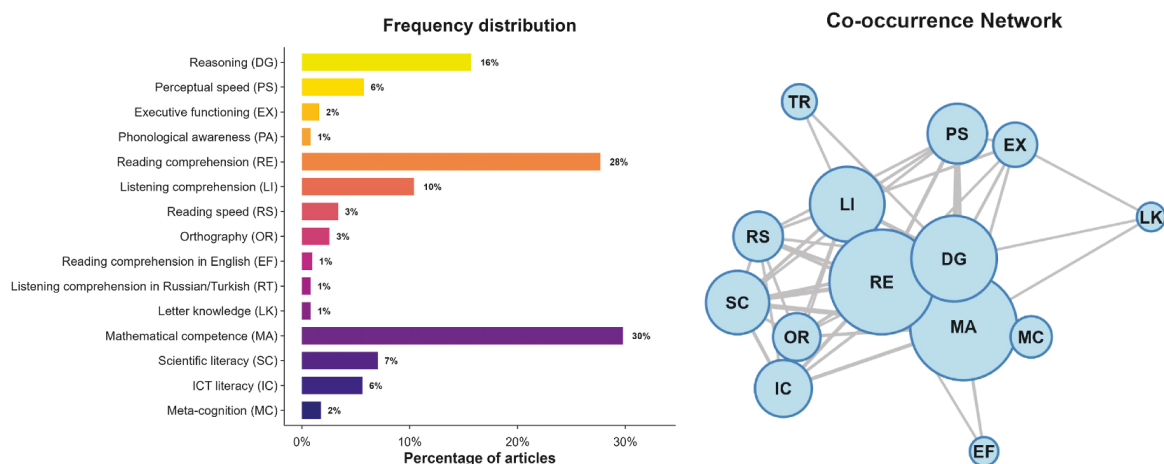


Fig. 7. Percentage of Articles on Research with Cognitive Abilities Using NEPS Data by Cognitive Domain
 Note. The percentage of articles with cognitive abilities do not sum to 100 because a given article may analyze multiple domains.

Table 2

Major topics of articles on research with cognitive abilities using NEPS data.

	Topic	Description	Percentage of articles	Representative articles
1.	Early cognitive development	Examines the development of verbal, mathematical, and scientific skills from preschool to primary school.	6.2% (16.0%)	Kähler et al. (2020) Seitz & Weinert (2022) Zhao & Gibson (2023)
2.	Development of reading comprehension	Studies factors influencing reading comprehension like intrinsic motivation or metacognitive strategies, primarily in secondary school.	2.2% (5.8%)	Attig et al. (2024) Gnams & Lockl (2023) Miyamoto (2024)
3.	Language proficiency and immigration	Investigates the acquisition and maintenance of minority languages and how they affect second-language proficiency and educational achievement.	1.4% (3.7%)	Höckel (2024) Novita et al. (2022) Seuring et al. (2020)
4.	Development of ICT literacy	Studies the development of digital skills among students and adults, including the impact of motivations and digital behavior.	2.4% (6.2%)	Gnams (2021) Hübner et al. (2023) Senkbeil (2022)
5.	Personality and achievement	Examines the relationship between personality traits, cognitive abilities, and academic outcomes such as teacher-assigned grades.	4.8% (12.3%)	Brandt et al. (2020) Roemer et al. (2022) Westphal et al. (2021)
6.	Self-concept and achievement	Examines how self-concept, interests, gender roles, and peer dynamics influence competence development.	1.9% (4.9%)	Ehrtmann & Wolter (2018) Lechner et al. (2019) Schneider et al. (2022)
7.	Extracurricular activities and achievement	Examines the relationship between out-of-school activities like private tutoring and environmental impacts on students' academic achievement.	4.3% (11.1%)	Heyne et al. (2024) Lockl et al. (2021) Nachbauer (2024)
8.	Educational aspirations and tracking	Explores students' aspirations and vocational education, including school tracking in secondary education and school-to-work transitions.	3.5% (9.1%)	Dochow & Neumeyer (2021) Bittmann (2022a) Schörner & Bittmann (2024)
9.	Vocational education and training	Focuses on the transition from school to vocational education and training, particularly for low-achieving students and migrants.	7.7% (19.8%)	Kohlmeier & Fischer-Neumann (2024) Lindemann (2020) Holtmann et al. (2021)
10.	Educational inequalities	Examines the origins and development of social disparities in cognitive development and educational achievement.	3.2% (8.2%)	Nennstiel (2023) Olczyk et al. (2023) Skopek & Passaretta (2021)

Note. The percentages refer to the share of articles in the entire bibliometric database, while the values in parentheses refer to the subset of articles using cognitive abilities.

development in secondary school (Lechner et al., 2019; Schneider et al., 2022). These often emphasized the role of gender-role orientation (Ehrtmann & Wolter, 2018) and social comparison processes (Von Keyserlingk et al., 2021).

Extracurricular activities. Research in this area investigated how extracurricular involvement and contextual factors influence academic outcomes. Studies investigated the effects of private tutoring (Heyne et al., 2024) or support programs in all-day schools (Nachbauer, 2024; Steinmann et al., 2019) on student achievement. In addition, several studies examined the educational consequences of the COVID-19 pandemic, particularly the impact of home learning environments, on educational outcomes for low-achieving students (Hawrot & Nusser, 2024; Lockl et al., 2021).

Educational aspirations and tracking. Another research strand focused on Germany's stratified school system and the role of educational and occupational aspirations. These studies explored how children's and parents' expectations influence each other and shape academic achievement (Dochow & Neumeyer, 2021; Schörner & Bittmann, 2024) and how academic performance predicts educational qualifications such as high-school graduation (Bittmann, 2022a).

Vocational education and training. Several studies investigated the transition from school to vocational training, with particular attention to the pathways of low-achieving students and migrants (see Fig. 8). These analyses frequently aimed at isolating causal mechanisms by controlling for cognitive competencies. Key research questions focused on factors influencing educational decision-making at the transition to upper secondary education (Kohlmeier & Fischer-Neumann, 2024), successful school-to-work transitions (Holtmann et al., 2021), and the consequences of failed transitions (Lindemann, 2020).

Educational inequalities. A prominent theme addressed the emergence and persistence of educational inequalities in cognitive abilities from infancy through adolescence. Numerous studies documented that social disparities in domain-specific competencies such as reading or mathematics often arise before school entry and tend to persist throughout the school years (Nennstiel, 2023; Passaretta et al. 2022; Skopek & Passaretta, 2021). Additional research examined the role of teacher biases in contributing to inequalities in student outcomes (Olczyk et al., 2023; Steinmann, 2024).

5.3.2. Research on contextual information using NEPS data

Although research on cognitive abilities represented a central focus of studies using NEPS data, an additional 316 articles (50.6% of the database) made use of the comprehensive information on contextual and background factors. The articles more frequently involved

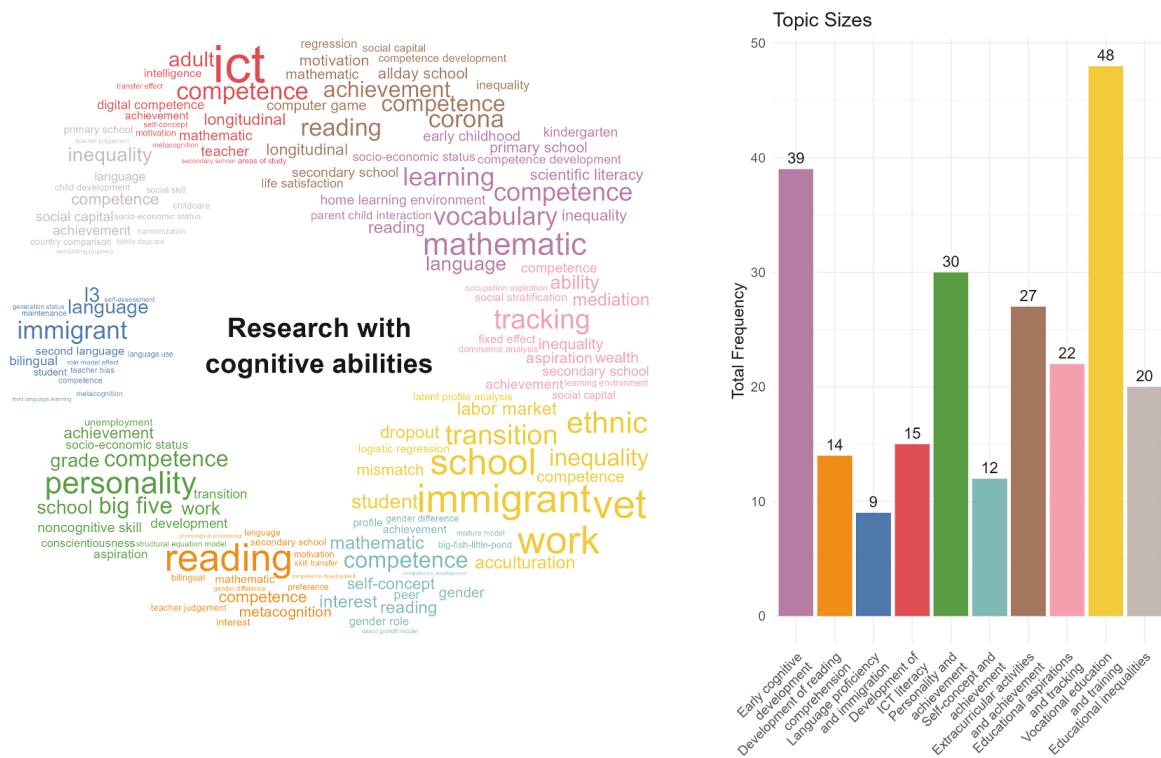


Fig. 8. Author-provided keywords by topic for articles on research with cognitive abilities using NEPS data.

adult participants (see Fig. 6) and addressed a diverse range of topics. About 6% of these studies analyzed several starting cohorts. Topic modeling revealed seven major research themes for articles without a cognitive analysis (see Table 3) which are illustrated in Fig. 9 using the most common author-provided keywords. The topics were again rather distinct (topic diversity: 0.84) with moderate semantic coherence (0.47), indicating interpretable topics.

Child development and education. A research strand examined predictors of socio-emotional development (Huang et al., 2022; Linberg et al., 2020), health (de la Rie et al., 2023; Panico et al., 2023), and well-being (Kleinkorres et al., 2023; Reuter et al., 2024) in young children and adolescents, with a particular focus on vulnerable groups (Goldan et al., 2022) and the role of parental practices

Table 3
Major topics of articles on research without cognitive abilities using NEPS data.

Topic	Description	Percentage of articles	Representative articles
1. Child development and education	Examines the impact of family, social environment, and educational settings on children's socioemotional development, health, and well-being.	11.0% (21.8%)	Huang et al. (2022) Karwath et al. (2023) Goldan et al. (2022)
2. Aspirations and educational transitions	Explores educational and occupational aspirations, educational transitions, and vocational education and training.	9.4% (18.7%)	Beckmann et al. (2023) Fischer-Browne et al. (2024) Wicht et al. (2024)
3. Higher education	Explores predictors and social inequalities in study trajectories and dropout in higher education.	7.8% (15.5%)	Breetzke et al. (2024) Haas (2023) Müller & Klein (2023)
4. Teacher education	Focuses on prospective teachers' beliefs, social competence development, and practice orientation.	3.4% (6.6%)	Carstensen & Klusmann (2021) Costa et al. (2023) Pozas et al. (2023)
5. Adult learning and participation	Explores factors influencing adult participation in non-formal and informal education, civic engagement, and volunteering.	3.7% (7.3%)	Bömmel & Heineck (2023) Granderath et al. (2021) Klinkhammer et al. (2024)
6. Employment and education	Explores the relationship between education and employment in adulthood, including the impact on labor market outcomes.	11.8% (23.4%)	Heß et al. (2023) Zeyer-Gliozzo (2024) dos Santos et al. (2024)
7. COVID-19 impact	Investigates the impact of the COVID-19 pandemic on well-being and working conditions.	2.7% (5.4%)	Bittmann (2022b) Handschuh et al. (2024) Zoch et al. (2022)

Note. The percentages refer to the share of articles in the entire bibliometric database, while the values in parentheses refer to the subset of articles without cognitive abilities.

participation, including civic (Klinkhammer et al., 2024) and political engagement (Bömmel & Heineck, 2023). Research also underscored the importance of education for adult health and well-being (Granderath et al., 2021; Kohl & Martin, 2023).

Employment and education. A major area of research examined the relationship between educational attainment and employment outcomes in adulthood (see Fig. 9). Studies analyzed the effects of education on wages (Kracke et al., 2018), labor market trajectories (dos Santos et al., 2024; Zeyer-Gliozzo, 2024), and phenomena such as overeducation (Schmelzer & Schneider, 2020). Further work investigated factors influencing workers' decision to engage in further education and training (Heß et al., 2023; Rüter, 2022).

COVID-19 impact. Another theme captured the wide-ranging effects of the COVID-19 pandemic on adults' lives, with a focus on parenthood and childcare challenges. This included studies on life satisfaction (Bittmann, 2022b; Handschuh et al., 2024), changes in childcare responsibilities (Zoch et al., 2021), and shifts in working conditions (Zoch et al., 2022).

5.3.3. Methodological research using NEPS data

Methodological research based on NEPS data was the focus of 66 articles, accounting for 10.6% of the bibliometric database. For these studies we investigated three broad areas (see Table 4):

Sampling and data collection. A line of research investigated methodological aspects in survey design and administration such as interviewer effects on survey duration (Pirralha et al., 2024) and data quality in both self-reports (Zoch, 2021) and cognitive tests (Rohm et al., 2021). Additional work examined mode effects and the validity of computer- and web-based testing formats (Gnams & Lenhard, 2024; Zinn et al., 2021).

Measurement instruments and psychometrics. A substantial portion of methodological studies focused on the presentation of new instruments developed for the NEPS (Matthes et al., 2014), adaptations of existing instruments for specific populations (Gnams & Nusser, 2024), and validation studies (Rodríguez Sánchez, 2020). Additionally, studies evaluated different approaches for the scaling of achievement tests (Deribo et al., 2023; Köhler et al., 2015, 2017) or introduced novel psychometric models addressing specific challenges of educational data (Steinmann et al., 2022; Welling et al., 2024).

Procedures for substantive research. Several studies used NEPS data to showcase advanced statistical techniques to support the interpretability and efficiency of substantive research, such as methods for estimating causal effects in nonrandomized data (Sengewald & Mayer, 2024), covariate selection in randomized intervention studies (Stallasch et al., 2024), continuous time dynamic models for longitudinal intervention effects (Hasl et al., 2024), and novel techniques for handling incomplete data (Aßmann et al., 2017; Hammon & Zinn, 2020).

6. Discussion

Education is widely recognized as a cornerstone for individual well-being, social participation, and occupational success throughout the life span, from childhood and adolescence into adulthood. LSAs are key resources that enable researchers to examine educational processes, identify factors that influence academic achievement, and explore broader individual and societal implications of learning using population-representative data (Hernández-Torrano & Courtney, 2021). With the NEPS, Germany has implemented a national LSA with a unique longitudinal, multi-cohort, and multi-context research design that captures the complexities of educational processes over time and allows researchers to trace competence development and educational outcomes from early childhood into adulthood (Artelt & Sixt, 2023; Blossfeld et al., 2019). This review, therefore, set out to assess how NEPS data has been used in empirical research and to evaluate its academic reach and impact.

6.1. Use of NEPS data in research

Within just over a decade, NEPS has become a cornerstone of empirical educational research in Germany and beyond. Despite its focus on a single educational system, the volume and visibility of its research output has positioned it alongside major international LSAs. While about 20% of publications appeared in German, reflecting its importance for the national research community, the majority were published in internationally renowned journals with above-average reputation. Their citation patterns, furthermore, underscore that the NEPS is not confined to the national discourse but is part of broader international debates on educational processes and competence development.

The disciplinary spread of publications showed the broad appeal of NEPS as a data infrastructure. As expected, research in education, sociology, and psychology constituted the core of NEPS-based publications. However, its use in related fields such as economics, demography, and statistics illustrates that NEPS supports diverse research agendas.

6.2. Thematic breadth of NEPS-based research

The thematic analysis of the reviewed literature revealed several key research areas. Central among them are studies on cognitive competencies which constitute one of the core pillars of the NEPS (Weinert et al., 2019). These studies predominately focused on children's early cognitive development, the acquisition of various domain-specific competences such as reading, the study of educational inequalities across the life course, and interplay between academic achievement and personality. The diverse themes explored using NEPS data underscore its versatility for understanding the origins, development, and consequences of cognitive abilities across different educational stages and social contexts. In addition, NEPS data was also prominently used for the study of non-cognitive skills, higher education, and labor market participation. Furthermore, the longitudinal research design and complex data structure made

NEPS an appealing source for methodological developments in survey design, psychometrics, and statistical techniques.

Despite the extensive research potential offered by the NEPS, scholarly attention has been unevenly distributed across topics. Research on cognitive competencies has largely concentrated on mathematical and reading abilities. This is partly a consequence of their coherent and repeated assessment across all cohorts and because they represent fundamental skills for successful participation in modern societies. In particular, sociological research on educational transitions and social inequality research frequently relied on these domains as indicators of general educational attainment (e.g., [Nennstiel, 2023](#); [Schörner & Bittmann, 2024](#)). In contrast, other competence domains have received comparably less attention and are more commonly addressed within educational and psychological studies with more specialized research interests in specific domains such as scientific literacy ([Kähler et al., 2020](#)), minority-language skills ([Edele et al., 2018](#)), or meta-cognitive abilities ([Edossa et al., 2023](#)).

A further notable focus of NEPS-based research was on early child development. NEPS is one of few longitudinal large-scale studies that provides comprehensive longitudinal data on psychological functioning from infancy onward. Developmental research, which has traditionally relied on small and often selective samples ([Doebel & Frank, 2024](#)), thus benefits substantially from access to large-scale, high-quality data that are rarely available in this field ([Attig et al., 2023](#)). At the same time, NEPS offers rich biographical data on educational and occupational trajectories across the life course. The detailed information on school transitions, vocational training, and labor market participation, particularly in the adult cohort, made NEPS an especially valuable data source for sociological research on education, employment, and life course dynamics (e.g., [dos Santos et al., 2024](#); [Zeyer-Giozzo, 2024](#)).

6.3. Multi-cohort sequence design of the NEPS

One of the distinctive strengths of the NEPS lies in its multi-cohort sequence design (see [Fig. 1](#)), which captures different stages of education and lifelong learning by following several age cohorts simultaneously. This design allows for both longitudinal analyses within cohorts and cross-cohort comparisons of competencies assessed within a common overarching framework ([Weinert et al., 2019](#)). In principle, it thus offers unique opportunities to examine developmental trajectories, cohort effects, and structural changes across the life course. To date, however, fewer than 10% of published articles have fully exploited this potential. Although integrative analyses of multiple cohorts are methodological demanding (e.g., [Aßmann et al., 2024](#); [Kezios et al., 2024](#)), several studies have used this approach. Researchers have combined data from different cohorts to construct synthetic life-course trajectories ([Skopek & Pasaretta, 2021](#)), to compare age groups across cohorts ([Nennstiel, 2023](#)), or derive meta-analytic estimates across cohorts ([Brunner et al., 2024](#)).

Notably, cross-cohort approaches were more prevalent in research on competencies, for which the NEPS represents a rare source of longitudinal achievement data spanning multiple age groups. Consequently, studies on cognitive development primarily drew on the childhood and school-based cohorts that allowed studying educational and developmental trajectories. In contrast, research with the age-heterogenous student and adult cohorts has more frequently focused on non-cognitive outcomes across educational stages.

6.4. Research gaps and opportunities for future research

Despite the considerable body of NEPS-based research, several important areas remain underexplored. The following topics illustrate examples of prominent gaps that offer promising opportunities for future inquiries into educational achievement and cognitive development using NEPS data.

To date, NEPS-based research on cognitive abilities has focused predominantly on reading comprehension (and its precursors) and mathematical competencies. In contrast, scientific literacy and ICT literacy have received disproportionately less attention, although both domains are assessed longitudinally and coherently in all cohorts. This imbalance is rather noteworthy given the increasing societal importance of STEM competencies. Scientific literacy, for example, is essential for individuals to engage with pressing public issues such as climate change, vaccination, and artificial intelligence ([Fischer et al., 2022](#); [Lindeman et al., 2023](#)). Similarly, ICT literacy has become a key competence in the digitalized labor market and knowledge society. With rising concerns over scientific skepticism and online misinformation (e.g., [Arechar et al., 2023](#); [Rutjens et al., 2021](#)), key challenges for modern society include the understanding of how these competencies develop, what social, educational, and institutional factors facilitate or hinder their growth, as well as projecting their long-term consequences for occupational and civic outcomes.

Another underexplored area pertains to adult literacy, particularly their role in shaping labor market outcomes. While a few studies have examined the development of literacy and numeracy in adulthood (e.g., [Lechner et al., 2021](#); [Wicht, Rammstedt, & Lechner, 2021](#)), only a limited body of research has investigated the practical consequences of these competencies. Notable exceptions include studies on reemployment after unemployment ([Gnams, 2017](#)) and the mismatch between job requirements and actual abilities ([Bischof, 2021](#)). However, most of the available studies focused on educational qualifications rather than actual abilities, leaving the broader potential of NEPS data in this area unused. The NEPS is one of rather few LSAs that includes repeated measurements of adult competencies alongside extensive longitudinal data on employment histories and income trajectories from administrative register data ([Bachbauer et al., 2022](#)). This provides a rare opportunity to explore how adult cognitive skills influence career progression and income development without relying on error-prone self-reports of occupational histories. Future research should, therefore, more fully exploit these data linkages to study how competencies predict upward and downward mobility or how economic conditions interact with cognitive development in adulthood.

A unique feature of the NEPS is the opportunity to link geographical information to the survey data. While some studies have used this approach to explore regional influences on educational decisions such as university enrollment ([Weßling & Bechler, 2019](#)), its potential for research on cognitive abilities remains largely untapped. A notable exception is a study that linked long-term exposure to

low-dose radiation (due to rainfall patterns following the Chernobyl disaster) to adult cognitive performance (Elsner & Wozny, 2023), thus exemplifying the potential of the NEPS for investigating how environmental or structural factors shape cognitive outcomes. Future research could extend this line of inquiry by integrating regional data on school quality, air pollution, teacher shortages, or local economic conditions to explore their effects on competence development across the life course.

Finally, although the NEPS was designed to study educational processes from a life course perspective, little research has addressed how major life events impact competence development or how competencies influence the likelihood or outcomes of such transitions (e.g., Garrouste & Perdrix, 2022; Vélez-Coto et al., 2021). The retrospective and prospective data on events such as family formation, unemployment, and retirement provides a unique opportunity to analyze the dynamic interplay between life events and cognitive development. For example, research could investigate whether job loss leads to declines in cognitive abilities, whether maternity leaves disrupt adult learning trajectories, or how competencies affect the timing and outcomes of retirement.

These examples, while not exhaustive, underscore that the full potential of the dataset remains underutilized in several important areas. The NEPS provides ample opportunities for future longitudinal and contextualized research on educational processes and cognitive development in Germany.

6.5. Limitations of the study

Several limitations of the review may affect the generalizability and comprehensiveness of the reported findings. First, the review focused exclusively on peer-reviewed journal articles, while excluding book chapters, dissertations, working papers, and other forms of gray literature. Given that NEPS data is frequently also used in student theses and non-peer reviewed outlets, the scope of identified research themes may not fully capture the breadth of work using NEPS data. Second, the review considered only publications reporting secondary data analysis, while NEPS-related findings are also cited in policy documents and institutional reports, which were not included. Consequently, the broader societal and policy impact of the NEPS is likely underestimated. Third, the study did not evaluate the quality of the reviewed publications. While the goal was to identify general trends in NEPS-related findings, it is important to recognize that the rigor of the data analysis varied across studies. Researchers should therefore carefully assess the methodological soundness of existing research before drawing on these findings. Finally, the adopted topic modeling approach, though effective for uncovering dominant themes in large text corpora, is inherently exploratory. Therefore, it may not reliably detect specialized or emergent research areas that are underrepresented in the database. Extending the present review with a qualitative content analysis may help identify more subtle trends and niche research themes that are not easily captured by automated text analysis.

7. Conclusion

The NEPS represents a unique German LSA that has substantially contributed to both national and international educational research over the past decade. Its longitudinal, multi-cohort design combined with a multi-contextual perspective has established the study as a leading data source across a wide range of academic disciplines. As demonstrated in this review, the research output based on NEPS data is comparable to and in some cases even exceeds that of many international LSAs. The breadth of topics addressed using NEPS data spans the entire life course, from early childhood through adulthood, encompassing both institutional learning environments and home contexts. While children's cognitive development and educational achievement in primary and secondary school were key foci, NEPS-based research also extended to higher education, school-to-work transitions, and career development in adulthood.

Despite the wealth of existing findings, this review also highlighted several underexplored areas that offer opportunities for future investigations. In particular, studies on adult literacy, the role of scientific and digital literacy in modern society, and the impact and consequences of life events remain relatively scarce. The combination of survey and competence data with rich geographical and administrative information makes the NEPS a unique data source to address novel and innovative research questions in this area. By drawing attention to these gaps, we hope to encourage researchers to capitalize on the potential of the NEPS and to further contribute to our understanding of educational processes and competence development over the life course.

Author contribution

Conceptualization: TG; Data curation: TG; Formal analysis: TG; Investigation: TG, MS, TK; Methodology: TG, MS; Project administration: TG; Software: TG, MS, TK; Supervision: TG; Visualization: TG, MS, TK; Writing – original draft: TG; Writing – review & editing: TG, MS, TK.

Ethical statements

The research did not involve human participants or animals and was thus exempt from institutional review.

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Conflict of interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.edurev.2026.100788>.

Data availability

The full data cannot be publicly shared because of copyright restrictions. A partial dataset and the analysis code are provided at <https://osf.io/vh8t5/>.

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