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DATA INFRASTRUCTURES AND THE (AMBIVALENT) EFFECTS OF RISING DATA INTEROPERABILITY

Insights from Germany

Sigrid Hartong, Annina Förschler, and Vito Dabisch

Introduction

With digital data playing an increasingly substantial role in educational practices and system monitoring, so too do the efficient and effective organization of these data. This organization refers to the networks of objects (the data itself, hardware, and software, but also policy "fragments," such as educational standards or funding formulas) and subjects (e.g., technicians, administrators, school actors, and intermediary agents) assembled around data and their socio-technical decontextualization, and recontextualization processes (data infrastructures; Hartong, 2018, p. 135). The implementation of such data infrastructures usually includes the advancement of data interoperability, which has been defined as the "ability of different information systems, devices or applications to connect, in a coordinated manner, within and across organizational boundaries to access, exchange and cooperatively use data amongst stakeholders" (Healthcare Information and Management Systems Society, Inc., 2020, para. 1). Data interoperability provides, as reform promoters argue, tremendous benefits, including fast data exchange (i.e., for teachers who need information about mobile students, for districts or schools who need to fulfill ongoing reporting requirements), an easy way to adopt personalized digital learning technologies to foster data-intensive research, and much more (US Department of Education, 2020). Pangrazio (2019) asserts that efficiencies can be achieved, saving time and money, if school data systems are made interoperable so that they can "speak to" each other without a "human intermediary." She continues that this has the advantage of enabling

> greater fluency of data across the various domains of a student's schooling experience – from enrolment and behavioral information to learning and

DOI: 10.4324/9781003045793-8

> reporting. Interoperability has the potential to streamline the sharing of information in ways that impact upon all aspects of student success and wellbeing.
>
> *(para. 7)*

Driven by such potential, numerous initiatives and massive investments have emerged worldwide to increase data interoperability, including the implementation and/or expansion of so-called interoperability frameworks and/or standards. Examples include the globally active Schools Interoperability Framework (SIF) by Microsoft (now Access4Learning; see Sellar, 2017, SIF Association, n.d., Wyatt-Smith et al., 2019), the US-provider "Ed-Fi Alliance" (see Ed-Fi Alliance, LLC, 2020), but also a range of smaller or sector-specific initiatives and standard-promoting actors, such as the German Alliance for Education (see Bündnis für Bildung [bBfB], 2019). At the same time, data interoperability is also dependent on underlying technical infrastructure that allows data to be collected, processed, and used, which, as reform promoters bemoan, has remained widely deficient in many countries.

In fact, such a functional yet often technically framed understanding of data infrastructures still shapes many debates on the opportunities (i.e., infrastructures are built and interoperability increased) and challenges (i.e., both are hindered) of digitalization (Förschler, 2018; Hartong & Förschler, 2019). Simultaneously, however, there is an emerging body of scholarly work that uses data infrastructures as a fruitful conceptual and methodological tool to trace the ongoing datafication and digitalization of education from a critical perspective (Sellar, 2015, 2017). Equally, the focus is placed on the organizational process of datafication (including data interoperability), yet this process is understood as carrying substantial power nested in the selective "relation-making" and the "in-formation" of objects and subjects into "flowable" data (Hartong, 2020). In other words, attention is paid to the ongoing socio-technical (de)recontextualization practices ("infrastructuring") needed to make data relational with other data. This is to legitimize these data as neutral, valid, and "holistic" representations of education, and to make these data relevant for educational actors.

This relational understanding of data infrastructures also explains why they could be substantially disruptive for education, through the creation of a different form of policy or practical context "that 'deforms' the existing jurisdictional systems and relationships" (Gulson & Sellar, 2018, p. 10). This can occur between educational actors, institutions, or systems, as well as between public and private or between state and non-state entities. Put differently, there appears to be a pressing need to understand the who and how of data "in-formation" and relation-making, which includes multiple "data mediators" (Hartong, 2016) or "boundary brokers" (Williamson, 2016) acting within or around data infrastructures. This understanding also needs to consider the often-hidden logic of infrastructural rule-setting and valuation (Mau, 2019), which may deeply affect how education is governed based on infrastructural (de)contextualization.

Data interoperability standards are a good example for tracing such moments of rule-setting and valuation as well as (de)contextualization. This is because they build on the definition of meta-data and data models, which not only regulate which data can enter the infrastructure and be transferred from one place to another, but also how they can be algorithmically processed and, consequently, what type of information can ultimately be produced from the data infrastructure (Kubicek et al., 2019). It is standardized rule-setting (including defining data formats, data business rules or terminological frameworks of data collection) which makes data interoperability a moment of significant "disruption," as it appears increasingly important with every investment in reducing data duplication and data alternatives for measuring "apparently" the same phenomenon.

Additionally, while the initial development of data interoperability frameworks might involve substantial debate and multiple stakeholders, such frameworks have become "ready to use" products, often promoted by powerful alliances or aligned with already dominant commercial software products (such as Microsoft), and willingly accepted by educational actors who lack time and technical and financial resources. As Pangrazio (2019) observes,

> given the commercial tensions and competing interests in many areas of data and software use, the push for establishing interoperability in particular markets and sectors often falls to industry-wide groups and community interests who act as catalysts for awareness-raising, campaigning and eventual brokering of agreed standards.
>
> *(para. 5)*

While data infrastructures and data interoperability offer multiple fruitful entry points to increase critical awareness for their disruptive potential, this goes well beyond the rise of "big data," but rather occurs for any kind of data collected through such infrastructures. Simultaneously, it seems important to not underestimate the high level of context sensitivity associated with data infrastructures. For example, as more recent comparative data infrastructure analyses show, influences of national, sub-national, and local factors – such as specific accountability regimes, politico-administrative traditions, or data protection legislation – can deeply affect the actual emergence, operation, and partly also deliberate restriction of data infrastructures (Hartong & Förschler, 2019; Lingard, 2019; Takayama & Lingard, 2019). A similar contextuality occurs when distinguishing between different types of data infrastructures, such as infrastructures for policy development, for accountability, or for school practice (Hartong et al., in press). There might also be great differences between different "stages" of development or sectors within individual data infrastructures, such as modelling, administration, piloting, data collection, or reporting (Hartong & Piattoeva, 2019; Kauko et al., 2018). Finally, distinctions must be made regarding different types of data interoperability, which not only include its level (for example, the interoperability of

data formats or of workflows), but also whether data collection is actually centralized or if subsystems are made interoperable without data centralization. An example of this is the German Core Data Set (Kerndatensatz [KDS]), which is discussed in detail later in this chapter (see Kubicek et al., 2019).

Following such a context-sensitive approach to better understand the disruptive potential of data infrastructures and interoperability, the goal of this chapter is to provide empirical insights into the German case which, when compared with other countries, can be regarded as a datafication and digitalization latecomer. Still, over the past decade, major transformations have been initiated, which have not only included significant expansion, standardization, and centralization of both administrative and performance data in school systems (Hartong & Förschler, 2019; Lange et al., 2014), but also – and particularly since 2012 – a growing investment in digital teaching and learning tools. While we demonstrate how context-specific conditions of possibility (Savage, 2019) strongly mediated and partly restricted data infrastructuring in Germany, we also show that emerging data infrastructures have started to change these very same conditions and will most likely become more powerful in the future. We explicate this (see "Understanding the 'disruptive' potential of data infrastructures" section below) using the transformations of standardized testing, state school monitoring, as well as school platforms/learning management systems as examples. The chapter closes with a summarizing discussion and questions that are yet to be addressed.

The German "Context" of Datafying and Digitalizing Education

Different from countries that have already created extensive educational data infrastructures and systems of e-governance such as Australia, the United States, or the United Kingdom (Hogan et al., 2016; Koyama, 2011, Ruppert, 2012; Williamson, 2016), in Germany, datafication and digitalization policies emerged much more cautiously. There are different context-specific reasons that can be identified for Germany's reluctance (see Hartong, 2019; Hartong et al., 2020). One is the German federal constitution, as states hold almost all responsibility for educational governance and use bodies, such as the Standing Conference of the Education Ministers of the German States (KMK), to defend this authority against the Federal Ministry of Education (BMBF). This also includes the centralization of data. Simultaneously, German federalism is characterized by a distinction between inner and outer school responsibilities, with the states being responsible for everything related to the content of schooling (including hiring and paying teachers, curriculum development, monitoring) and local communities being responsible for school buildings, administrative staff, and technical infrastructure (Hartong et al., 2020). To date, this distinction is reflected in the lack of links between school administration systems, statistical data, monitoring systems, and performance data.

After a shocking performance in the Programme for International Student Assessment (PISA) in 2001, German policymakers announced a "turn" towards

data-based, output-oriented governance (including the implementation of national education standards and standardized testing), followed by broad initiatives to expand, better coordinate, and centralize both administrative and pedagogical data, including performance data (Lange et al., 2014). Part of these initiatives was the KMK Core Data Set resolution in 2003, in which – for the first time in German history – the states agreed to record a defined amount of nationally standardized, individualized data (including school, student, and teacher data, yet excluding test performance data). In subsequent years this initiative strongly pushed the infrastructuring of educational data across policy spaces within the German federation. At the same time, and as mentioned earlier, the KDS did not nationally centralize the data collection, but rather all disaggregated data remained within the individual state data systems. Still, however, there was a significant increase of interoperability because state data was now (supposed to be) collected in the same way. A centrally assigned student identification number – which was discussed in the beginning stage of the KDS implementation – was abandoned due to heavy protest from many states, teachers, and students. Instead, numerous states introduced their own student identification systems.

During that reform period, the influence of context also became clearly visible regarding a strong traditional skepticism against the marketization and for-profit actors in the governance of education. Hence, within emerging data infrastructures it was often research and public institutions (sometimes even established for that purpose) that became responsible for (and potentially then contracted out elements of) the development of testing, reporting, and data management tools. To date, it has remained significantly more difficult for the EdTech industry to build up or directly enter the datafication and digitalization market in Germany, compared with other countries around the world (Hartong & Förschler, 2019).

Finally, the German context can be characterized as a system of rather high teacher professionalism and autonomy, long governed through a combination of extensive professional training and the state provision of "input" resources. As a consequence, skepticism against any kind of high-stakes data, standardized or external testing, and ranking of schools has remained high, which also means teacher (but also student) data related to any performance measurement are highly protected.

While all these factors deeply affected the implementation and operation of data infrastructures and restricted data interoperability, policy developments also show how these *de facto* factors became increasingly confronted with the centralizing and standardizing, often self-reinforcing, dynamics of data infrastructuring (Hartong & Förschler, 2019), as well as with a growing number of reform promoters, particularly with the rise of the "digital agenda" after 2012 (Förschler, 2018). Since 2012, there has been a remarkable explosion of new intermediary policy networks, which brought together actors from various sectors and levels of policy, either directly (e.g., Bitkom, Digital Education Pact) or more indirectly (e.g., Alliance for Education/BfB, Forum Education Digitalization/fbd), interwoven

with EdTech interests. All of them characterized Germany as dramatically lagging globally, regarding either digital education in general, or data infrastructures and interoperability in particular, as well as hanging on to an outdated federal policy architecture. Simultaneously, actors such as Dataport (see Dataport, n.d.) or the IT planning council[1] (see IT-Planungsrat, 2020), increased their investments in cross-state collaboration, data system transfer, or harmonization, as well as in coordinating the work of statistical offices at state and national levels (Hartong, 2019). This to a growing extent fostered cross-state (not supra-state) data infrastructuring, while bypassing the "old" political conflict. In various states, this also included multiple data security law adaptations, which explicitly allowed individual data to leave the schools, but not the states, if anonymized.

In 2016, both the BMBF as well as the KMK responded to these shifting policies by politically cementing a digital agenda, which heavily supported data infrastructuring, centralization and standardization. Pushed by the BMBF and KMK initiatives, 2017 and 2018 saw extensive digitalization, including the implementation of numerous digital education platforms that increasingly use single sign-on (SSO) identification tools. Such products not only envision the digital classroom, but also facilitate the linking of data generated via learning tools with other monitoring data, such as school information systems, test data, and school statistics (Hartong, 2018).

While it remains to be seen how these developments will further change the German education context, the policy transformations thus far point to the ambivalent role data infrastructuring has played, ranging from contextual restriction/mediation to infrastructure-driven change (disruptive potential) of educational (policy) context. The following section is devoted to a better understanding of this ambivalence, using three different examples.

Understanding the "Disruptive" Potential of Data Infrastructures: Three Examples from Germany

The three examples illustrated in this section point to data infrastructures that emerged for distinct purposes (for example, data to inform policymaking, monitoring of schools, and/or improvement of classroom practice). These reflect the influence of the contextual conditions of possibility mentioned earlier in this chapter, but simultaneously the substantial de-/re-contextualizing dynamics set free by the processes of infrastructuring.[2]

The Transforming Infrastructures of Standardized Assessments

After the turn to the 21st century, two "nationally" standardized assessments were introduced in Germany: (1) the sample-based Bildungstrend to compare aggregated performance data of the states and their subsequent fulfillment of the national standards set in relation to the reforms, and (2) the census-based Vergleichsarbeiten (VERA) to improve classroom practices, based on the measurement of individual

students' performance, which was again oriented towards the fulfilment of national standards.

Both assessments originated from different contexts. The Bildungstrend had its roots in an oversampled PISA study to compare the states' performances in the assessment, but after 2006 it was transformed and re-designed to monitor the states' educational standards achievements and was then institutionally transferred to the newly established Institute for Educational Quality Improvement (Institut zur Qualitätsentwicklung im Bildungswesen [IQB]), under the supervision of the KMK. Still, the Bildungstrend was supposed to generate meta-knowledge about states' average performance and thus inform national policy and overall system monitoring.

In contrast, VERA originated from a test initiative by seven German states in 2004, coordinated by a university in southern Germany but used individually and very differently in each of the states to support teachers in improving classroom practices. VERA was not used for accountability or for policy development. Triggered by the emerging national reform agenda and the monitoring strategy of the KMK, however, both assessments became integrated officially into one coherent testing infrastructure, obligatory for all states and aligned with the national education standards, with the IQB taking over coordination (Hartong, 2018). This is an example of the way in which changing infrastructure alters the policy and governing context of schooling, with the IQB now not only producing extensive datapools between local, state, national, and also international contexts, but also aligning these different test contexts and contents into one coherent, standardized (and in that sense interoperable) meta-frame.

Still, however, the testing infrastructure remained significantly restricted, which is clearly visible when looking at the different parts of the infrastructuring process of test data. While the IQB is completely responsible for developing, administering, and reporting the Bildungstrend, VERA has taken the lead in developing, piloting, and scaling the tests (which also is an important practice of valuation), as well as providing standards-aligned learning tasks for teachers to support test preparation and test-related skill achievement. The states have remained responsible for administering VERA and for mediating the test data between schools and administration individually, including optional adaptations and modularization of the test due to schools' individual needs (see IQB, n.d.-a). Additionally, no individual test data are reported back to the IQB, but only aggregated data samples for test piloting and further development. The states are required to refrain from grading the test or publishing and publicly ranking the test data of individual schools (KMK, 2018). As a result of these restrictions, VERA not only still varies considerably between the states, but there is also a deliberate waiver of interoperability regarding the links between test data and grading, public platforms and also supra-state collection of individual test data (see Hartong & Piattoeva, 2019). Nevertheless, there are still significant consequences of the ongoing VERA transformations, which refer to the gradual centralization/expansion of testing into/within the IQB (lately

also including the development of nationally standardized school graduation tasks, see IQB, n.d.-b). These transformations have made state test data gradually more, though not fully, interoperable. It remains to be seen how this will change further with VERA now gradually transforming into an online assessment (for example, Institut für Schulqualität der Länder Berlin und Brandenburg e.V. [ISQ-BB], for the states Berlin and Brandenburg, see ISQ-BB, n.d.) and some states already grading and reporting the test results via digital online portals (e.g., Zentrum für Empirische Pädagogische Forschung [zepf], see zepf, 2020). At the same time, there is also growing data interoperability *within the individual states*, namely between VERA data collected in the schools/for classroom development and the data systems used in the state agencies for monitoring school performance and development, explicitly made possible with the KMK's VERA resolution of 2018.

The Transforming Infrastructures of State School Monitoring

With the rise of the national education reforms, German state-level education agencies (Bildungsbehörden auf Bundeslandebene) have been urged to produce growing amounts of nationally standardized data (including the KDS and the aforementioned tests) and to use that data for more effective and efficient school leadership and monitoring. Consequently, over the past decade, investments in data infrastructures and interoperability have significantly increased, which includes data transfer between individual schools and state agencies, but also includes data transfer within different state agencies' institutions, departments, or sectors.[3]

Again, the German states approached data system transformations differently. States opted early on for either a centralized solution, in which data from all schools within the state were collected within the same data systems, or they held on to a decentralized solution, in which school data systems vary but a growing amount of standardized data reports are required to be submitted to centralized state databases (Hartong et al., 2020, p. 7). Unsurprisingly, the number of states choosing a centralized (though potentially voluntary) solution has grown, and this trend seems likely to continue in the future. This is also due to the fact that in many cases, states have either joined forces and bought (or received free-of-charge) systems from other states, or they have partnered with external providers that produce solutions for multiple states. Some of the many examples of this are Hamburg, which adopted and further developed Brandenburg's school management software WeBBSchule, and Bavaria and Baden-Wuerttemberg, which each developed its system in collaboration with the private provider ISB AG (which hosts the system edoo.sys; ISB AG, 2020).

At the same time, as mentioned above, in many states, there has remained a significant infrastructural gap between the organization of performance data – often exercised by newly founded quality and/or school monitoring institutes (Rürup, 2018) – and the more traditional organization of school statistics and

resource planning. Often this occurs in concert with the statistical institutes of the states, which serve more sectors than education. For example, in Hamburg, most education data within the state school agency are centrally stored within a data warehouse, and data generated by the quality institute are still organized within a separated database. For the quality institute's work with statistical data, it receives selected data cubes from the state agency. Thus, the fragmentary nature of many school monitoring infrastructures (see Breiter & Lange, 2019) goes well beyond the gap between statistical and performance data.

Despite this fragmentation, there has been a clear shift towards data-based school supervision and consultancy practices, such as setting target agreements with principals for school development. Data used for this purpose range from financial and resource information, to aggregated test or graduation exam data and class cancellations. Different from the IQB that aligns tests nationally (see previous section), data are usually reported separately, often based on distinct data formats, time frames, or meta-data, even though some states (such as Hamburg, Brandenburg, and Bremen) try to integrate them into "at a glance" school data profiles. As mentioned previously, the German system is also characterized by a rather high skepticism towards high stakes testing data, which is especially true in relation to the usage of such data for holding individual teachers accountable. For instance, individual class or student VERA data should not be included in school supervision[4], but also unfulfilled target agreements or performance measurements in most cases do not lead to any formalized "hard" consequences for the schools (such as in the United States; for Berlin, see Baur, 2016). Importantly, this does not mean that the context of school supervision and consultancy has not become, or is increasingly becoming, affected by the ongoing infrastructuring dynamics, but rather that it seems important to closely trace how and where it is occurring.[5] Hereby, a key role is apparently played by a growing number of anonymization initiatives (in Germany, it is referred to as "pseudonymization"), which in many states have made it possible to process individual (particularly longitudinal) student and teacher data beyond the school level. Additionally, as recent debates on the implementation of a national education register indicate, transformations may lead Germany to nationally centralized individual databases (Fickermann & Weishaupt, 2019).

The Transforming Infrastructure of School Platforms and Learning Management Systems

The third example that illuminates the ongoing dynamics, as well as the disruptive potential of data infrastructuring in Germany, is the rise of school platforms and learning management systems (LMS).[6] Driven by the goal to support digital learning and teaching, while simultaneously making school data management more efficient, such platforms or LMSs often combine features such as file storage, communication interfaces, calendars, curriculum development tools,

learning analytics and grading management, classroom organization, school administration, and human resource management. This means that a context-sensitive approach needs to consider the included features of a particular platform or system, how it is used by different users, and how it relates to other kinds of data infrastructures.

While school platforms or LMSs are still less common in Germany than in many other countries, their implementation significantly increased with the rise of the digital agenda after 2012, particularly with the national digitalization initiatives of 2016. As a result, a growing number of schools have implemented some kind of LMS, either individually or as part of a city- or state-led initiative. Again, there are substantial differences between the states, meaning that they each offer different market conditions for vendors. Some states developed one "ready-to-use" LMS (either through in-house initiatives or through the buy-in of vendor products), and they actively encourage schools to use that standardized technology. At the same time, even though particular vendors operate within different state markets (such as the platform itslearning), there is, at least so far, no cross-state LMS or platform operation. This disparity recently caused the federal government to initiate a national school platform solution (named School Cloud) by the SAP-associated (SAP, n.d.) research institute Hasso-Plattner-Institut (HPI; see HPI, 2020). While this initiative is still in its infancy, it recently gained tremendous momentum with COVID-19 school closures.

Simultaneously, and in response to this competing national platform initiative, mid-sized LMS providers increased their efforts and gained substantial market influence in Germany, such as itslearning. Originating from a Norwegian initiative in 1998, itslearning has become one of the leading LMS providers in Europe and beyond, until it was recently sold to the global investment organization Sanoma (Sanoma, 2019)). Itslearning is a web-based platform for learning materials, grading, curriculum design, communication, and school administration, while simultaneously offering multiple interfaces to applications, including encyclopedias, online-tutoring, and subject-specific learning tools. At the same time, itslearning actively promotes data interoperability among different stakeholders, including automated data exchange across school, parent, and state agency databases, but also features classroom data for monitoring and reporting purposes (itslearning, 2020).

In Germany, itslearning gained particular attention as part of a public-private partnership in the state of Bremen, where the state education agency not only made the platform available to all its schools, but also integrated itslearning into standard preparatory training for principals at the Bremen Institute for Teacher Training. The platform receives individual student and teacher data from the central state school monitoring system to more easily create classes, courses or to assign tasks to students.[7] At the same time, the vendor and the Bremen school consultancy agency (Institute for Schools [LIS]) worked together to refine and adapt the platform to the German/Bremen context. Importantly, this included

prohibiting (technically deactivating) the processing of teachers' and students' log data and also the usage of itslearning data for any kind of supra-school monitoring.

Additionally, despite its state-wide application, schools in Bremen still widely differ in how they use itslearning. While some schools and individual teachers use the platform primarily as a file storage and communication tool, others transferred significant amounts of pedagogical tasks to the platform. Interestingly, as with the dynamics described previously in this chapter, the more schools work with itslearning, the more it seems to stimulate more extensive usage, digital centralization (of administrative and pedagogical/performance data), and the elimination of alternate products.

Conclusion and Outlook

As the three examples show, Germany offers an interesting case to trace both the importance of (restricting) conditions of possibility when seeking to understand data infrastructures and interoperability, and the actual power, or the disruptive potential, of data infrastructures for education policy, governance, and practice over time. As argued at the beginning of this chapter, this potential derives mostly from ongoing standardization (as visible in the alignment of state school monitoring infrastructure among states) and centralization (as visible in the VERA testing infrastructures or in the case of itslearning). Both include significant shifts of discourse, actor constellations, but also substantial decontextualization and recontextualization regarding which data are collected, how, by whom, and for what purpose. While the German context might, in many ways, still thwart the infrastructuring of data a lot more than is the case in other countries, in Germany such discourse and actor shifts as well as de- and recontextualization processes are already clearly visible. As an example, while the implementation of a national student identification number was heavily pushed back 15 years ago, more recent debates on a national student register go almost unnoticed by the opponents of data centralization. One important reason lies in the aforementioned shift towards "pseudonymization" as a working solution to protect individual student data, while still making these data usable for policymaking or research (see Fickermann & Weishaupt, 2019).[8] Here, Germany mirrors global discourses on data infrastructure and interoperability, which today have often either shifted towards questions of (deficient) functionality or towards requesting "good" data security laws (often named "safe data"), the fulfillment of ethical considerations or the alignment of data (collection/processing) to standards (see Wyatt-Smith et al., 2019).

While we do not argue that legal and ethical issues are not extremely important, particularly given that data misuse or abuse is still prevalent, our point is that a critical perspective on data infrastructures and interoperability should not focus on these issues alone. Put differently, important questions could be neglected as soon as the focus is put solely on the definition of standards, ethical checklists, or

data ownership – all of which are not only limiting, but actually also further push (because they legitimize a particular way of) data infrastructuring. For example, what is the actual difference between individual data being collected anonymously or non-anonymously within a nationally centralized database, when in both cases these data cause "real" consequences for policy and governance? Why could it be problematic to have all data collection (done either by public or private actors) following the same standard instead of provoking disagreement, tension – or even critical reflection – on rules of data in-formation and, thus, on the ongoing politics of data and data infrastructures?

Consequently, if we take these kinds of questions seriously, a major implication for action lies in strengthening the awareness and critical understanding of data infrastructuring as the emergence of "educational settings" (Decuypere, 2019), which to a growing extent "in-form" what is made visible and acted upon as schooling. In other words, only if we better understand why such infrastructures are educational, or disciplinary, on whom and how (and here is a pressing need for further research), the modes and effects of their disruption can be grasped, problematized, and ultimately regulated. This does not mean that infrastructures form fixed modes of governance. As the case of Germany shows, data infrastructures reveal an ongoing dynamic, while always being dependent on their actual enactment, for example, by people using the data. At the same time, as the illuminated examples made clear, even for the latecomer Germany, it is this ongoing, self-reinforcing dynamic that warrants sustained global attention.

Disclosure Statement

The presented research was funded by the Deutsche Forschungsgemeinschaft (DFG, German Research Foundation) – project number HA 7367/2–1, and by the German Federal Department of Education and Research (BMBF) – project number 01JD1803D.

Notes

1 Even though it is not specific to the field of education, a major federal reform in 2009 was the newly inserted Article 91c of the Basic Law, which heavily promotes infrastructure of administrative data. It promotes, "the legal prerequisites for seamless electronic communication among federal, state, and local government agencies" (IT Planning Council, 2020, para. 2). To implement this article, the federal and state governments adopted the State IT Treaty, which also included the establishment of the IT Planning Council as the body responsible for information technology cooperation in Germany.

2 The findings illuminated in this chapter derive from research data generated and analyzed by the authors from a range of previous and ongoing research projects. All projects are built on the analysis of policy documents, laws and ministerial circulars, website information, interviews with policy actors, and school officials, as well as (in the case of itslearning) participatory observations. For more detailed methodological explanations, see Datafied (2020), Hartong and Förschler (2019), and Hartong and Piattoeva (2019).

3 This for example includes interfaces between the local resident registries and school information system to monitor student numbers and school attendance, as in Hamburg or Bremen.
4 Yet allowing it at all to be used for supervision (and thus accountability) purposes can already be interpreted as an effect of data infrastructuring.
5 In four German states, this is currently analyzed in the Datafied project (see Datafied, 2020). One example of tracing these dynamics is the transformation of social indices for schools (Hartong & Breiter, in press).
6 For the purpose of this chapter, we use the terms LMS and learning platform interchangeably to refer to a particular type of data infrastructure. We simultaneously acknowledge the challenge of clear definitions, which also applies to School Management Information Systems (SMIS), Learning Content Management Systems (LCMS), and School Clouds (Breiter & Lange, 2019; Hughes & Attwell, 2009).
7 A similar development can be observed in Hamburg, where itslearning has become linked to the centralized state school portal eduPort.
8 The infrastructure of research data has been an often-underestimated driving force in the overall emergence of data infrastructure in schools. For example, and similar to the OECD, the IQB acquired an enormous database of student performance data and background information. This database is further integrated with other datasets (e.g., PISA) within an IQB in-house research database, which makes it available for re-analysis and secondary analysis.

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