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The development of ICT skills in adolescence at the intersection of gender and family background

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ABSTRACT

We examine how gender and family background impact adolescents' information and communications technology (ICT) skills, defined as the ability to effectively interact with digital technologies and to use them as a tool to process information. Using objective assessment data from the National Educational Panel Study Starting Cohort Grade 9 (NEPS-SC4), which includes 8828 students in non-academic and 5309 in academic tracks in German secondary schools, we analyzed ICT skills in grade 9, with follow-up data in grade 12 for students in academic tracks. Results reveal a gender gap favoring males in both tracks in grade 9, which widens in grade 12 among academic track students. In academic schools, gender and social background interact in affecting ICT skills, with no gender differences among socially privileged students. In non-academic schools, gender differences persist in grade 9, regardless of family background. Concerning skill growth in academic schools, the gender gap disappears for students with higher economic capital. In sum, these results suggest that in academic schools, more privileged students experience more gender-egalitarian socialization.

1. Introduction

In the last two decades, advancements in information and communications technologies (ICT) have led to far-reaching changes in the labor market, earning structures (Carretero et al., 2017) and everyday lives. ICT has become a primary good (Sen, 1999) and a key driver of productivity and power (Castells, 1996), both scarce and desired (van Dijk, 2006). Accordingly, ICT skills—the ability to effectively engage with ICT—have emerged as a key social and cultural proficiency necessary for successful participation in society (ETS, 2002). These skills do not only comprise the functional knowledge of computer and software applications, but also the ability to locate and evaluate information and to use it effectively, which requires problem-solving skills, metacognition and critical thinking (Senkbeil et al., 2013). Thus, ICT skills have become a new fault line along which social inequalities in employability, income, and social participation emerge or are reinforced (Falck et al., 2021; Grundtke et al., 2018; Nahuis and de Groot, 2003).

At the same time, research has shown that ICT skills are stratified by key allocation criteria to life chances, such as social background, ethnicity, or gender (Wicht et al., 2021). Gender differences in ICT skills warrant particular attention because they might contribute to the persistent horizontal and vertical occupational gender segregation and the gender pay gap. Moreover, in an

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increasingly digitalized labor market, both men and women need solid ICT skills to thrive. Emerging evidence suggests that gaps in ICT skills may have more significant consequences than those in other cognitive domains. On the macro level, Liu and Grusky (2013) showed that ICT skills have gained value in the U.S. labor market, highlighting the growing role of ICT skills in social stratification. On the micro level, Hertweck and Lehner (2023) demonstrated that girls are less likely to pursue STEM careers unless they possess strong ICT skills in secondary school, while for boys, ICT skills are unrelated to STEM choices when cognitive skills are controlled. Given these previous findings, it is considered an important task for educational researchers and practitioners to counteract ICT skills gender gaps already in childhood and adolescence (International ICT Literacy Panel, 2007).

Recent longitudinal studies have shown that gender is a crucial dimension of social inequality in the initial level and development of adolescents' self-assessed ICT skills in favor of males, while the findings regarding performance-based assessed ICT skill differences by gender are mixed (Gerick et al., 2019; Gnambs, 2021; Park and Burford, 2013; Siddiq and Scherer, 2019). Additionally, previous research has shown that ICT skills vary substantially by parental economic and cultural capital as well as by ethnicity (Fraillon et al., 2014, 2019; Senkbeil, 2017; Vennemann et al., 2019). We do not know yet how gender and family background gaps in ICT skills intersect among adolescents. Considering the relevance of ICT skills for career choices, employment chances and lifetime earnings, detecting such intersections is important in order to assess whether disadvantages add up in particular groups, whether they are unrelated to each other, or whether they mitigate each other. If, for example, the gender gap in ICT skills is small or non-existent among privileged youth, while it is large among non-privileged youth, this might affect career choices among these groups in different ways and lead to a higher amount of gender segregation, a larger gender wage gap and in increasing difficulties to fill ICT-related positions in lower-skilled occupational segments of the labor market, compared to higher-skilled segments. Such imbalances pose threats to the economy and individuals alike. For education policy, such differentiated results can provide valuable insights into which groups of students should be particularly encouraged to develop ICT skills at the secondary school level to avoid such imbalances.

In the present study, we aim to investigate how gender and family background intersect concerning the initial level and development of performance-based assessed ICT skills in adolescence, a period when major educational and vocational decisions are made based on individual proficiencies (Eccles, 2011; Hadjar and Aeschlimann, 2015). Hence, we ask: does the gender gap in the level and development of ICT skills vary by parental economic and cultural capital as well as ethnic background? We propose two competing hypotheses: Drawing on theories and findings of more gender-egalitarian socialization among privileged youth, we hypothesize that the gender gap in ICT skills levels and growth will narrow among adolescents from families with higher cultural and financial capital and German family language (Hadjar and Aeschlimann, 2015; Hartung et al., 2005). Conversely, based on the "gender equality paradox" theory, we hypothesize that the gender gap in ICT skills levels and growth may widen among these youth (Breda et al., 2020; Charles, 2017). We use representative longitudinal two-wave data (grades 9 and 12) from the German National Educational Panel Study (NEPS; Blossfeld and Roβbach, 2019), which includes results from objective assessments of ICT skills. Germany presents an interesting case due to its socially selective early tracking into academic and non-academic school tracks, which strongly influence skill development trajectories. While exploring the precise mechanisms underlying variations in ICT skills and their development is beyond the scope of this study, it provides first insights into how gender differences in ICT skills relate to other dimensions of social stratification.

2. Gender gaps in ICT skills

Prominent theories in sociology and psychology (e.g., Eccles and Wigfield, 2020) posit that gender differences in skills primarily arise from gendered socialization experiences, which shape young people's engagement in skill acquisition. Gender stereotypes, that is, simplistic or oversimplified generalizations of men's and women's attributes, behaviors, and characteristics, reflect general expectations of how boys/men and girls/women will behave (Ellemers, 2018). Since "science and technology are produced by, and constitutive of, masculine identities and male power" (Halford and Savage, 2010), ICT is stereotypically considered a male domain, at least in terms of its technological core (Gebhardt et al., 2019). Halford and Savage have pointed out that the increased usage of the Internet might have changed this by making access to ICT easier than before (and a similar argument might be made for smartphones). But among adults, ICT-related jobs (Armstrong et al., 2018), as well as private digital usage patterns, still differ widely along the lines of gender (van Deursen and van Dijk, 2009; Dholakia et al., 2003).

Consistent with these assumptions, the broad body of research on ICT self-concepts, interests, usage patterns, and subjective evaluations of ICT skills consistently point to gender differences in favor of boys (Borokhovski et al., 2019; Gebhardt et al., 2019; Lau and Yuen, 2015). These findings are confirmed by two recent meta-analyses (Borokhovski et al., 2019; Cai et al., 2017). Additionally, some recent studies show that during adolescence males exhibit higher growth in ICT self-confidence than females (Park and Burford, 2013), while others do not find gender differences in the individual development of confidence (Gnambs, 2021).

In contrast to this line of research, findings from recent studies on gender differences in objective, performance-based assessments of ICT skills are inconsistent (for a recent overview, see Gnambs, 2021). Some mainly cross-sectional and single-country studies indicate higher ICT skills in males (e.g., Goldhammer et al., 2013 [Germany]; Kuhlemeier and Hemker, 2007 [Netherlands]). Others show higher skills of females (e.g., Aesaert and Van Braak, 2015 [Belgium]; Fraillon et al., 2019 [different countries around the globe]; Gebhardt et al., 2019 [USA]; Hohlfeld et al., 2013 [USA]; Kim et al., 2014 [Korea]). And still others show no gender differences in ICT skills (e.g., van Deursen and van Dijk, 2009 [Netherlands]; Gnambs, 2021 [Germany]; Hargittai and Shafer, 2006 [USA]; Hatlevik and Christophersen, 2013 [Norway]; Siddiq et al., 2017 [Norway]). A recent meta-study by Siddiq and Scherer (2019), based on 46 studies, estimated a small overall advantage for girls but found considerable heterogeneity in associations. Longitudinal evidence is scarce. One recent longitudinal study for Germany based on NEPS data found a stronger growth of ICT skills among males than among females in the age range of 15–18 years (Gnambs, 2021).

In sum, the results from previous research suggest that ICT is a field, where self-concepts are consistently gendered in advanced societies, while skills are not. One explanation for the mixed results could be differences in measurement. Based on data on 14 countries participating in the 2013 *International Computer and Information Literacy Study* (ICILS), Gebhardt et al. (2019) found that results are sensitive to operational definitions of ICT skills and modes of assessment. Girls performed better than boys on items that required creating and transforming information, while boys outperformed girls on items that required knowledge about and understanding computer use or using information safely and securely. Also, item format made a difference: so-called "large tasks", which required creating a product, were relatively easier for girls, while constructed and multiple-choice items were relatively easier for boys. We contribute to the heterogeneous state of research testing the gender gaps in ICT skills for the case of Germany, assuming that these gaps might not be homogeneous, but differ among adolescents with privileged and non-privileged family backgrounds.

3. Family background gaps in ICT skills

Although previous research and theorizing emphasize the relevance of cultural background, socialization processes, and the transmission of stereotypes in explaining gender differences in skill development, the predominantly psychological research in this area has often overlooked the possibility that adolescents' differential learning environments, which are socially and culturally stratified, might shape their gendered learning experiences (Fox et al., 2009; Parker et al., 2019). In the case of ICT, this is particularly relevant. Similar to other skill domains, such as languages, math, or science, ICT skills require literacy skills and intelligence (Senkbeil, 2022). But in contrast to these domains ICT skills are largely acquired at home (Senkbeil, 2017), which makes them more prone than other skill domains to "primary effects" of education—differences in performance induced by the family's social background (Boudon, 1974).

The reasons for inequalities in skills by *social background* are manifold: families from different social backgrounds are differently equipped with resources, which may help their children in skill acquisition. According to Bourdieu (1979), helpful resources take three basic forms, economic, cultural, and social capital. Economic capital, for example, helps to acquire the necessary hard- and software to use ICT skills at home, such as computers, tablets, and smartphones. It can also be used to directly foster the children's ICT skills via private tutoring. Families' cultural capital is particularly important with regard to explaining the intergenerational transmission of educational inequalities. Following Bourdieu (1979), cultural capital consists of three closely interwoven aspects: objectified capital (cultural goods such as books or works of art), institutionalized capital (academic titles and certificates), as well as incorporated cultural capital (inherent attitudes, behaviors, and knowledge acquired through education). Familial cultural capital hence shapes the home learning environment of children via the books at home, language use, subjects of family discussions, everyday interaction practices, and joint cultural activities. High economic and cultural resources usually go along with more and higher-quality social capital, because persons from a certain background tend to meet primarily members of the same background during their lives. This results in segregated social networks that differ in sources of information, support, values, practices, and role models, which could be relevant to ICT skills and practices. Quantitative empirical studies showed pronounced social differences in ICT skills, in particular by parental cultural capital, in Germany (Senkbeil et al., 2019) as well as in many other countries (Fraillon et al., 2020). ICT usage and equipment differ less. However, better-off students possess not only smartphones, but also computers, which allow more advanced ICT tasks, and they use ICT more often for school-related tasks at home (Senkbeil et al., 2019).

Similar to social background, pronounced ICT skill differences by ethnic background are visible in Germany. These differences are highest among the first generation of migrants and decrease in later generations (Vennemann et al., 2019). Multivariate analyses showed that migration background per se is not relevant for explaining differences in ICT skills, but *family language* is highly significant when social background is controlled for (Fraillon et al., 2020; Vennemann et al., 2019).

4. Intersections between gender and family background

Previous research has shown that skill differences by gender and their growth over time are unclear and seem to depend on the facets of ICT under view and their measurement (Gebhardt et al., 2019). At the same time, there are marked gaps in ICT skills by social background and family language. In sum, previous research suggests that the level and development of gendered ICT skills might be shaped by social and ethnic differences.

This result is consistent with the concept of intersectionality, which highlights the heterogeneity of gender as a social category. In general, intersectionality refers to the idea that social categories such as class, gender, and ethnicity (among others) function not as single, mutually exclusive entities, but as reciprocally constructing phenomena that in turn shape complex social inequalities (Collins, 2015). Accordingly, an individual's specific location at the interface of these categories determines one's experience of the world (Codiroli Mcmaster and Cook, 2019; Collins, 1990; Crenshaw, 1989, 1991). This idea may be transferred to quantitative research on educational inequalities by analyzing *intercategorical complexity*, an approach that calls for adopting existing analytical categories to document relationships of inequality among social groups and changing configurations of inequality along multiple and conflicting dimensions (McCall, 2005, p. 1773). This perspective implies that it is not sufficient to focus on gender, social background, or ethnic disparities alone, as done in the studies mentioned so far, but in combination, these social categories produce more complex patterns of educational inequalities (Codiroli Mcmaster and Cook, 2019; Gross et al., 2016). In our study, we ask whether gender differences in ICT skills—the social category we focus on—are moderated by students' social background, reflected by their parents' economic and cultural capital, as well as by ethnic background.

4.1. Narrowing gender gaps in ICT skills by advantaged social and ethnic backgrounds

As yet, no research addresses whether inequalities in ICT skills are shaped by intersections of gender and family background. However, to derive our hypotheses we rely on studies on gendered beliefs and gendered behaviors, as well as on research findings on other skill domains, such as math, which is considered a male domain in a similar way to ICT (Lindberg et al., 2010).

Explanations for social and ethnic differences in gendered self-concepts, interests, and attitudes relevant to skill acquisition often relate to habitus-specific socialization (see the review by Hartung et al., 2005), which results in more egalitarian gender ideologies among adolescents from a more advantageous parental background (Kulik, 2002). First, parents with high cultural capital are less likely than those with low cultural capital (and similarly, ethnic minorities) to work in gender-segregated occupations, thus representing less traditional role models for their children (Hadjar and Aeschlimann, 2015). Studies showed that females show more egalitarian gender roles (Boehnke, 2011) and are more likely to pursue male-dominated occupations (Fiebig and Beauregard, 2011) if their mothers hold non-traditional positions in education, occupational status, and labor force participation. Second, parents with higher cultural capital and without migration background are more exposed to gender-egalitarian ideas and less accepting of gender stereotypes (Brooks and Bolzendahl, 2004; Davis and Greenstein, 2009). A study by Bryant (2003) showed that the level of traditionalism among college students decreases after four years of college. As a result, parents with higher cultural capital may raise their children in a more gender-egalitarian way. According to research findings on gender ideologies and socialization, gender should have a lower influence on ICT interests, attitudes, aspirations, and thus ICT skills of socially privileged compared to disadvantaged young people and ethnic minorities, leading to narrowing gender gaps in ICT skills among privileged youths. Several studies corroborated these assumptions. For example, in the UK, Codiroli Mcmaster (2017) found that young women from disadvantaged backgrounds were less likely to study STEM compared to advantaged young women. In the Netherlands, similar patterns were found (Van de Werfhorst, 2017).

4.2. Widening gender gaps in ICT skills by advantaged social and ethnic backgrounds

Other studies, which focused on study choices in STEM fields, however, showed inconsistent results related to gendered beliefs and gendered behaviors that do not uniformly support the above assumptions (Codiroli Mcmaster and Cook, 2019). In the U.S., young, disadvantaged women were more likely than advantaged women to study STEM subjects, while social background did not affect young men (Ma, 2011). Zarrett et al. (2006) found that among young adults in the U.S., white females were the least interested in computer tasks and considered themselves the least competent at hard computer tasks (e.g., programming and software development). In contrast, African American females were as self-confident and interested in computing tasks as males (Zarrett et al., 2006). Similarly, a study by Sáinz and López-Sáez (2010) showed that the gender gap in attitudes toward computers is stronger among adolescents from high-SES families, compared to low-SES families.

Also, several studies suggest the gender gap in math achievement to be larger among adolescents from high-than from low-SES families (Lubienski et al., 2013; McGraw et al., 2006). Bécares and Priest (2015) found that parental SES and wealth strongly decide performance disadvantages among eighth graders in the US and explain profound ethnic inequalities. Within these groups of advantages and disadvantages, math and science skills turned out to be gendered, particularly among the most privileged students, with boys outperforming girls, while interests and perceived skills in these two domains were less consistently gendered. Gottburgsen and Gross (2012) analyzed intersectionalities in students' math skills in more than 50 countries, based on PISA 2006 data. Their results suggest as well that math skills are strongly determined by social background, and less consistently by gender or migration background. Girls with a migration background and low SES performed particularly low, followed by boys with similar background characteristics and girls without a migration background and low SES. The highest math scores were reached by boys with high SES and no migration background.

A recent explanation for these counterintuitive results stems from comparative research on occupational gender segregation. Several studies showed that gender segregation is higher in more affluent countries, suggesting that women in more affluent contexts have a greater leeway to "indulge their gendered aspirations" (Charles, 2017) for non-STEM education and occupations, which involve less lucrative careers because these contexts allow them to carry the economic costs associated with these career decisions. Additionally, attitudes towards different occupational fields seem to be more gendered in more affluent societies, possibly because concerns about material security are less salient in these contexts (Charles, 2011; Charles et al., 2014; Charles and Bradley, 2009; Sikora and Pokropek, 2012). In line with these results, Breda et al. (2020) recently showed that stereotypes associating math with men are more pronounced among adolescents in affluent and egalitarian societies. As an explanation for this so-called "gender-equality paradox", they argue that economic development and increasing gender equality do not go along with a suppression of traditional gender norms, but with a re-shaping into more horizontal forms of gender differentiation.

As Budge et al. (2023) recently showed for aspirations for computing jobs in Israel, the gender-equality paradox might not only refer to the macro level of countries' affluence and gender composition but also be visible on the micro level within a single country at a single point in time. Higher gender gaps in ICT skills might be expected among socially and ethnically advantaged adolescents, (a) because affluence and the risks of making economically insecure choices are distributed unequally among social groups, and (b) ethnic minorities keep their culturally shaped attitudes towards different occupational fields after migration, at least for some time. An additional argument supporting these assumptions comes from work on socially stratified child-rearing practices (Lareau, 2011): it is particularly high-SES parents who are sensitive to specific interests and skills of their offspring and cultivate these interests and skills. Hence, high-SES adolescents might be more exposed to gendered parenting patterns and extra-curricular activities than low-SES adolescents (Lubienski et al., 2013).

5. The present study

This study aims to shed light on the social and ethnic heterogeneity of initial gender-specific ICT skills and their development in secondary education in Germany, taking into account adolescents' familial economic and cultural capital as well as their home language. We define ICT skills as the skills necessary to comprehend, use, evaluate and communicate information conveyed by electronic media that people need to lead satisfying lives in personal and economic terms in modern-day societies (Senkbeil et al., 2013). We draw on data from the National Educational Panel Study, "Starting Cohort 4: School and Vocational Training: Educational Pathways of Students in Grade 9 and Higher" (NEPS-SC4). In the study, ICT skills were assessed twice, first in grade 9, followed by a second assessment in grade 12. Hence, our study refers to a phase in secondary education that is particularly relevant for the investment in specific skills that shape study choices in upper secondary school as well as in post-school vocational and academic education. While basic skills such as reading or math are taught from the beginning of school, ICT skills are more specific and are imparted later in the school career, mostly in secondary education. Our study taps into a phase in adolescence when career choices are being made, often based on gendered stereotypes towards different occupational fields, which require ICT skills to a highly different degree.

The NEPS ICT assessments were conducted in paper-pencil mode, used multiple-choice questions, focused not only on basic, but also on advanced skills, and did not encompass large, creative tasks (for details, cf. section 6.2). For these reasons, we expect advantages for boys in the initial level of ICT skills. According to a previous study based on the same data as ours (Gnambs, 2021), these advantages should increase over time. We also expect that low parental financial and cultural capital, as well as non-German family language hamper ICT skills. Concerning intersecting social inequalities, we examine whether the gender gap in ICT skills narrows or widens with social background and family language. We test two competing hypotheses. (1) Based on theory and research findings of more gender-egalitarian socialization among privileged youth, the gender gap in ICT skills level and growth should narrow among youth from families with higher cultural capital, higher financial capital, and German family language. (2) In contrast, the gender gap in ICT skills level and growth among these youth should widen in line with theories postulating and studies supporting the gender equality paradox.

We test these hypotheses separately among two groups of grade 9 students: those attending an academic school track [Gymnasium, Gymnasium tracks in comprehensive schools] and those attending a non-academic track [Hauptschule, Realschule, schools with multiple educational programs, non-Gymnasium tracks in comprehensive schools]. In Germany's highly stratified school system, track selection happens very early—usually in grade 5—and is not only based on previous school performance but also by social and migration background, as a large stock of literature has shown (Bachsleitner et al., 2022, p. 103). Hence, school composition in these tracks differs strongly in terms of both skills and family backgrounds, shaping students' skill development and attainment later in life. Regarding ICT skills, the ICILS 2018 study reported substantial positive effects of school-average SES on learning outcomes (Fraillon et al., 2020). Studies based on NEPS data found that learning progress during secondary schooling is affected by the exposure to different school tracks, and these differences could be partly explained by the skill composition of the class (Traini et al., 2021). In the period under view, grade 9 to grade 12, students in non-academic tracks typically finish school and continue learning in other contexts, such as firm-based or school-based training, further schooling, vocational preparation schemes, or jobs. In contrast, academic track students continue school in the same relatively homogeneous context as before. ICT skills thus hold greater immediate importance for non-academic track students, as they are critical for vocational placement, whereas they are less urgent in academic contexts. Furthermore, the timing, formats, and contents of ICT programs in secondary school differ between the non-academic and academic tracks (Schwarz et al., 2021; Starruβ, 2010, p. 203). In sum, these considerations suggest that tracks constitute highly differing learning environments, which have affected students' skills in grade 9 for several years. Therefore, it seems more adequate to analyze intersectionalities within these contexts than overall.

Since students from disadvantaged family backgrounds are concentrated in the non-academic track, whereas students in the academic track are positively selected, we expect the effects of family background to be less pronounced in both of our groups of students than in previous research. We refrain from postulating hypotheses on differential effects between the two groups of students, because neither theory nor previous research suggests particular differences.

Due to the large amount of missing information on ICT skills at the second measurement point for students attending non-academic tracks, we restrict the analyses of ICT skills growth in grade 12 to students in the academic track (see section 6.3 for details; for a similar approach, see Hübner et al., 2023). Analyzing inequalities in skills growth in grade 12 is particularly relevant for this group of students, because computing lessons are often shifted to the upper secondary level (grades 10–13) in the academic track (Starruβ, 2010, p. 203). Examining the intersection of gender and family background on ICT skill growth enables us to derive conclusions about the development of the gender gap in ICT skills, about the timing of the impact of family background on this gap and about the stability of intersectional inequalities in ICT skills during this crucial phase.

6. Method

6.1. Sample

We conducted our analyses based on two-wave data on students' ICT skills from the National Educational Panel Study (NEPS), "Starting Cohort 4: School and Vocational Training: Educational Pathways of Students in Grade 9 and Higher" (Blossfeld and Roβbach, 2019). The data comprise a large and representative sample of 16,425 ninth-grade secondary school students in 648 schools in Germany. The first survey was carried out in the fall of 2010, followed by semi-annual or annual follow-up surveys. NEPS offers extensively validated standardized assessments of ICT skills, which were administered repeatedly to the same respondents.

We excluded a total of 1532 students who attended special needs schools where ICT skills were not assessed, or for whom the type of school was unknown. This information was essential for conducting separate analyses for academic and non-academic tracks. Additionally, we excluded 737 students lacking data on grade 9 ICT skills, as this is a critical predictor of ICT skills at the second measurement time point in our imputation model. Furthermore, we removed 19 students with missing data on migration background. Our analytical sample consists of 14,137 students (49.8 % females) attending 523 secondary schools (62 % students in the non-academic track).

6.2. Variables and measures

ICT skills. Assessments of students' ICT skills were developed in NEPS specifically for longitudinal analyses. ICT skills were first assessed in grade 9 (wave 1; 2010/11), followed by a second assessment in grade 12 (wave 7; 2013/14). The assessments for grades 9 and 12 contain different items that allow an accurate measurement of ICT skills in each age group. The two assessments were linked with an anchor group design to enable scaling them on the same metric and thus to compare mean levels longitudinally (Senkbeil and Ihme, 2012).

ICT skills—the ability to comprehend, use, and communicate information conveyed by electronic media—were defined from a functional perspective in NEPS. This approach emphasizes the knowledge and skills necessary for individuals to navigate everyday challenges and lead personally and economically satisfying lives (Senkbeil et al., 2013). Similarly to other prominent ICT frameworks (ETS, 2002; Katz, 2007), the NEPS assessment covers five types of software applications (word processing/operating systems, spreadsheet, presentation and graphics software, e-mail/communication apps, and internet/search engines) and four process components (access, create, manage, and evaluate) (Ihme et al., 2015). The process components represented either technological literacy (access or create) or information literacy (manage or evaluate) (Ihme et al., 2015).

Students' skills were assessed in the classroom, where one test instructor from the survey institute and one supervisor from the teaching staff were present. The formats included simple and complex multiple-choice questions, where test-takers selected the correct solution from up to six options. Each item assessed one process component and one software application. Most items included screenshots, such as those of an internet browser, database, or spreadsheet, to prompt responses (for example items, see Ihme et al., 2015). The grade 9 test included 36 items and the grade 12 test 31 items. Both tests were speeded. Reliability was good (Grade 9 WLE reliability = 0.81; Grade 12 WLE reliability = 0.73) (Senkbeil and Ihme, 2012, 2017). Validity analyses with NEPS data revealed high content validity and test fairness by gender and school type (Senkbeil et al., 2013).

NEPS provides Warm's mean-weighted likelihood estimator (WLE; Warm, 1989) scores as estimates of each individual's skills, which are derived from an Item-Response-Theory model (Pohl and Carstensen, 2012). The WLEs are on a logit-scale with a mean of zero and unconstrained variance. The WLEs express individuals' most likely skill scores given their item responses. The tests were linked across waves to allow for longitudinal mean-level comparisons (Fischer et al., 2016).

Gender. In the NEPS student survey, respondents were asked in every interview whether they are female or male, which in our view reflects their self-defined gender; however, only in a binary way (cf. Westbrook and Saperstein, 2015 for a critical discussion on questions as these). Since very few persons (n = 40) reported a change of gender during the study, we were unable to analyze this group separately. Hence, we coded gender as a dummy variable with male students as the reference group. We used the first available measurement between waves 1 and 7. When gender information was missing from the students, we supplemented it with data provided by their parents.

We use three indicators to reflect different aspects of social background: household income, parental educational attainment, and the number of books available at home.

Family economic capital. We used the monthly equivalence income to measure families' economic capital. The variable is based on information on household composition and monthly net household income from the parent survey in the first survey wave. If respondents declined to report the exact value of their income, they were asked for income intervals. To harmonize the data, the mean value of the income interval was used. We used the equivalence weight proposed by the OECD (factor of 0.5 for other persons over 14 years in the household, 0.3 for children up to 14 years). To normalize the right-skewed income distribution, the variable was logarithmized.

Highest parental educational qualification. We used the highest degree mentioned in waves 1 to 7 in the student and parent survey to capture the institutionalized cultural capital of the family. We distinguished between a tertiary education degree (ISCED levels 5 and 6) and lower qualifications (reference category).

Number of books available at home. This variable is the most frequently used measure of objectified cultural capital (see Heppt et al., 2022; Sieben and Lechner, 2019, for validation studies). The measure was collected from students in wave 1. The scale ranges from 1 (none or only very few books) to 6 (enough to fill a shelf unit); the questionnaire supports students' assessments of the number of books by visual illustration.

Language use. The migration population in Germany in the age of our analysis sample is quite large and ethnically diverse. In 2010, 29 percent of the children aged 10–15 years in Germany had an immigration background, mostly second generation (Destatis, 2017). 70 percent of this population were from European countries, with the largest groups being from Turkey (25 %), former Yugoslavia (10 %), Poland (8 %), the Russian Foundation (6 %), and Italy (5 %). 15 percent were of Asian descent, primarily from Kazakhstan (5 %) (Destatis, 2017). Students from all major immigrant groups in Germany face educational disadvantages compared to non-immigrant peers, particularly in subjects reliant on German language proficiency (Hunkler and Schotte, 2023). A significant factor in this gap is Germany's past policy of recruiting unskilled workers for its industrial base, resulting in a negatively selected immigrant population with low socio-economic status (Gebhardt et al., 2019, p. 286, 294). In our analysis sample, sample sizes are too small to distinguish

major ethnical groups. Furthermore, as language proficiency turned out to be a more decisive predictor of ICT skills than ethnic background in general in previous studies (Fraillon et al., 2020; Vennemann et al., 2019). For these reasons, we considered students' language use at home instead of ethnic background as axis of intersectionality, distinguishing between (a) students who speak predominantly or exclusively a language other than German with parents or siblings and (b) students who speak predominantly or exclusively German with both parents and siblings (the reference category).

6.3. Selectivity analyses and multiple imputation of missing values

Table 1 provides sample statistics for students with and without valid Grade 12 ICT assessment data. Attrition rates differ significantly between school tracks. Students in the non-academic track typically left school after grade 9 or 10, making them more difficult to reach, whereas most students in the academic track were still in school in grade 12. Accordingly, ICT test data was available for two-thirds of students in the academic track in grade 12 (66 %), compared to only one-fifth of students in the non-academic track (20 %). To examine the dropout process in more detail, we conducted a linear probability model to predict non-response in grade 12 using all variables relevant to our analyses. Initially, we found higher dropout rates among students with lower ICT skills, female students, students with fewer books at home, lower parental educational qualifications, and lower income. However, after including the school track in the analysis, the regression coefficients changed considerably, with some variables losing their statistical significance, reflecting the socially selective school system in Germany. School track emerged as the most significant predictor of dropout ($B = 0.38$, $p < 0.001$), explaining 10 percent of the variance in non-response.

Given the very high amount of missing information on ICT skills at the second measurement time point for students in the non-academic track, we decided not to impute ICT skills for this group. Consequently, our analysis of ICT skill change focuses exclusively on the sample of students in the academic track. There is no established threshold for using multiple imputations, however, statistical literature advises selectivity analyses and strong auxiliary variables when missing data exceeds 30 percent (Newman, 2014). We argue that the higher the non-response rate, the higher the likelihood that non-response is influenced by unobserved variables, especially by events and developments after the last survey participation. This risk is especially pronounced for students in non-academic tracks due to the diverse paths they take after grade 9/10. While most students in the academic track continue schooling (84 % in our analysis sample), students in the non-academic track follow various paths. Many enter one of more than 400 specialized vocational education and training programs, others pursue further schooling, and still others start prevocational training or unskilled work. These paths differ highly in terms of provided ICT skills and other factors predicting panel participation, such as learning experiences, self-esteem, or time availability. Participants' pathways and the associated ICT skills cannot be reliably predicted based on available data from earlier waves.

To deal with missing values in the dependent and independent variables, we drew on a two-level multiple imputation procedure with random intercepts to create 60 imputations using Blimp 3.1 (Enders et al., 2018). This imputation procedure allowed us to take into account the multilevel structure of the data. We carried out separate imputations for academic and non-academic school tracks for grade 9 ICT skills. As explained above, we only imputed ICT skills at the second measurement time point for students in the academic track. The imputation model included all variables used in the analysis models, including the relevant interaction terms for our intersectionality analyses. In addition, we considered auxiliary variables, including migration background (up to the second generation; Olczyk et al., 2014) and the highest parental socioeconomic status as measured by the International Socio-Economic Index (Ganzeboom et al., 1992).

6.4. Analytic strategy

Our analyses of ICT skills were conducted in two steps. First, we examined gender differences in ICT skills among grade 9 students attending academic and non-academic tracks and gender differences in ICT skills growth among students in the academic track from

Table 1
Sample statistics by non-response and predictors of non-response, linear probability model.

	Sample statistics				Regression			
	Response		Non-response		w/o school type		w/school type	
	Mean	S.D.	Mean	S.D.	*B*	S.E.	*B*	S.E.
Female, ref. male	0.54		0.47		−0.05***	[0.01]	−0.03*	[0.01]
Language use, ref. (mostly) German	0.12		0.16		−0.04	[0.02]	−0.03	[0.02]
College or university degree, ref. other	0.39		0.21		−0.09***	[0.02]	−0.03	[0.02]
Number of books	4.24	1.39	3.50	1.46	−0.06***	[0.01]	−0.03***	[0.01]
Equivalence income (ln)	7.30	0.47	7.11	0.50	−0.03***	[0.01]	−0.01	[0.01]
Grade 9 ICT skills	0.36	0.91	−0.22	0.89	−0.11***		−0.04***	[0.01]
School type, ref. academic	0.34		0.80				0.38***	[0.03]
Constant					0.65***	[0.02]	0.38***	[0.02]
R^2					0.12		0.21	
N	5460		8677		7175		7175	

Notes. Source: https://doi.org/10.5157/NEPS:SC4:12.0.0. Continuous variables were standardized in the regression models. Cluster robust S.E., N (schools) 523. *p < 0.05, **p < 0.01, ***p < 0.001.

grade 9 to grade 12. For this purpose, we estimated general linear models with gender and students' family background variables as predictors of initial skills and their change. For the model predicting change, we followed the ANCOVA or conditional approach and regressed grade 12 ICT skills on grade 9 ICT skills (Werts and Linn, 1970). In the next steps, we additionally included interaction terms between the different family background variables and gender in separate models, to examine whether gender differences in initial levels of ICT skills and their development vary according to students' family backgrounds. The sample characteristics by gender and the academic and non-academic track are presented in Table 2.

All analyses were conducted using Stata 17. To account for the clustering of observations within schools, we used a Huber-White sandwich estimator to obtain cluster-robust standard errors (Williams, 2000). We *z*-standardized all continuous variables within the subsamples of students attending academic and non-academic schools. Thus, the regression parameters indicate standardized mean differences and as such a measure of effect size.

7. Results

Descriptive results show that in the non-academic track, male students in grade 9 had, on average, 0.05 (SE 0.02, $p < 0.05$) higher ICT skills than female students. In the academic track, male students in grade 9 had, on average, 0.08 (SE 0.02, $p < 0.001$) higher ICT skills than female students. With a Cohen's d of 0.07 (non-academic track) and 0.10 (academic track), these unadjusted mean gender differences correspond to negligible or small associations according to recent guidelines (Gignac and Szodorai, 2016). To contextualize the grade 9 results, Fig. 1 shows the mean gender differences (with 95 % confidence intervals; *z*-standardized values) in ICT skills in contrast to reading and numeracy skills in grade 9. The results show that gender differences are larger in both domains than in ICT. Females performed better in reading, while males performed better in numeracy, both in the non-academic and the academic track.

Furthermore, male students attending the academic track showed, on average, 0.19 (SE 0.02 $p < 0.001$) higher growth in ICT skills from grade 9 to grade 12 than female students. Here, Cohen's d of 0.22 points to a medium effect size. After accounting for the development of reading and numeracy skills over the same period, the effect size adjusted slightly to 0.20 (SE = 0.03). This negligible change suggests that gender differences in ICT skill growth persist independently of differences in the development of reading and numeracy skills.

Table 3 shows the results of unmoderated models (i.e., models with all variables but without interaction terms) for ICT skills in grade 9 for students in both tracks, as well as changes in ICT skills from grade 9 to 12 for students in the academic track. The results indicate gender differences in ICT skills favoring males in both tracks in grade 9 as well as in ICT change over time in the academic track. The effect sizes are comparable to those in the unadjusted models presented previously. We also found that students who predominantly did not speak German at home showed significantly lower initial ICT skills, but there were no differences in ICT growth by language use. Students with parents holding a college degree and those with more books at home exhibit higher initial ICT skills. Having more books at home also benefits ICT skill development, while a college degree does not. Economic capital, measured by household equivalence income, correlates with ICT skills in grade 9 for students in the non-academic track but not in the academic track, nor does it impact ICT skill development in the academic track. When comparing effect sizes in grade 9 between the academic and the non-academic tracks, notable differences emerge. Most remarkably, the link between initial ICT skills and gender was twice as strong in the academic sample as in the non-academic sample. In contrast, the relationship between income and ICT skills was significantly stronger in the non-academic sample—six times greater than in the academic sample, where the correlation was not statistically significant. All other correlations were almost consistent across both samples.

7.1. Does the gender gap in ICT skills vary by economic capital?

Fig. 2 shows the gender gap in ICT skills in grade 9 in the non-academic track (left) and in the academic track (right) for different values of household equivalence income and 95 % confidence intervals. As male students form the reference group in our analyses, values above the zero line indicate gender differences in favor of females, and values below the zero line indicate gender differences to the detriment of females. Unless the 95 % confidence interval for the predicted gender gap includes zero, the differences can be

Table 2
Sample statistics.

	Non-Academic					Academic				
	Male		Female			Male		Female		
	Mean	S.D.	Mean	S.D.	N	Mean	S.D.	Mean	S.D.	N
ICT skills grade 9 (WLE)	−0.34	0.88	−0.39	0.79	8828	0.65	0.80	0.58	0.76	5309
ICT skills grade 12 (WLE)	0.66	0.79	0.44	0.68	1856	1.43	0.76	1.19	0.63	3604
Monthly equivalence income, in €, logarithmized	7.07	0.47	7.03	0.47	4289	7.38	0.46	7.36	0.48	3441
Highest parental education, ref. no college	0.18		0.14		7563	0.49		0.44		5014
No. of books at home (categories 1–6)	3.35	1.47	3.36	1.40	8583	4.44	1.30	4.57	1.22	5246
Language use at home, ref. (mostly) German	0.16		0.18		8164	0.09		0.09		5046
Age at first measurement (in years)	14.89	0.75	14.80	0.73	8783	14.57	0.65	14.47	0.59	5293
N	4681		4147		8828	2417		2892		5309

Source: https://doi.org/10.5157/NEPS:SC4:12.0.0

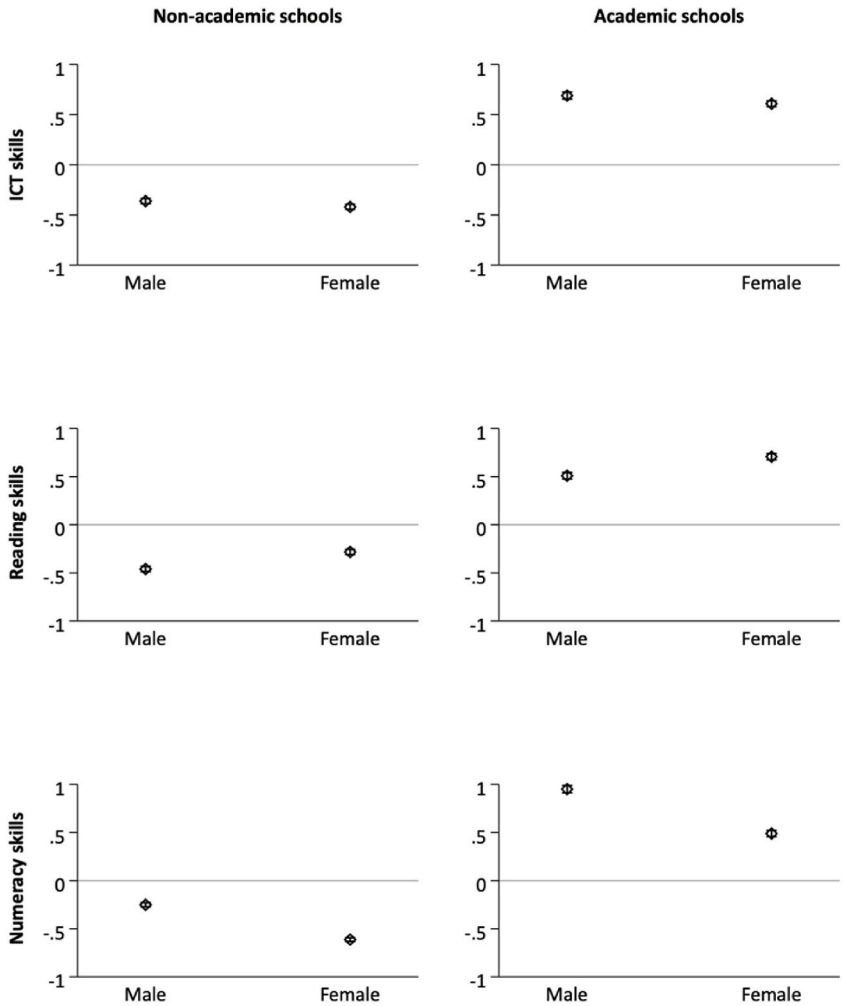

Fig. 1. Mean gender differences in ICT, reading, and numeracy skills in grade 9 by school type.

Table 3
Unmoderated regression models predicting ICT skills in grade 9 and their change in grade 12.

	Non-academic		Academic			
	Grade 9		Grade 9		Change	
	B	S.D.	*B*	S.D.	*B*	S.E.
Female, ref. male	−0.05*	[0.02]	−0.11***	[0.03]	−0.28***	[0.03]
Language use, ref. (mostly) German	−0.29***	[0.03]	−0.33***	[0.06]	−0.09	[0.05]
College or university degree, ref. other	0.07*	[0.03]	0.08*	[0.03]	0.03	[0.03]
Number of books, std.	0.20***	[0.01]	0.18***	[0.02]	0.08***	[0.02]
Equivalence income (ln), std.	0.11***	[0.02]	0.02	[0.02]	0.02	[0.02]
Grade 9 ICT skills, std.					0.54***	[0.01]
Constant	0.07*	[0.03]	0.06*	[0.03]	0.15***	[0.03]
Max. FMI	0.41		0.30		0.53	
Average RVI	0.16		0.12		0.52	
N(persons)	8828		5309		5309	
N(schools)	374		163		163	

Notes. Source: https://doi.org/10.5157/NEPS:SC4:12.0.0. Cluster robust S.E., 60 imputations, continuous variables standardized. *p < 0.05, **p < 0.01, ***p < 0.001.

considered statistically significant. Due to the standardization of all continuous variables, the x-axis labels refer to standard deviations of the income scale and the predictions refer to gender differences in ICT skills in standard deviations. Full results of regression analyses can be found in Table A1 in the appendix.

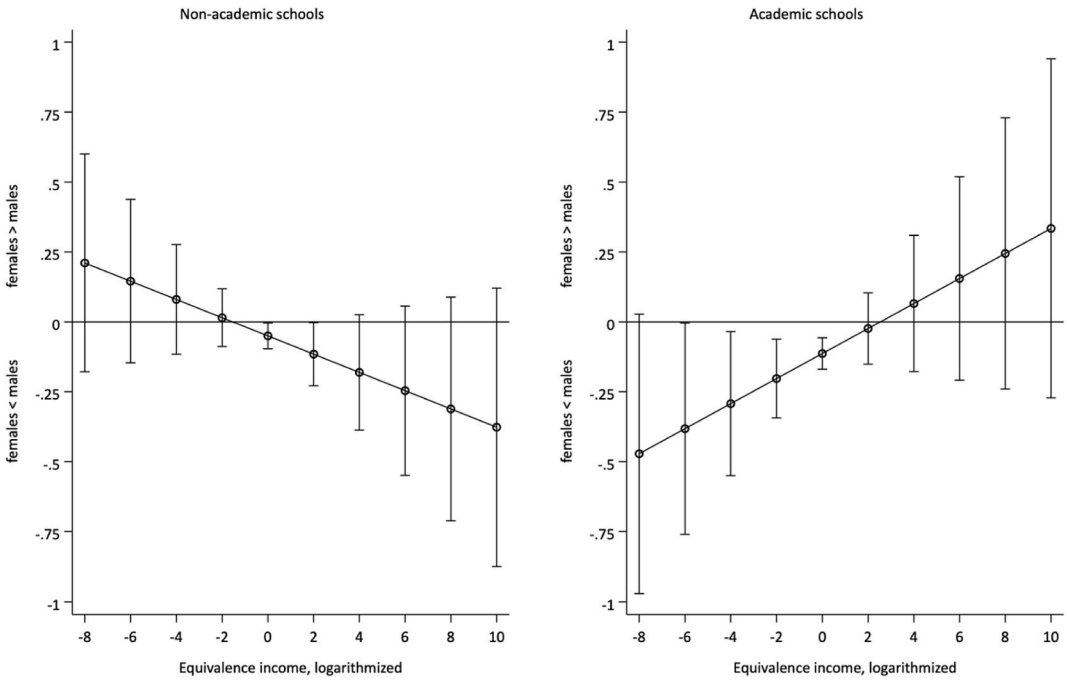

Fig. 2. Predicted gender differences in ICT skills in grade 9 as a function of equivalence income (ln), ref. males.

As shown in Fig. 2, in non-academic schools, there are no statistically significant gender differences in ICT skills across different income levels. However, in academic schools, gender differences are evident among students with below-average incomes (values below 0) favoring males. However, the interaction terms for the gender differences in ICT skills by income in grade 9 are not statistically significant (Table A1).

Fig. 3 displays the gender gap in ICT skill change from Grade 9 to 12 among students in academic schools. Similar to initial ICT skills, the gender gap favoring males decreases as income increases and disappears altogether for incomes exceeding two standard

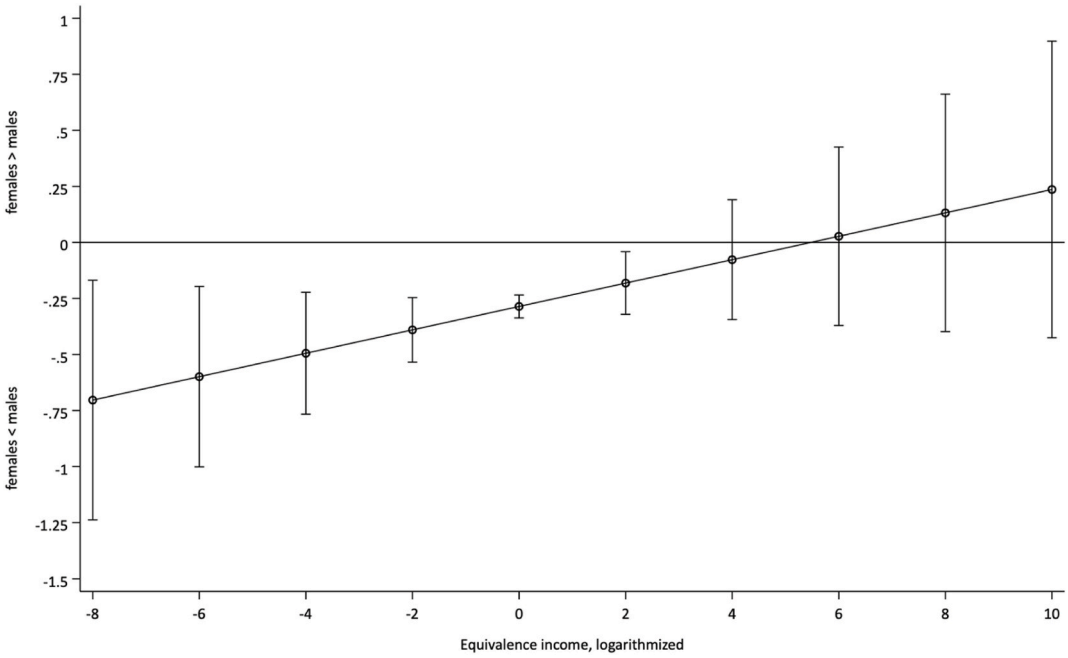

Fig. 3. Predicted gender differences in ICT skill change from grade 9 to grade 12 among students attending academic schools as a function of equivalence income (ln), ref. males.

deviations above the mean. However, at mean levels, the interaction term is not statistically significant (Table A1).

7.2. Does the gender gap in ICT skills vary by parental education and the number of books in the household?

Figs. 4 and 5 show the results for the relationships between gender differences in ICT skills in grade 9 in non-academic schools (left) and in academic schools (right) as a function of the highest parental educational qualification, and the number of books in the household. The full regression results can be found in lables A2 and A3 in the appendix.

Concerning parental education, we found contrasting associations between academic and non-academic schools. For students in non-academic schools, the gender gap in ICT skills favoring males in Grade 9 is apparent only among those whose parents hold a college degree. In contrast, the gender gap for academic school students shows the opposite trend and is only observed among students whose parents lack a college degree. However, the estimated interaction relationship is not statistically significant (see Table A2). Regarding the number of books at home, we found no differences in gender gaps among non-academic track students. However, for students in academic schools, gender differences in ICT skills in grade 9 decrease as the number of books increases. This association is statistically significant at the 5 % level of statistical significance (see Table A3).

Figs. 6 and 7 illustrate how the highest parental qualification and the number of books available at home affect the gender gap in ICT skill development in academic schools. The results point to a gender gap in ICT skill change favoring males, regardless of whether their parents have a college degree, as reflected in the statistically insignificant interaction (Table A2). Similarly, gender differences in ICT skill change from Grade 9 to Grade 12 persist regardless of the number of books at home (see Table A3).

7.3. Does the gender gap in ICT skills vary by family language?

Fig. 8 shows the interaction between gender differences in grade 9 ICT skills in non-academic and academic schools and non-German family languages. The full regression results can be found in Table A4 in the Appendix.

The results suggest no significant gender differences in grade 9 ICT skills for students in non-academic schools, whether they mostly speak German at home or not. In academic schools, males exhibit higher ICT skills in grade 9 than females, again regardless of family language. Also, the regression results presented in Table A4 show no statistically significant interaction association. This might be due to the small number of cases in the group of students with non-German family language.

Fig. 9 shows the gender gap in ICT skill development in academic schools depending on the family language. The results indicate no statistically significant differences in the gender gaps between students speaking German or another language at home. Also, the relevant interaction term is statistically insignificant (Table A4).

8. Discussion

We examined gender differences in performance-based ICT skills of grade 9 adolescents in both non-academic and academic

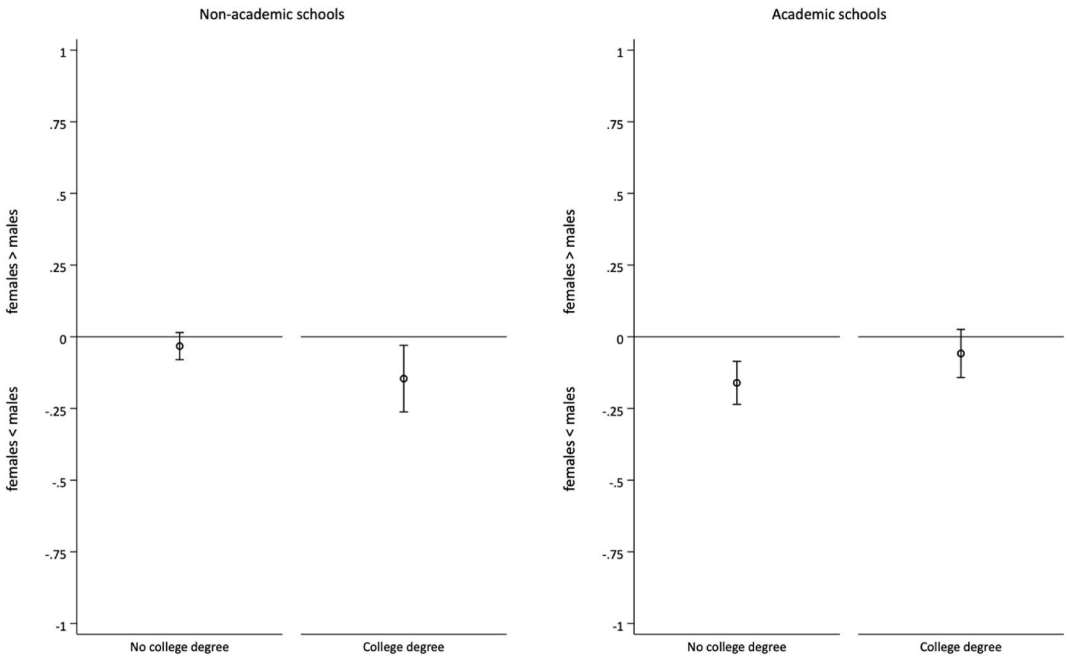

Fig. 4. Predicted gender differences in ICT skills in grade 9 as a function of parental education, ref. males.

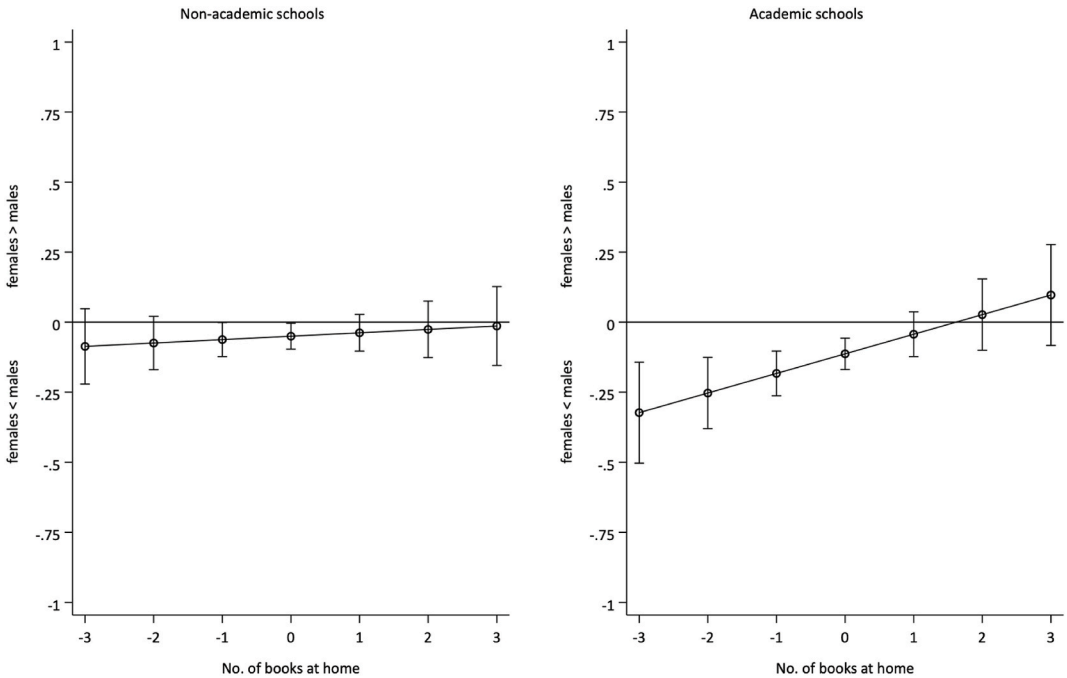

Fig. 5. Predicted gender differences in ICT skills in grade 9 as a function of the number of books at home, ref. males.

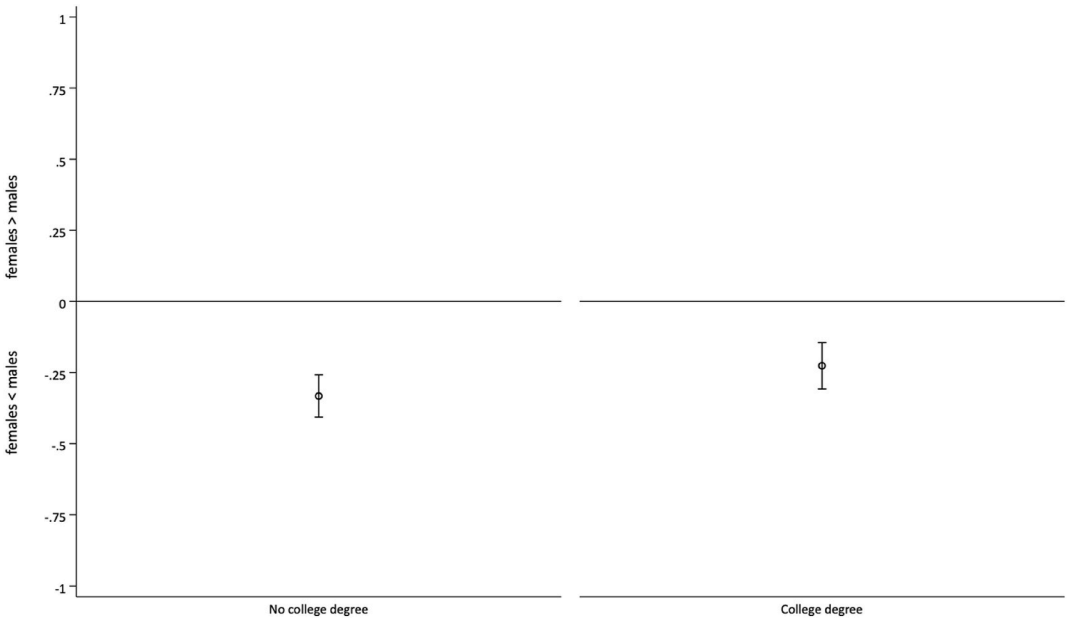

Fig. 6. Predicted gender differences in ICT skill change from grade 9 to grade 12 among students attending academic schools as a function of parental education, ref. males.

schools and assessed changes over three school years in academic schools. Our focus was on the intersections of gender and family background, including economic capital, the highest parental educational qualification, the number of books available at home and family language. We used large-scale, representative longitudinal data from the German National Educational Panel Study. Analyzing non-academic and academic tracks separately acknowledges Germany's stratified school system, where early sorting is influenced by social and migration backgrounds (Bachsleitner et al., 2022, p. 103). Non-academic and academic tracks constitute highly different contexts, with regard to the social and skills composition of peers (Traini et al., 2021), the timing of leaving school, and the timing, format, and content of ICT programs (Starruβ, 2010, p. 203), creating distinct learning environments that have shaped students' ICT

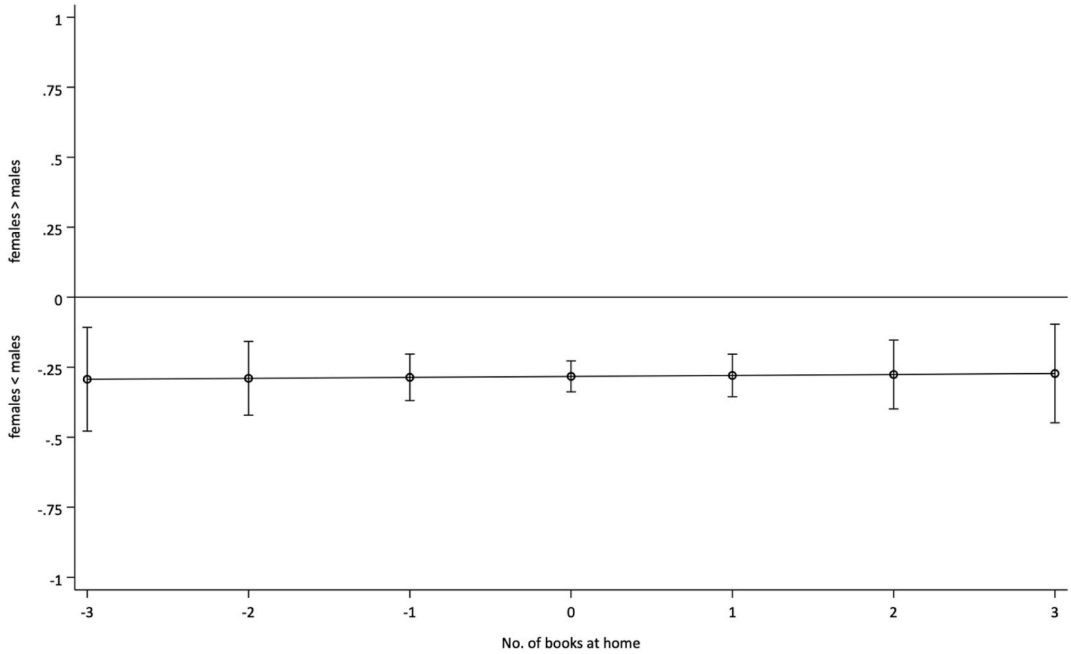

Fig. 7. Predicted gender differences in ICT skill change from grade 9 to grade 12 among students attending academic schools as a function of the number of books at home, ref. males.

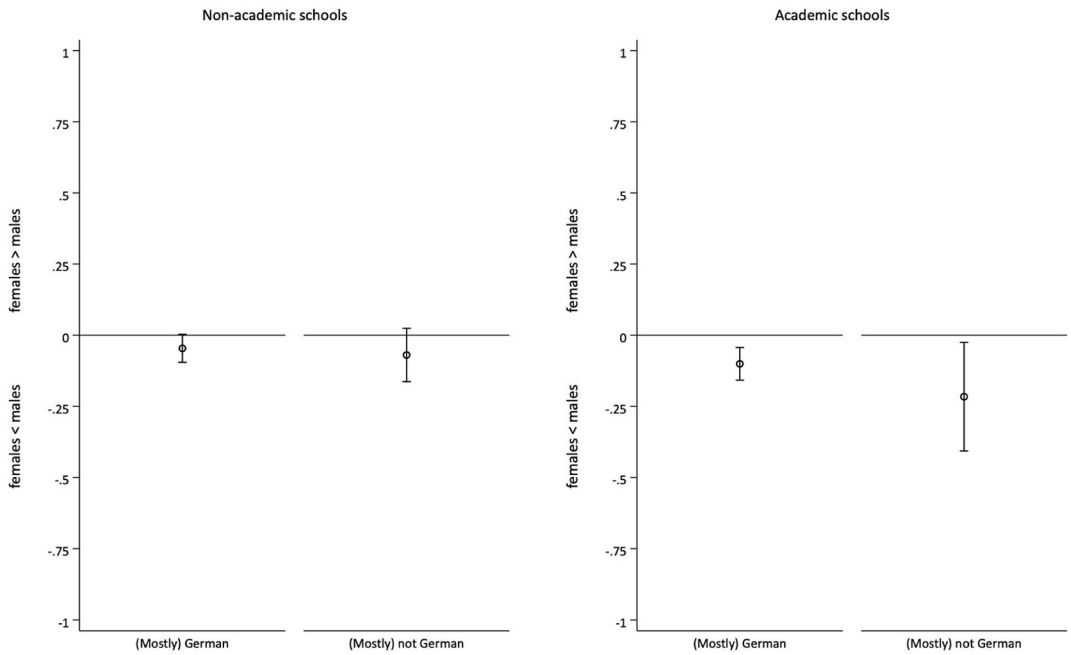

Fig. 8. Predicted gender differences in ICT skills in grade 9 as a function of language use at home, ref. males.

skills in grade 9 over the years.

First, our examination revealed small, but consistent gender differences in grade 9 ICT skills favoring male students in both non-academic and academic schools, which widened in grade 12 among academic students. This result adds to the inconsistent findings on gender differences in primarily cross-sectional previous research, which found either no gender differences or advantages for one gender (Siddiq and Scherer, 2019 for a meta-analysis). The relationship between initial ICT skills and gender was twice as strong in the academic sample as in the non-academic sample. The stronger gender association in academic schools may arise from differences in how ICT education is approached in academic and non-academic tracks. Although most federal states and tracks offer integrative basic

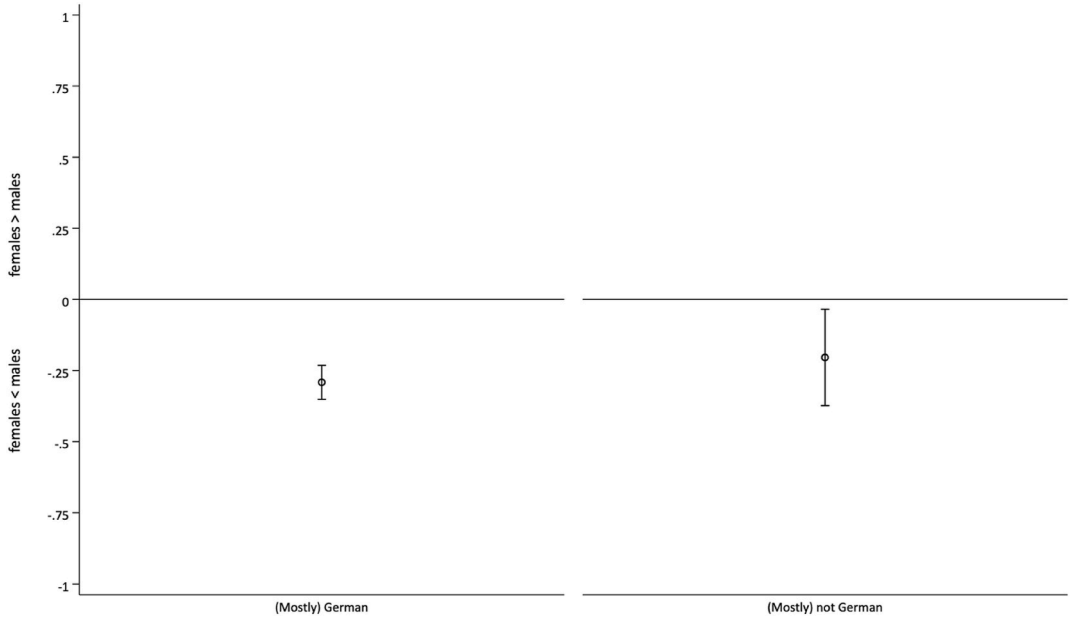

Fig. 9. Predicted gender differences in ICT skill change from grade 9 to grade 12 among students attending academic schools as a function of language use at home, ref. males.

education, academic schools often defer computer science curriculum to the upper secondary school level (*gymnasiale Oberstufe*, grades 10–13) and offer more elective options for acquiring ICT skills (Starruβ, 2010). This might allow for a greater influence of societal gender stereotypes in ICT interests on ICT skill acquisition up to grade 9 (Master et al., 2016). In contrast, non-academic schools with a vocational education focus typically incorporate computer science topics more specifically and in some federal states (*Länder*) compulsorily in their lower secondary level curricula (Starruβ, 2010). Increased opportunities for gender-specific, interest-based course selection in the upper secondary level of academic school may also explain the expanding gender gap in grade 12 ICT skills, as females often express less interest in ICT than males (Sáinz and López-Sáez, 2010; Zarrett et al., 2006).

Second, consistent with earlier studies (Fraillon et al., 2020; Gerick et al., 2019; Vennemann et al., 2019), we observed significant social and family language differences in ICT skills. Students who primarily speak a language other than German at home and those whose parents do not hold a college degree and who have fewer books at home had lower ICT skills compared to their predominantly German-speaking peers and students with more educational resources. Conversely, economic capital significantly impacted grade 9 ICT skills only among non-academic students, even when accounting for parents' educational qualifications, the number of books at home, and family language. The stronger correlation between income and ICT skills in non-academic schools may result from the greater students' diversity in social and economic backgrounds, which can influence access to and engagement with digital technologies. Parental economic resources are necessary to acquire not only a mobile phone, but also a computer to practice one's ICT skills. Due to the positive selection of students in the academic track, this standard might usually be given. Among students from academic-track schools, differences in ICT skills are more related to parents' educational qualifications and the number of books at home than to the economic resources needed to access digital technologies. This aligns with the finding that the number of books at home is positively correlated with ICT skill growth among academic students, while parental education, economic resources or the family language have no impact.

Third, we found some interactive associations for predicting ICT skills in grade 9 by gender and family background mostly among students in the academic track. Thus, examining overall gender differences in skills alone conceals heterogeneity in these relationships. Our results for the academic track suggest that the gender gap in favor of males decreases as familial economic and educational resources (measured by parental education and the number of books at home) increase. Concerning family language, we found no differences in the gender gap in ICT skills. Given the interrelation of ICT skills, self-concepts, and value orientations (Eccles et al., 1990), our findings support previous research on differential gendered ICT self-concepts, interests, and aspirations that vary with family social background (Hadjar and Aeschlimann, 2015; Kulik, 2002), as more privileged students might be exposed to more gender-egalitarian ideas and role models. The moderating role of familial monetary resources might be explained by the fact that higher family income might be associated with a double-earner model, and accordingly with positive maternal role models. In the non-academic track, hardly any significant interactions were found, with one exception: gender differences in ICT skills were apparent among students with college-educated parents, but not among students with lower-educated parents. Hence, in this group, parents' educational qualification has a contradicting moderating effect as among students in the academic track. This result is not easy to explain; it might be caused by the fact that only a small and specific selection of children with college-educated parents are in non-academic schools. The absence of other significant intersections between gender and family background in grade 9 ICT skills in non-academic schools can be attributed to the school curriculum, which mitigates gender gaps in ICT skills from the outset and allows

for minimal adjustments based on family characteristics.

Fourth, as for the change in ICT skills from grade 9 to grade 12 among academic students, we found an increasing gender gap in ICT skills, but no differences in this gap concerning parents' educational qualifications, the number of books at home and family language. This result suggests that family educational resources influence gender gaps in ICT skills early on, but do not exert additional influence on ICT development in higher secondary education. This finding contrasts with studies from the U.S. on gender differences in math and science skills, which indicate larger gender gaps among high SES students (Bécares and Priest, 2015; Lubienski et al., 2013; McGraw et al., 2006). However, the gender gap narrowed with increasing parental economic capital. The reason for this decline could lie in the motives for and patterns of use of digital technologies, which vary according to social background (Senkbeil et al., 2019). Considering that the young people in the sample are about to make important educational and career decisions, acquiring ICT skills is related to career aspirations and interests. From this perspective, the narrowing gender gap by parental income may be related to pursuing STEM subjects that promise social success in today's world, which may be less gender-typical in high-income families.

Overall, our results on ICT skills among students in non-academic schools do not suggest any moderation of the (small) gender gap in ICT skills by family background, while our results on the gender gap in ICT skills in academic schools are largely in line with hypothesis 1, which assumed more gender-egalitarian socialization among youth with privileged family background. Regarding the skills gap in grade 9, we found no gender gap among students with college-educated parents, above-average books at home and German language background. Regarding the gender gap in skills growth, we found a declining gender gap with higher financial capital. In contrast, none of our results in this group of students spoke in favor of the competing hypothesis 2, which assumed a wider gender ICT gap among socially and ethnically advantaged students along the lines of the gender equality paradox. Among students in the non-academic track, one result hints in the direction of hypothesis 2: among students with college-educated parents, there was a significant gender gap in ICT skills, while among students with lower-educated parents, no significant gap could be found. However, we are reluctant to interpret this as evidence for the gender equality paradox because gender differences were small in general and the group of students in non-academic schools with college-educated parents is small and might be specially composed.

Furthermore, our analyses among students in the academic track showed that gender differences in initial ICT skills in grade 9 were moderated more by family social background than gender differences in the development of ICT skills. The reason for this could be on the one hand path dependency in skill development, and on the other hand, the observation period studied. With increasing age, social contexts outside the family, such as peer groups or teachers, might play an increasingly important role in affecting students' investment in ICT skills, leaving behind the influence of family social context. These results resonate with the claim of situated expectancy-value theory that it is mainly the cultural milieu that forms culturally grounded belief systems, which get internalized into subjective task values and achievement-related choices and performance when children grow up (Eccles and Wigfield, 2020). Later in their lives, these internalization processes have already taken place, which might explain both path dependence and the larger impact of social contexts outside the family.

8.1. Limitations and directions to future research

Despite the large-scale and longitudinal advantages of the data, our study has several limitations. First, the NEPS measurement of ICT skills employed in this research reflects a unidimensional construct, which did not differentiate the technological and informational dimensions of ICT skills (Katz, 2007). Not distinguishing these dimensions may suppress gender differences in ICT skills in favor of male students, as female students are consistently found to have stronger literacy skills compared to males (see meta-analyses by Lietz, 2006; OECD, 2019; Yu and Hu, 2022), which are especially related to the information dimension of ICT skills. Literacy skills are particularly important for informational internet use (e.g. finding, selecting, selecting, and evaluating information), and strategic internet use (e.g. using the internet by developing a direction toward a specific goal or taking the right action to achieve that goal; van Deursen and van Dijk, 2016). Future research on gender differences in ICT skills could benefit from distinguishing between the two dimensions. The NEPS data allows for a separation of the process components.

Second, our study of ICT skill growth among academic students is based only on two-wave data during adolescence. For this reason, we cannot make any statements about the stability and the shape of change over the entire life course within the individual groups studied. Therefore, it remains an open question at which points in the life course changes occur and at which points stabilities are evident. Further studies with multiple measurement time points could provide answers to these questions.

Third, our study does not allow for conclusions regarding cross-country differences in gendered ICT skill gaps, and as such, it cannot shed light on the mixed findings related to gender gaps in performance-based ICT skills across countries. While Germany was selected as a critical case due to its early and socially selective educational tracking system, which significantly influences skill development, the findings may not be directly applicable to other contexts. Each country may exhibit distinct patterns in ICT skill gaps due to variations in educational systems, cultural contexts, and policy frameworks. In addition, a systematic comparison of gender gaps in ICT skills with those in other domains, such as numeracy and reading, could offer valuable insights. Examining the interdependencies between gendered ICT skills and gender gaps in other skills, as suggested by prior research (Hübner et al., 2023; Wicht et al., 2021), would further enhance our understanding of how these gendered skills develop and interact across different countries.

Fourth, future research could benefit from exploring more nuanced measures of ethnic background as a distinct axis of intersectionality, rather than relying solely on a binary classification of home language, which may oversimplify the complexity of ethnicity. Each language category can encompass ethnically diverse groups and variations in language use within the same ethnic group, suggesting that a broader and more precise approach to measuring ethnicity could offer deeper insights. In our study, the inclusion of direct ethnicity measures alongside home language is limited by insufficient case numbers.

Finally, our analyses of differences in ICT skills at the intersection of gender and family background are only descriptive, leaving us

to question why the observed differences in ICT skills as well as in their growth over time occur. Future research could examine the social and psychological mechanisms underlying gender differences in ICT skills development along with economic and cultural capital as well as ethnicity. For example, a recent study found that ICT-related self-confidence, motives, and breadth of ICT usage incrementally predicted secondary school students' ICT skills (Senkbeil, 2022). Such factors could reveal why there are differences in gender gaps in ICT skills along family background.

8.2. Conclusions

Our study has shown that there are gender gaps in ICT skills in favor of males and social origin gaps in favor of students with more parental resources. Both types of inequalities tend to increase during upper secondary school. Gender and social origin do not operate independently of one another but interact. Girls from disadvantaged families develop lower ICT skills than boys, while there are no gender differences between girls and boys from advantaged families, suggesting that privileged students might be exposed to more gender-egalitarian ideas and role models than disadvantaged students. In Germany, these inequalities strongly depend on the school context: gender differences are significantly greater in the academic than in the non-academic track, and the interaction between gender and social origin was only found in the academic track. Early tracking at age 10 and the social and skill-based sorting processes that go along with it produce two highly different learning environments that, according to our results, manifest a highly salient dimension of intersectional inequality that was neglected in earlier research.

The results of our study thus reinforce the growing interest in intersectionality in quantitative empirical research. They show that neglecting intersections of gender, family background and school environment masks crucial heterogeneities in gender differences in students' ICT skills and their development along with social background characteristics. Understanding and addressing the subtle intersectional differences in ICT skills is important, because research suggests that skills gaps in ICT have different consequences than gaps in other cognitive skills, such as reading or numeracy. For example, recent research showed that high ICT skills are essential for pursuing STEM subjects, particularly for girls (Hertweck and Lehner, 2023).

We also found that family context, with its sociostructural characteristics, played a weaker role in predicting ICT skill growth and structuring gender inequalities than it did for initial ICT skills in grade 9. This shifts the focus to social contexts outside the family, such as schools or peer groups, that might play a more important role in developing ICT skills further during adolescence. These factors should be focused on in future research to ensure that more socially disadvantaged females, with initially lower proficiencies, acquire the ICT skills essential in the 21st century to meet the challenges of an increasingly digitalized world.

CRediT authorship contribution statement

Alexandra Wicht: Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Data curation, Conceptualization. **Corinna Kleinert:** Writing – review & editing, Writing – original draft, Methodology, Conceptualization.

Availability of data and materials

The analyses are based on data from the National Educational Panel Study (NEPS): Starting Cohort Grade 9, https://doi.org/10.5157/NEPS:SC4:12.0.0 (H.-P. Blossfeld and Roβbach, 2019; NEPS Network, 2021). The authors are not the owners of the data and have no permission to distribute this data; however, the data is available for scientific use under restricted conditions to comply with the relevant data protection regulations and to ensure the anonymity of the participants. The basis for the use of the data is a data-use agreement. The authors got access to the NEPS data through the Research Data Centre at LifBi—Leibniz Institute for Educational Trajectories at: https://www.neps-data.de/Data-Center/Data-Access (accessed on May 9, 2024). The analysis code used in this study is publicly available at https://doi.org/10.7802/2877.

Declaration of competing interests

We have no known conflicts of interest to disclose.

Appendix A

Table A1
Table A1 Predictors of ICT skills in grade 9 and their change in grade 12, with the interaction of gender and income.

	Non-academic		Academic			
	Grade 9		Grade 9		Change	
	B	S.D.	*B*	S.D.	*B*	S.E.
Female, ref. male	−0.05*	[0.02]	−0.11***	[0.03]	−0.28***	[0.03]
Language use, ref. (mostly) German	−0.29***	[0.03]	−0.33***	[0.06]	−0.08	[0.05]

(*continued on next page*)

Table A1 (*continued*)

	Non-academic		Academic			
	Grade 9		Grade 9		Change	
	B	S.D.	*B*	S.D.	*B*	S.E.
College or university degree, ref. other	0.07*	[0.03]	0.08*	[0.03]	0.03	[0.03]
Number of books, std.	0.20***	[0.01]	0.18***	[0.02]	0.08***	[0.02]
Equivalence income (ln), std.	0.13***	[0.02]	−0.01	[0.03]	−0.02	[0.03]
Female × equivalence income (ln), std.	−0.03	[0.02]	0.04	[0.03]	0.05	[0.03]
Grade 9 ICT skills, std.					0.54***	[0.01]
Constant	0.07*	[0.03]	0.06*	[0.03]	0.15***	[0.03]
Max. FMI	0.38		0.29		0.60	
Average RVI	0.22		0.15		0.61	
N(persons)	8828		5309		5309	
N(schools)	374		163		163	

Notes. Source: https://doi.org/10.5157/NEPS:SC4:12.0.0. Cluster robust S.E., 60 imputations, continuous variables standardized. *p < 0.05, **p < 0.01, ***p < 0.001.

Table A2
Predictors of ICT skills in grade 9 and their change in grade 12, with the interaction of gender and parental education.

	Non-academic		Academic			
	Grade 9		Grade 9		Change	
	B	S.D.	*B*	S.D.	*B*	S.E.
Female, ref. male	−0.03	[0.02]	−0.16***	[0.04]	−0.33***	[0.04]
Language use, ref. (mostly) German	−0.29***	[0.03]	−0.34***	[0.06]	−0.08	[0.05]
College or university degree, ref. other	0.12**	[0.04]	0.03	[0.05]	−0.03	[0.05]
Female × college or university degree	−0.11	[0.06]	0.10	[0.06]	0.11	[0.06]
Number of books, std.	0.20***	[0.01]	0.18***	[0.02]	0.08***	[0.02]
Equivalence income (ln), std.	0.11***	[0.02]	0.02	[0.02]	0.02	[0.02]
Grade 9 ICT skills, std.					0.54***	[0.01]
Constant	0.06*	[0.03]	0.09*	[0.03]	0.18***	[0.03]
Max. FMI	0.52		0.20		0.50	
Average RVI	0.21		0.07		0.55	
N(persons)	8828		5309		5309	
N(schools)	374		163		163	

Notes. Source: https://doi.org/10.5157/NEPS:SC4:12.0.0. Cluster robust S.E., 60 imputations, continuous variables standardized. *p < 0.05, **p < 0.01, ***p < 0.001.

Table A3
Predictors of ICT skills in grade 9 and their change in grade 12, with the interaction of gender and books at home.

	Non-academic		Academic			
	Grade 9		Grade 9		Change	
	B	S.D.	*B*	S.D.	*B*	S.E.
Female, ref. male	−0.05*	[0.02]	−0.11***	[0.03]	−0.28***	[0.03]
Language use, ref. (mostly) German	−0.30***	[0.03]	−0.33***	[0.06]	−0.08	[0.05]
College or university degree, ref. other	0.07*	[0.03]	0.08*	[0.03]	0.03	[0.03]
Number of books, std.	0.19***	[0.02]	0.14***	[0.02]	0.08**	[0.02]
Female × number of books	0.01	[0.02]	0.07*	[0.03]	0.00	[0.03]
Equivalence income (ln), std.	0.11***	[0.02]	0.02	[0.02]	0.02	[0.02]
Grade 9 ICT skills, std.					0.54***	[0.01]
Constant	0.07*	[0.03]	0.06	[0.03]	0.15***	[0.03]
Max. FMI	0.40		0.29		0.63	
Average RVI	0.14		0.09		0.67	
N(persons)	8828		5309		5309	
N(schools)	374		163		163	

Notes. Source: https://doi.org/10.5157/NEPS:SC4:12.0.0. Cluster robust S.E., 60 imputations, continuous variables standardized. *p < 0.05, **p < 0.01, ***p < 0.001.

Table A4
Predictors of ICT skills in grade 9 and their change in grade 12, with the interaction of gender and language use at home.

	Non-academic		Academic			
	Grade 9		Grade 9		Change	
	B	S.D.	*B*	S.D.	*B*	S.E.

(*continued on next page*)

Table A4 (*continued*)

	Non-academic		Academic			
	Grade 9		Grade 9		Change	
	B	S.D.	*B*	S.D.	*B*	S.E.
Female, ref. male	−0.05	[0.02]	−0.10***	[0.03]	−0.29***	[0.03]
Language use, ref. (mostly) German	−0.28***	[0.04]	−0.27***	[0.08]	−0.13	[0.07]
Female × language use	−0.02	[0.05]	−0.12	[0.10]	0.09	[0.09]
College or university degree, ref. other	0.07*	[0.03]	0.08*	[0.03]	0.03	[0.03]
Number of books, std.	0.20***	[0.01]	0.18***	[0.02]	0.08***	[0.02]
Equivalence income (ln), std.	0.11***	[0.02]	0.02	[0.02]	0.02	[0.02]
Grade 9 ICT skills, std.					0.54***	[0.01]
Constant	0.07*	[0.03]	0.06	[0.03]	0.16***	[0.03]
Max. FMI	0.48		0.28		0.57	
Average RVI	0.19		0.11		0.62	
N(persons)	8828		5309		5309	
N(schools)	374		163		163	

Notes. Source: https://doi.org/10.5157/NEPS:SC4:12.0.0. Cluster robust S.E., 60 imputations, continuous variables standardized. *p < 0.05, **p < 0.01, ***p < 0.001.

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