17. The early roots of the digital divide: socioeconomic inequality in children's ICT literacy from primary to secondary schooling

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1 INTRODUCTION

The ubiquity of digital technologies profoundly affects how we find, process, and evaluate information in contemporary societies. Successfully navigating the vast fluxes of online information, beyond mastering digital devices, is essential for raising integrated and informed citizens. The new set of skills necessary to master and benefit from recent technological innovations received different names, ranging from digital competencies, information and communications technology (ICT) literacy, to 21st Century Skills (Carretero et al., 2017; ETS, 2002; Fraillon et al., 2019; van Laar et al., 2017).[2]

Digital competencies are also crucial for labour market success. Post-industrial economies experienced a hardwired workplace digitalisation driven by the fast-paced outbreak of personal computers and digital devices (Bisello et al., 2019), the internet, robotics, and artificial intelligence (Fernández-Macías & Bisello, 2021). Jobs in science, technology, engineering, and mathematics, which require high levels of analytical and digital skills, are among the most rewarding and complementary to technological change (Liu & Grusky, 2013) and account for the lion's share of productivity and employment growth in many countries.

Nowadays, most jobs require at least basic digital competencies (González Vázquez et al., 2019) due to technological change and occupational upgrading (Oesch & Piccitto, 2019). However, the increasing demand for ICT skills in the digital age coincides with a shortage of workers (existing and prospective) mastering such skills (Carretero et al., 2017; European Commission, 2021). Besides, those jobs with the largest share of routinary tasks, which involve less analytical and ICT skills, are at the highest risk of automation and redundancy (Acemoglu & Restrepo, 2021).

For all these reasons, international institutions (Conrads et al., 2017; OECD, 2019a)[3] and national governments agree (ACARA, 2018) on the strategic importance of incorporating ICT competencies in educational systems' curricula as early as possible to prepare students (and teachers) for full participation in digital societies. The COVID-19 pandemic has sped up the digital transition by highlighting the importance of students' and parents' ICT literacy to fight educational inequalities in the context of home schooling (Engzell et al., 2021).

The existing research highlighted three dimensions of the digital divide: ICT access, ICT usage, and ICT literacy (Scheerder et al., 2017). The widespread availability of internet connection and portable devices from the late 2000s shifted the focus from discussing inequality in access to inequality in usage and literacy (OECD, 2015; van Deursen & van Dijk, 2014). High socioeconomic status (SES) students tend to use ICT for educational purposes (van Dijk, 2012) (i.e., doing homework; retrieving information; reading news) more than their less-advantaged schoolmates (see also Becker, Chapter 16 in this volume). Mechanisms underlying this relationship are parental cultural resources and ICT skills (Becker, 2021; Gracia et al., 2020; Notten & Becker, 2017).

ICT access and ICT use do not automatically guarantee that young generations develop advanced digital skills, however. According to the International Computer and Information Literacy Study (Fraillon et al., 2018), over one-third of the students age 15 lack basic digital competencies in 9 out of 14 European Union countries. What is more, family background correlates with students' proficiency in ICT skills (Fraillon et al., 2018, 2019; Scherer & Siddiq, 2019). SES inequality in ICT literacy may be particularly relevant to social mobility. SES gaps in 'hard' skills – like mathematics, science, and reading – are well documented already from preschool age in many countries in and outside Europe (Bradbury et al., 2015; Feinstein, 2003; Passaretta, Skopek, & van Huizen, 2022; Skopek & Passaretta, 2021; von Hippel & Hamrock, 2019). These early gaps remain rather constant over schooling and account for a big chunk of the intergenerational transmission of educational and occupational attainment (Barone & Werfhorst, 2011; Jackson, 2013; Kerckhoff et al., 2001). An additional social divide in the development of digital skills would prevent disadvantaged students from fully reaping the benefits of the digital age and even exacerbate the intergenerational transmission of social disadvantage.

2 RESEARCH QUESTIONS AND CONTRIBUTION

Notwithstanding the relevance of ICT literacy for social mobility, we know little about SES gaps in ICT literacy compared to traditional academic domains (Scherer & Siddiq, 2019). Moreover, while SES gaps in ICT skills among adolescents (Aesaert & van Braak, 2015; Fraillon et al., 2019) and adults (OECD, 2019a) are well documented, we know little about when these gaps emerge and how they evolve in childhood (Lazonder et al., 2020). And yet research focused on family- and school-level mechanisms underlying social inequality in ICT literacy is scant.

This chapter deepens on the roots, the evolution, and the drivers of SES inequality in ICT literacy[4] among children and pre-adolescents in one of the largest democracies in Europe, that is, Germany. We complement the existing literature by addressing the following research questions:

1. When does SES inequality in ICT literacy emerge and how does it evolve over primary and lower secondary schooling?
2. Which family (i.e., ICT access and usage patterns) and school characteristics (i.e., tracking, ICT facilities) explain SES inequalities in ICT at various points of children's life course?

Drawing data from the German National Educational Panel Study (NEPS) (Blossfeld et al., 2011), we follow up two cohorts of elementary and lower secondary students from age 7 (grade 3) to age 16 (grade 9). The NEPS implemented a consistent testing strategy using the Test of Technological and Information Literacy (TILT) (Senkbeil et al., 2013). TILT is a reliable and validated instrument to measure ICT meta-competencies beyond technical mastery of devices (i.e., declarative and procedural knowledge of hardware and software) (Senkbeil et al., 2013). Hence, TILT measures skills that will not become obsolete despite future technological change. The use of a reliable and consistent instrument is a major advantage over most of the previous research, which often used inconsistent ICT measures and definitions (Siddiq et al., 2016).

The measurement of ICT skills remains controversial, however (Siddiq et al., 2016). ICT literacy involves cross-domain skills like problem solving, critical thinking, and metacognition in accessing, managing, integrating, evaluating, and creating digital information (ETS, 2002; Gnambs, 2021). Although these ICT skills positively correlate with traditional hard skills, like general cognitive ability and domain-specific competencies, ICT literacy is widely considered a unidimensional construct (Hatlevik et al., 2017; Senkbeil et al., 2013; Siddiq et al., 2016). Against this background, one interesting question is how SES inequality in ICT literacy ranks and evolves compared to SES gaps in core competencies, such as reading, maths, and science (Azzolini & Schizzerotto, 2017). Relatedly, it is also interesting to understand whether SES gaps in ICT literacy are just by-products of SES inequalities in parenting and school environments shaping hard skills (i.e., through cross-fertilisation). To the best of our knowledge, no studies have tried to find answers to these questions in a unified research design. This chapter contributes to filling these gaps by asking:

3. How do SES inequalities in ICT benchmark with inequalities in other traditional competence domains (hard skills)?
4. Are there SES gaps in ICT literacy among children with similar proficiency levels in the traditional competence domains (hard skills)?

3 THEORY AND CONTEXT

3.1 Parents, Schools, and Social Inequality in ICT Literacy

Extensive research from the sociology of education, the economics of education, and developmental psychology has documented how family resources shape children's skills development early in life (Bourdieu, 1986; Duncan & Magnuson, 2011; Farkas, 2003; Francesconi & Heckman, 2016).

Cultural reproduction theories highlight how families' unequal stock and transmission of cultural capital explain SES inequality in academic achievement (Bourdieu & Passeron, 1990). The previous research has examined the following dimensions in the transmission of cultural capital between parents and children: reading habits (i.e., bedtime stories), educational material resources (i.e., books, educative games, computers), cultural communication (i.e., teaching them to be analytical, to reason, and to be argumentative), and extracurricular activities (Jæger & Breen, 2016). Furthermore, parents with high cultural capital tend to follow an educational strategy of 'concerted cultivation' for their children (i.e., structured activities, supervision of homework) (Lareau, 2003), while working-class parents are more likely to follow a 'natural growth' strategy, which generally involves less supervision and organised time (Bodovski & Farkas, 2008).

This framework was also applied to the case of SES inequality in ICT access, use, and literacy through the concept of digital capital (Drabowicz, 2017; Ignatow & Robinson, 2017). Digital capital is '"a set of internalised abilities and aptitudes" (digital competencies) as well as "externalised resources" (digital technology) that can be historically accumulated and transferred from one arena to another' (Ragnedda et al., 2020, pp. 793–794). High-SES parents, having high cultural and digital capital, use ICT more for informational purposes than low-SES parents (van Deursen & van Dijk, 2014) and can maximise their children's learning opportunities arising from the use of technology.

High-SES families tend to monitor their children's amount and use of digital devices by setting time rules and encouraging educational activities (i.e., using computers for doing homework and learning; retrieving information; reading news; emailing) (Chaudron, 2015; Livingstone et al., 2015; Nikken & Opree, 2018; Notten & Becker, 2017; OECD, 2015). Overall, these parental practices related to different patterns of ICT usage by family SES are similar to those explaining SES gaps in time use and educational achievement (Cano et al., 2019; Gracia et al., 2020). Altogether, family resources and parenting strategies may foster educationally oriented ICT use and children's ICT literacy in the same way they intensively nurture the development of hard skills like vocabulary, reading, and numeracy skills (Farkas, 2003; Fernald et al., 2013; Lugo-Gil & Tamis-LeMonda 2008).

Although ICT is not a specific subject in many education systems, school learning environments may also shape SES inequality in ICT literacy. Schools' differences in average students' ability and SES composition (Robinson et al., 2018) and ICT infrastructures and staff training (European Commission, 2013, 2019; Gerick, 2018; Redecker, 2017; van de Werfhorst et al., 2022) might account for a substantial share of SES gaps in ICT literacy. For instance, schools equipped with modern devices with internet connection in the classroom, disposing of principals and teachers trained in digital learning methods (Borgonovi & Pokropek, 2021), or even offering extracurriculars on coding and robotics might considerably boost students' ICT literacy (Gerick et al., 2017) and the SES inequality therein. In the specific case of Germany, Gerick et al. (2017) found a positive association between teachers' use of ICT in schools and students' ICT literacy.

3.2 The German Context

Germany employs the largest amount of ICT specialists in the European Union (European Commission, 2021). Besides, only 27.3 per cent of German students in grade 8 (age 14) lack basic ICT skills, which is a relatively low level when compared with countries such as Italy (62.7 per cent) or Luxembourg (50.6 per cent) (Fraillon et al., 2018). Nevertheless, Germany displays high levels of SES inequality in ICT literacy (Fraillon et al., 2019) and other competence domains (OECD, 2018) among adolescents. Adolescence may represent the end of a process starting long before, however. How do SES gaps in ICT literacy evolve as children navigate primary and lower secondary schooling? Germany represents an interesting theoretical case to examine this question as the German education system is often described as a strong sorting machine.

Germany applies early school tracking at age 10–12 (after grades 4 or 6, respectively). Children are tracked into academic or vocational pathways leading to very different educational certificates and occupational opportunities. Some federal states enforce binding recommendations linked to students' ability for tracking (Buchholz et al., 2016). Hence, some authors argue that early school tracking functions as a bottleneck that reinforces early SES gaps in skills and contributes to low educational mobility (Bol & van de Werfhorst, 2013; OECD, 2018). Notwithstanding the potential dis-equalising role of tracking, SES gaps emerge long before school and remain stable even after tracking (Skopek & Passaretta, 2021). This chapter contributes to this debate by analysing the evolution of SES gaps in ICT skills compared to hard skills before and after school tracking.

4 DATA, VARIABLES, AND METHODS

4.1 Data

We use information from the *Kindergarten cohort* (Starting Cohort 2 or SC2 henceforth) and the *Grade 5 cohort* (Starting Cohort 3 or SC3 henceforth) of the German NEPS (Blossfeld et al., 2011).[5] SC2 and SC3 sampled schools in the first stage and students in the second stage. SC2 comprises a representative sample of children attending the first year of kindergarten in 2010/2011 (N = 2,996) and followed up until grade 4. SC3 includes a representative sample of children attending grade 5 in 2010/2011 (N = 6,112) and followed up until grade 9. Both cohort samples were supplemented by refreshment samples in Wave 3, which represents grade 1 for SC2 (N = 6,341) and grade 7 for SC3 (N = 2,205). Overall, these samples are representative of German schools and students.

We employ data from nine waves overall: three (Waves 4–6) from SC2 and six (Waves 1–6) from SC3. The nine waves cover a period ranging from grade 2 to 9 (age 7–16 approximately). Children were tested in a variety of competence domains in each wave. Nevertheless, the number and type of tested domains varied across waves (even within the same cohort). ICT literacy was tested three times over the observation window: grade 3 in SC2 (age 8 approximately) and grades 6 and 9 in SC3 (age 12 and 15 approximately). Testing in other domains (maths, science, and reading) did not perfectly coincide with ICT literacy but took place in a similar time frame.[6] Table 17.1 provides details on the timing of testing for each of the competence domains.

The data do not allow us to follow the same children throughout the whole period, but the cohort-sequences design of the NEPS allows an approximation based on cohort comparisons and comparable measures. Our comparison hinges on two cohorts and their respective refreshment samples. Longitudinal attrition rates were generally low but occurred in both cohort samples (Zinn et al., 2018). The school-based sampling design resulted in substantial (but not selective) attrition at the transition from kindergarten to first grade (Wave 2 to 3 in SC2). We used the design weights and the longitudinal weights provided by the NEPS to account for disproportions in the initial samples and potential attrition over waves.

The analytical samples for the description of the evolution of SES inequality in achievement change for each domain and wave as we aim at maximising sample size. We draw on smaller subsamples when assessing the drivers of SES gaps in ICT literacy and the residual SES gaps (when comparing equally achieving students in hard skills) to accommodate listwise deletion on key mediators and test scores. Overall, depending on the analyses, our samples range from 3,473 to 5,102 students in SC2 and from 1,576 to 3,462 students in SC3. Table 17A.2 in the Appendix shows that the magnitude of SES gaps in ICT literacy in the overall samples and the restricted subsamples are virtually identical.

Table 17.1 Measurement of variables over panel cohorts and survey waves

	Starting Cohort 2: Primary school			Starting Cohort 3: Secondary school				
Wave	Wave 4	Wave 5	Wave 6	Wave 1	Wave 2	Wave 3	Wave 5	Wave 6
Grade	Grade 2	Grade 3	Grade 4	Grade 5	Grade 6	Grade 7	Grade 9	Grade 9
Students' age	7–8	8–9	9–10	11–12	12–13	13–14	14–15	15–16
Survey year	2013–2014	2014–2015	2015–2016	2010–2011	2011–2012	2012–2013	2014–2015	2015
Students' competencies								
ICT literacy		X			X		X	
Reading competence			X	X		X		X
Maths	X		X	X		X	X	
Scientific literacy		X			X		X	
Computer access, parental control[a] and type of use at home								
Computer access:								
Since when[b]		X						
Availability at home[c]					X		X	
Parents' control:								
Time[d]			X					
Type use[e]			X					
Who decides time[f]						X		
PC use type:[g]								
Intrinsic Motivation		X						
Learning use		X						
Computer access at school and school characteristics								
PC availability[h]				X			X	
School track[i]					X		X	

Note: [a] Students' evaluations (target questionnaire). [b] Dummy: 1 = Since one year or more ('*Since when do you use a computer?*') [c] Dummy: 1 = I have my own ('*Can you use a computer at home?*') [d] Four-point scale from (1) completely disagree to (4) completely agree ('*My parents pay a great deal of attention to how much time I spend watching TV or playing on the computer*') [e] Four-point scale from (1) completely disagree to (4) completely agree ('*My parents pay a great deal of attention to what I do on the computer*'). [f] Dummy: 1 = Both myself and my parents or my parents only ('*Who decides in your family: How much time you should spend on computer?*'). [g] Composite indexes (two components) from PCA. Six items (statements on computer use). Four-point scale from (1) don't agree at all to (4) completely agree. Intrinsic motivation: (1) fun to use; (2) interesting; (3) would use more. Learning use: (4) learn new things; (5) look up things; (6) learn a lot. [h] Information from principals' questionnaire. Composite index (one component) from PCA. Six items (school equipment): (a) number of computers available to students; (b) number of computers available to teachers; (c) number of computer rooms; (d) percentage of computers with less than two years (over number of computers); (e) the number of computers in classrooms; and (f) the number of full-time teachers with computer science as a school subject. Answers are divided by the number of students in G5 and G9. [i] Dummy: 1 = Gymnasium.

4.2 Variables

4.2.1 ICT literacy

ICT literacy is a meta-competence measured with a paper-and-pencil test (31–36 items with multiple-choice responses) and designed explicitly by the NEPS: TILT (Senkbeil et al., 2013). TILT embraced the ETS (2002) definition of ICT literacy (see note 3), conceptualised as a unidimensional construct comprising the facets of process components and software applications. Computer literacy's process components[7] represent cognitive and technological aspects of the knowledge and skills needed for a problem-oriented use of modern ICT. The facet of software comprises applications[8] used to locate, process, present, and communicate information. Apart from a few items asking for factual knowledge, most items ask students to accomplish computer-based tasks with realistic problems. TILT shows good internal reliability ($\alpha \approx 0.8$) and longitudinal invariance. The test is scaled using item response theory to link the scores across waves and even allow for longitudinal mean-level comparisons in absolute terms (Senkbeil & Ihme, 2017; Senkbeil et al., 2014). Table 17.1 provides details on the timing of measurement of ICT and all variables used in the analyses.

4.2.2 Other domain-specific competencies

Domain-specific competencies come from low-stakes tests (test scores) on mathematics (24 items), reading (33 items), and scientific literacy (26 items). These tests are scaled with item response theory and follow a similar methodology compared to large-scale international assessment studies (e.g., PISA) (Pohl & Carstensen, 2013; Weinert et al., 2011). Test scores in maths, science, and reading, likewise ICT literacy, are provided by NEPS as weighted maximum likelihood estimates representing best estimates of children's ability.

4.2.3 Skill stratification

Following the literature on inequality in tests scores, we standardise competence scores within waves to have a mean of 0 and a unit standard deviation in each wave (Bradbury et al., 2015; Passaretta et al., 2022; Reardon, 2011). Hence, we focus on SES inequality in relative terms, that is, by comparing the average relative position of children from different SES backgrounds in the distribution of achievements. In this framework, the longitudinal comparison informs us about changes in SES inequality's relative and not absolute (proficiency) amount. The grade-based design of the NEPS resulted in age variations among children taking a competence test in a particular wave. Part of this variation is substantively related to SES, for example, in the case of grade repetition; part is likely due to sampling error. We removed non-SES-related differences in age before standardisation via residualisation of test scores on a cubic function of exact age at test in each wave. Details on the residualisation procedure can be found in Skopek and Passaretta (2021).

4.2.4 Parental SES

We use the highest years of parental education in the first wave of participation as the primary indicator for family SES. Although not covering all facets of SES (Duncan et al., 2015), parental education is one of the most important and stable factors determining the family's socioeconomic position. We complement the analyses by using a complementary SES measure: the highest parental occupation measured by the International Socio-Economic Index of Occupational Status (ISEI 08) (Ganzeboom & Treiman, 1996). Both highest parental education and occupation are used in the analysis as metric variables. However, the findings are presented in graphical form and refer to predicted gaps between children with high, medium: and low parental education or occupation (high: 16 years or ISEI 70; medium: 14 years or ISEI 50; low: 12 years or ISEI 30).

4.2.5 ICT access, parental control, and student use

Information on ICT access, parental control, and student use is retrieved from children's questionnaires. Questionnaires differ in SC2 and SC3, thus making the indicators not directly comparable. Also, not all information came from the same waves when ICT literacy was tested. If available only once over the observation window, we consider the indicator as time fixed. If available more than once, we consider indicators as time varying and match them to the respective (or the closest) wave of testing.

4.2.6 ICT access

We use a dummy to proxy students' access to computers at home in grades 3, 6, and 9. In grade 3 (SC2), the dummy reports whether students used the computer at home for more than one year (= 1). In grades 6 and 9 (SC3), the indicator reports whether students had their own computer at home (= 1).

4.2.7 Parental ICT control

In grade 4 (SC2), parental control is proxied by two continuous variables measuring agreement to the following statements: (1) 'my parents pay a great deal of attention to how much time I spend watching TV or playing on the computer'; and (2) 'my parents pay a great deal of attention to what I do on the computer'. In grade 7 (SC3), parental control is proxied by a dummy reporting if parents decide students' time on computers at home (= 1).

4.2.8 Student ICT use

In grade 3 (SC2), information on students' type of computer use is captured by two composite indices extracted from a principal component analysis fed with six Likert-scaled items: (a) using the computer is interesting; (b) using the computer is fun; (c) I would like to use the computer more; (d) using the computer to look up things; (e) learning new things; (f) I learn a lot doing things on the computer. The two indices measure (1) students' intrinsic motivation for use (a–c) and (2) use for educational purposes (d–f).

4.2.9 ICT infrastructures at school

Information on school infrastructures is retrieved from the principals' questionnaires available for SC3 (only in grades 5 and 9). We construct a composite index measuring availability of ICT infrastructures and teaching staff. The index is extracted from a principal components analysis comprising six items:[9] (a) number of computers available to students; (b) number of computers available to teachers; (c) number of computer rooms; (d) percentage of computers with less than two years; (e) number of computers in classrooms; and (f) number of full-time teachers with computer science as a school subject. Whenever relevant, availability is weighted by the number of students in the respective grade (per 10 students). Information on these items is collected twice: in grade 9, when ICT literacy is tested, and in grade 5, when ICT literacy is not tested. We use information from grade 5 to proxy information for grade 6.

4.2.10 School track

The NEPS provides information on the school track in each wave for SC3 (grade 5 and higher). It is important to note that, although unusual, children may change track over secondary schooling. However, the tracking information is time invariant in practice because of the school-based design of the NEPS (children who changed school were followed up individually; however, we disregarded individual follow-ups and focused on the school-based sample of children). We distinguish children enrolled in the academic track (1 = gymnasium) from children enrolled in vocational and comprehensive schools.

4.2.11 Sociodemographic controls

We control for migration background (1 = at least one parent born abroad) in all models to have a sharper measure of SES inequality in achievement. Moreover, we control for gender to increase the precision of the estimates (even if gender is orthogonal to SES). However, in the first part of the analysis, we also show the extent and evolution of gender and migration inequalities in achievement to benchmark SES inequality.

4.3 Estimation

The analysis is divided in three parts. The first part examines the evolution of SES gaps in ICT literacy over primary and lower secondary education. We also benchmark SES gaps in ICT literacy with gaps in 'hard skills' (maths, science, and reading) and gender and migration-related gaps more generally. This first part relies on ordinary least squares (OLS) models that express children's achievement as a function of SES, gender, and migration background. OLS models are estimated separately in each wave, competence domain, and SES indicator (parental education or parental occupation, respectively).

The second part of the analysis combines OLS regression models with the Karlson-Holm-Breen (KHB) decomposition method (Breen et al., 2021) to quantify the contribution of family- and school-level characteristics to observed SES inequality in ICT literacy. More precisely, we decompose the residual SES gaps when conditioning on gender and migration background. Note that the information regarding the school and family environments differs in each wave (for example, school characteristics and tracking are only available in grades 6–9). Therefore, the decomposition results are not entirely comparable across grades. We consider different sets of mediators at the family level – ICT access (grades 3, 6, and 9), parental control (grades 3, 6, and 9), and students' type of use (grade 3 only). At the school level, we consider ICT infrastructures (grades 5 and 9 only). We show the results for parental education only, but results for parental ISEI were virtually identical. Figure 17.2 reports the main results from the models including all home- and school-level mediators available in each grade simultaneously. Table 17A.1 in the Appendix reports results from the models including home- (altogether) and school-level mediators (with and without tracking) stepwise.

The third part of the analyses explores whether SES inequality in ICT skills still holds when comparing children with similar levels of hard skills. To this end, we use OLS models regressing ICT literacy on parental SES (parental education only), gender, migration background, and with and without including z-standardised scores in hard skills among the covariates. We consider z-standardised scores in maths, science, and reading as measured in the grade before (preferable) or in the same grade when ICT literacy was tested (whenever available).[10] We run the analysis separately in grades 3, 6, and 9.

All the analyses are implemented using NEPS design weights and/or longitudinal weights that account for sampling design and attrition.

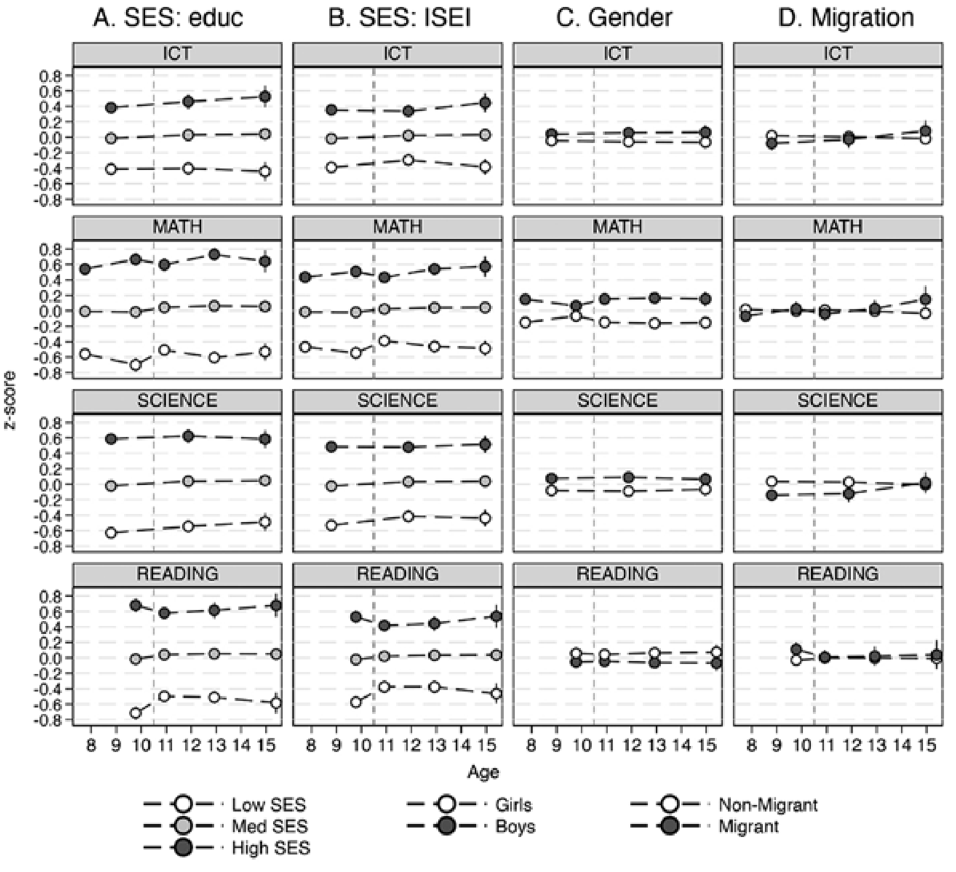
5 FINDINGS

5.1 SES Inequality in ICT Literacy

Figure 17.1 (panels A–B) shows the evolution of SES inequality in ICT literacy, maths, science, and reading between grades 2 and 9 (age 7–16 approximately). The figure reports predictions for children with low- (12 years of education or ISEI 30), medium- (14 years or ISEI 50), and high-SES parents (16 years or ISEI 70). The results are striking. SES inequality in ICT literacy is apparent as early as in grade 3 (age 8) of primary school. When looking at differences by parental education (Panel A), the early gap amounts to around 0.8 standard deviation comparing children with high- and low-educated parents (high–low gap); this high–low gap increases to 0.9 standard deviation only by the end of lower secondary schooling (grade 9). Panel B documents a virtually identical pattern when looking at differences by parental occupational status. Hence, there is little evidence that SES gaps in ICT increase or decrease over primary and lower secondary schooling in Germany.

It is worth noting that SES gaps in ICT literacy are slightly less pronounced than gaps in hard skills. This is particularly true in the case of parental education (when looking at the parental occupational status differences are less visible). However, these slight differences do not build a strong case for lower SES inequality in ICT compared to other domains, especially if we consider that differences across domains are not formally comparable. Aside from the magnitude of SES differences across domains, there is a striking similarity in how such differences evolve over schooling. Social inequality in hard skills does not seem to change much after grade 2 of primary education; instead, like for ICT literacy, SES inequality remains constant over schooling. All in all, the strength and evolution of SES gaps in ICT literacy seem not to differ much compared to classical competence domains that were widely analysed in the previous research.

Figure 17.1 (Panels C–D) also shows the evolution of gender and migration-related inequality in the same competence domains and time window for comparison. Comparing SES inequality vis-à-vis gender and migration inequalities also results in a striking portrait. SES gaps in ICT literacy and other domains are astounding in effect size compared to gaps by gender or migration background. Boys seem to perform better than girls in maths, mirroring a common finding in the literature. This gap remains constant up to grade 9 but is strikingly lower in magnitude (0.35 standard deviation approximately) compared to gradients by parental education or occupational status. All in all, there are no meaningful differences by gender or migration background in maths, science, or reading. ICT literacy is no exception; boys and girls seem to perform equally on average, as do migrants and natives. What is more, inequality by gender or migration background in ICT literacy (like science and reading) does not emerge as children navigate throughout primary schooling and even when they are tracked in secondary schooling.

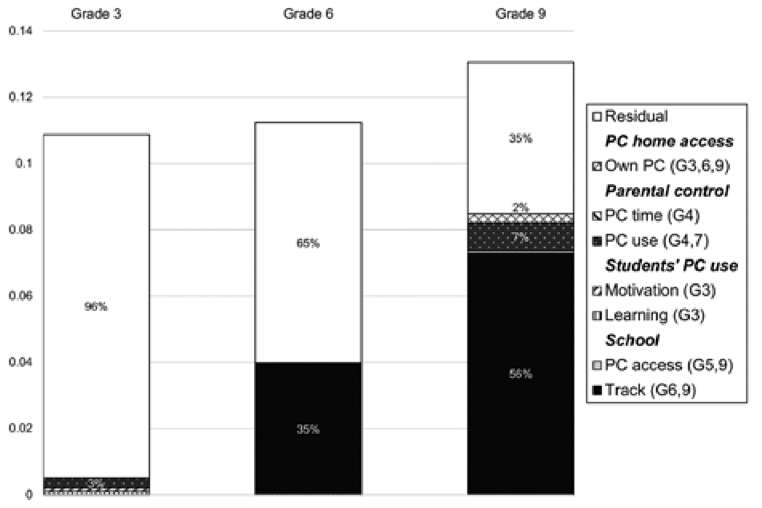


Note: Predictions from OLS regression models estimated separately by wave, competence domain, and SES indicator. All models include simultaneously gender, migration background, and parental SES (parental education or ISEI) among the covariates. Scores are standardised by wave. 95 per cent confidence intervals shown. Vertical dashed lines separate cohorts (SC2 grade 2–5, and SC3 grade 5–9). Data weighted.

Figure 17.1 SES (parental years of education and ISEI), gender, and migration gaps in standardised ICT, maths, science, and reading competencies

5.2 Drivers of SES Inequality in ICT Literacy

This section reports results from the decomposition of SES gaps in ICT in grades 3, 6, and 9. As shown in Figure 17.2, in grade 3, only around 4 per cent of the total association between parental SES and ICT literacy ($\beta = 0.108$, see Table 17A.1 in the Appendix) is mediated by family-level characteristics, that is computer access at home (−0.4 per cent), parental control over ICT timing (0.1 per cent), use type (2.68 per cent), and students' intrinsic motivation to use ICT and learning use (1.9 per cent). Moreover, this small percentage is statistically indistinguishable from 0 at the conventional level ($p < 0.05$, see Table 17A.1 in the Appendix). Thus, access, parental control, and children's motivation and use patterns seem to not substantially mediate the observed SES gap in ICT literacy in grade 3.



Note: Estimations from the linear KHB decomposition method. All models control for gender and migration background. Data weighted.

Figure 17.2 Decomposition of the total SES–ICT literacy association in grades 3, 6, and 9: the role of family and school-level factors

The decomposition in grade 6 offers a different picture. It is important to keep in mind that, from grade 5, students are tracked in academic or vocational schools with a very different composition of students' SES and ability. Students' sorting into academic and vocational tracks account for around 35 per cent ($p < 0.000$) of the SES–ICT literacy association in grade 6 ($\beta = 0.113$). School track is the only characteristic explaining SES inequality; neither family-level factors nor ICT infrastructures at school explain SES gaps in grade 6.

In grade 9, home- and school-level characteristics altogether explain 65 per cent ($p < 0.000$) of the observed SES gap in ICT literacy ($\beta = 0.131$). However, school tracking alone accounts for 56 per cent of the SES gap in ICT literacy ($p < 0.000$), while school ICT infrastructures do not play any role (0.5 per cent). This result resembles what was found in grade 6. The availability of computers at home and parental control account for only around 9 per cent of the observed gaps.

Although comparability across grades is limited, our analysis suggests that selection into different school tracks accounts for the biggest chunk of the digital divide found in secondary schooling (grades 6 and 9). School tracking from primary to secondary schooling strongly selects students by academic skills and parental SES and likely diminishes students' heterogeneity by ability and SES within the tracks. Therefore, it is not surprising that neither family- nor other school-level characteristics play a role beyond tracking. Nonetheless, the increased proportion of SES gaps explained by tracking between grades 6 and 9 may be interpreted as indirect evidence that tracking may be a driver of SES inequality over secondary schooling beyond selection. However, the present analyses does not allow to distinguish between mechanisms of selection and causation related to the role of tracking.

It is worth noting that the absence of mediation by ICT infrastructures at school holds even when we exclude the school track among the mediators (see Table 17A.1 in the Appendix).

Home-level characteristics also explain SES inequality in ICT literacy, but to a much lower extent, around 4 to 9 per cent in grades 3 and 9, respectively.

5.3 Is SES Inequality in ICT Literacy Explained by SES Inequality in Hard Skills?

General cognitive ability or intelligence load on many meta-competencies including problem solving, abstract reasoning, and verbal and numeracy skills. Therefore, general intelligence also correlates with manifest competencies like maths, science, or reading (Rindermann, 2007). ICT literacy may be no exception. SES inequality in ICT literacy may reflect hidden, higher-order differences in general cognitive ability. So, does SES inequality in ICT skills still hold when comparing children with similar levels of hard skills? Are the mechanisms explaining SES inequality in ICT literacy unique? Or are there common mechanisms explaining SES inequality in ICT literacy and hard skills?

Table 17.2 SES gradient in z-standardised ICT literacy in grades 3, 6, and 9 (total and residual after accounting for hard skills)

	Grade 3 (SC2)		Grade 6 (SC3)		Grade 9 (SC3)	
	Total	**Residual**	**Total**	**Residual**	**Total**	**Residual**
Parental SES	0.102***	0.01	0.117***	0.005	0.129***	−0.006
	(0.009)	(0.009)	(0.010)	(0.008)	(0.017)	(0.013)
Hard Skills	No	Yes	No	Yes	No	Yes
N	4,460	4,460	3,309	3,309	3,177	3,177

Note: Results from linear regression models. All models control for gender and migration background. Parental SES measured by parental years of education. Z-standardised scores in hard skills (maths, science, and reading) are included simultaneously. Grade 3: maths measured in G2; science in G3; reading in G4. Grade 6: reading and maths measured in G5; science measured in G6. Grade 9: reading and maths measured in G7; science measured in G9. Robust standard errors in parentheses. Significance levels: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Data weighted.

As Table 17.2 shows, we could not detect any SES difference in students' ICT literacy when conditioning on hard skills. This result holds in all grades, suggesting that parental practices explaining SES gaps in hard skills (e.g., educational activities and behavioural strategies) might also explain SES inequality in ICT literacy. However, these results are also compatible with the idea that strong competencies in reading, maths, and science help develop ICT literacy via cross-fertilisation dynamics. These results are not surprising if we consider that ICT literacy and hard skills are moderate to highly correlated[11] (r ranging from 0.4 to 0.7) and both part of a higher-order hierarchy of general cognitive abilities. Additional analyses predicting proficiency in hard skills (maths, science, reading) conditioning on the remaining domains and ICT literacy show that a statistically significant and sizeable residual association between SES and hard skills remains. Altogether, these results may suggest that hard skills themselves might be antecedent and help the development of ICT literacy through cross-fertilisation (and not the other way around).

6 DISCUSSION AND CONCLUSION

This chapter analysed the roots, evolution, and drivers of SES inequality in ICT literacy over primary and lower secondary education in Germany. Our analyses added to the interdisciplinary literature on social stratification, skill formation, and the digital divide in several ways. First, we benchmarked SES gaps in ICT literacy with gaps by gender and migration background. The sociological scholarship is often concerned with gender and migration-related inequalities in educational achievement. However, our study showed that gender- and migration-related inequalities are by far lower compared to inequalities by socioeconomic background. Second, we benchmarked SES inequality in ICT literacy with inequalities in traditional academic domains, like mathematics, science, and reading. This direct comparison is of theoretical relevance because traditional academic domains are often subject to formal teaching in the classroom, while ICT is often not directly taught in school. Third, we moved beyond a static portrait of SES gaps in ICT literacy among adolescents as measured by the International Computer and Information Literacy Study or PISA data. Rather than considering adolescence as the origin of a stratification process unfolding in later life, we opened the possibility that adolescence may represent the end of a stratification process starting already in primary school. Fourth, we attempted to establish which family- and school-level factors contribute to SES inequality in ICT literacy at different ages.

The chapter reported five main findings: (1) SES gaps in ICT literacy exist as early as age 8–9 (grade 3) and are similar in magnitude compared to gaps in hard skills; (2) SES gaps in ICT literacy remain stable over primary and lower secondary schooling up to age 14–15 (grade 9); (3) family and school ICT access and use do not substantially explain SES gaps in ICT at any age; (4) school tracking is a relevant (although not necessarily causal) pathway through which SES inequality manifests in secondary school; (5) the SES gap in ICT literacy does not hold after conditioning on previous students' differences in hard skills.

Sizeable and persistent SES gaps in ICT literacy mirror the previous scholarship documenting that SES gaps in hard skills emerge in early childhood and remain stable thereafter (Bradbury et al., 2015; von Hippel & Hamrock, 2019). This finding was also documented in Germany and with respect to a variety of competence domains (Linberg et al., 2019; Skopek & Passaretta, 2021). This chapter highlighted that ICT literacy is no exception; the roots of social inequality in this new and allegedly essential set of skills for the digital age may be sought in the early stages of children's lives.

The tiny contribution of ICT access and use to social inequality in ICT literacy is surprising. On the one hand, the minor role of ICT infrastructures in school is in line with the provocative argument put forward by the Coleman report in the 1960s, that is, family environments (within-school inequality) are more important than school differences (between-school inequality) in explaining SES inequalities in students' achievements. On the other hand, differences in ICT access, parental control, and students' use at home do not explain SES gaps either.

We found that tracking (from grade 4) accounts for a big chunk of SES inequality in ICT literacy in lower secondary education. This is likely due to selection processes that lead high achievers, high ability, and high SES students to attend the academic track, which also gives the best opportunities for learning and cognitive development in Germany. Indeed, selection into school tracks is based on students' ability but also SES (irrespective of ability) in Germany. At the same time, the observed increase in the mediating role of tracking from grade 6 to 9 suggests that tracking may be driving achievement beyond selection, for example due to curricular differentiation and peer effects. However, our findings cannot disentangle selection or causation mechanisms behind the importance of tracking, nor can they disentangle the importance of inequality mechanisms operating in and out of the school or be generalized to countries without early tracking.

The 'absence of mediation' of school and family factors related to ICT access and use may also result from poor measurement. Measurement error in the family- and school-level indicators would artificially deflate the importance of these factors in explaining the observed SES gaps in ICT literacy. Had we had more comprehensive information on schools' ICT teaching plans, staff training, and own perception of competencies, the role of school characteristics would likely be stronger (European Commission, 2013, 2019; Gerick et al., 2017). The same rationale applies to the minor role of ICT access, parental control, and students' ICT use at home. However, it is unlikely that our findings are only driven by measurement error for two reasons. First, our composite indices of school ICT infrastructures and ICT use at home are rich. Second, we found SES gaps in the patterns of ICT use at home and ICT infrastructures at school, which would be very unlikely if these measures were completely flawed.

Finally, we could not detect social inequality in ICT literacy when looking at similarly performing children in traditional competence domains like maths, science, and reading. This finding suggests that the very mechanisms driving SES gaps in digital skills may be similar to those driving socioeconomic inequalities in hard skills. It might be the case that social inequality in ICT literacy simply echoes common inequality mechanisms that are responsible for unequal proficiency in hard skills. Future studies may dig deeper into these dynamics to understand whether and to what extent mechanisms driving socioeconomic inequality in ICT literacy and hard skills differ in any meaningful way.

NOTES

1. This research has been funded through the European Commission's JRC Centre for Advanced Studies and the project Social Classes in the Digital Age (DIGCLASS). We are grateful to Jan Skopek, Leire Salazar and Manuel Valdés for their feedback.
2. We use the terms 'ICT literacy' and 'digital literacy' (or skills/competencies) interchangeably in this chapter (for details on different definitions see Rodrigues et al., 2021).
3. 21st Century Skills Movement; European Commission's *Digital Education Action Plan 2021–2024*; *European Digital Competence Frameworks for Citizens and Educators* (Carretero et al., 2017; Redecker, 2017); PISA-2021 ICT framework (OECD, 2019b).
4. Main definitions of ICT literacy: (a) International Computer and Information Literacy Study – 'Individual's ability to use computers to investigate, create, and communicate in order to participate effectively at home, at school, in the workplace, and in society' (Fraillon et al., 2013, p. 17); (b) Educational Testing Service – 'ICT literacy is the interest, attitude and ability of individuals to appropriately use digital technology and communication tools to access, manage, integrate and evaluate information, construct new knowledge, and communicate with others in order to participate effectively in society' (ETS, 2002, p. 2); (c) Digital Competence Framework for Citizens – '(1) Information and data literacy (e.g., Evaluating data, information, and digital content); (2) Communication and collaboration (e.g., interacting and sharing through digital technologies); (3) Digital content creation (e.g., developing digital content and programming); (4) Safety (e.g., protecting devices, personal data, privacy, health, well-being, and the environment); (5) Problem solving (e.g., solving technical problems, creatively using digital technologies)' (Carretero et al., 2017).
5. This inquiry uses data from the NEPS: Starting Cohort Kindergarten, 10.5157/NEPS:SC2:8.0.0. From 2008 to 2013, NEPS data were collected as part of the Framework Program for the Promotion of Empirical Educational Research funded by the German Federal Ministry of Education and

Research. As of 2014, NEPS is carried out by the Leibniz Institute for Educational Trajectories at the University of Bamberg in cooperation with a nationwide network.
6. One of our aims was to compare the evolution of SES inequality in ICT literacy vis-à-vis other domains (maths, science, reading) over primary and lower secondary education. To this aim, we extended the overall observation window by +/– 1 wave maximum compared to the observation window for ICT literacy (grades 3–9, age 8–15).
7. '(1) *Access*: knowledge of basic operations used to retrieve information (e.g., entering a search term in an internet browser, opening and saving a document); (2) *Create*: the ability to create and edit documents and files (e.g., setting up tables, creating formulas); (3) *Manage*: the ability to find information within a program (e.g., retrieving information from tables, processing the hits returned by a search engine); (4) *Evaluate*: the ability to assess information and to use it as the basis for informed decisions (e.g., assessing the credibility of the information retrieved)' (Senkbeil et al., 2013).
8. '(a) word processing and operating systems, (b) spreadsheet and presentation software, (c) e-mail and other communication applications, and (d) internet and internet-based search engines' (Senkbeil et al., 2013).
9. We did not include the information on schools' internet access due to the very high correlation with these items ($r > 0.9$).
10. The only exception is reading in the equation predicting ICT literacy in grade 3. Unfortunately, reading scores were only available for the grade following the grade of testing for ICT literacy. The inclusion of z-standardised scores measured in different grades in the right-hand side of the equation resulted in a substantial drop in sample size in all grades. Table 17A.2 in the Appendix shows an estimate of the total SES–ICT literacy association in the full sample and the restricted sample (hard skills) for comparison. Notwithstanding the lower sample size, SES gradients are very similar in the full and restricted samples in each grade.
11. $r_{ICT\text{-}math} = 0.42$ (grade 3); 0.56 (grade 6); 0.62 (grade 9); $r_{ICT\text{-}science} = 0.48$ (grade 3); 0.62 (grade 6); 0.69 (grade 9); $r_{ICT\text{-}reading} = 0.41$ (grade 3); 0.54 (grade 6); 0.61 (grade 9).

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APPENDIX

Table 17A.1 Linear KHB decomposition of SES gaps (parental years of education) in z-standardised ICT literacy by groups of mediators/drivers and grade

	Grade 3 (SC2)		Grade 6 (SC3)		Grade 9 (SC3)	
SES–achievement association	**Coef.**	**SE**	**Coef.**	**SE**	**Coef.**	**SE**
			Home (access, control, use)			
Total	0.108***	(0.011)	0.113***	(0.011)	0.128***	(0.016)
Residual	0.104***	(0.011)	0.111***	(0.011)	0.116***	(0.016)
Difference	0.005+	(0.002)	0.002	(0.002)	0.012***	(0.003)
Mediation (%)	4.28+		1.46		9.47***	
N	3,473		2,943		3,086	
R^2	0.08		0.07		0.11	
			Home + school (access)			
Total			0.111***	(0.015)	0.131***	(0.020)
Residual			0.111***	(0.015)	0.114***	(0.020)
Difference			0.000	(0.002)	0.017**	(0.005)
Mediation (%)			0.14		12.82**	
N			1,606		1,576	
R^2			0.06		0.13	
			Home + school + tracking			
Total			0.111***	(0.014)	0.131***	(0.020)
Residual			0.073***	(0.015)	0.046*	(0.019)
Difference			0.038***	(0.006)	0.085***	(0.010)
Mediation (%)			34.59***		64.99***	
N			1,606		1,576	
R^2			0.13		0.22	

Note: All models control for gender and migration background. Robust standard errors in parentheses; significance levels: + $p < 0.10$, * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Data weighted.

Table 17A.2 SES gradient (parental years of education) in z-standardised ICT literacy in the full sample (Figure 17.1) and the restricted subsamples for the decomposition analyses (drivers) and the analyses conditioning on hard skills (hard skills) by grade

	z-standardised ICT literacy		
	Full sample	Restricted subsamples	
		Drivers	**Hard skills**
Grade 3 (SC2)			
Parental SES	0.099***	0.108***	0.102***
	(0.009)	(0.011)	(0.009)
N	5,102	3,473	4,460
Grade 6 (SC3)			
Parental SES	0.108***	0.111***	0.117***
	(0.010)	(0.015)	(0.010)
N	3,462	1,606	3,309
Grade 9 (SC3)			
Parental SES	0.121***	0.131***	0.129***
	(0.015)	(0.022)	(0.017)
N	3,310	1,576	3,177

Note: All models control for gender and migration background. Robust standard errors in parentheses; significance levels: * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$. Data weighted.