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Plugging in at school: Do schools nurture digital skills and narrow digital skills inequality?

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A B S T R A C T

Information and communication technology (ICT) have become indispensable in contemporary schools in post-industrialized countries. Whether schools have succeeded in vesting students with the needed digital skills important in today's highly digitalized societal landscape however remains unclear. In this paper, we examine whether school resources in terms of ICT infrastructure, use of ICT in education, and availability of technical expertise are pertinent to students' digital skillfulness. We also investigate whether such school ICT resources are unevenly distributed among students of different socioeconomic backgrounds, and whether students of different socioeconomic backgrounds unevenly benefit from these resources. In doing so, we illuminate school ICT resources' role in the process of intergenerational transmission of inequalities. To test our expectations, we employ ICILS 2018 data on 14,183 students in 751 schools across seven OECD countries. Our findings indicate that schools indeed play a meaningful role in nurturing digital skills, namely through students' use of ICT in educational tasks. We also find that students from more advantageous socioeconomic backgrounds more often attend well ICT-resourced schools, pointing at the uneven distribution of school ICT resources in a way that reflects social reproduction processes. Alongside that, the availability of technical expertise in schools seems particularly fruitful for low-SES students' digital skills development. This evinces that schools compensate for limited ICT skills socialization in the family, pointing at social mobility processes.

1. Introduction

The call to vest students with necessary digital skills to function in a highly digitalized societal landscape is one that schools are inexplicability drawn to and expected to answer; not least because it upholds the mantle of education and readying students for the labour market (Ilomäki et al., 2016; Lawrence & Tar, 2018). Towards this end, notable investments and a fervent push for the integration of information and communication technology (ICT) in schools have been made (for a policy review see Kozma (2008), and for an EU specific review see Salajan (2019)). While significant scholarly effort has been devoted to understanding what promotes and sustains school ICT integration (Bingimlas, 2009; Lawrence & Tar, 2018; Tondeur et al., 2009), whether school ICT resources pay off in students' digital skills remains ambiguous (see Timotheou et al. (2023) for a review). This ambiguity extends further still, as whether school ICT resources are equally available to and equally benefit students from different socioeconomic backgrounds has hardly been examined (Rafalow, 2020). In this paper, we seek clarity on these fronts. We forward two lines of investigation, scaffolded by insights from educational, media and communication, and social inequality literature.

Our first line of investigation concerns the *general effect* of schools' ICT resources, that is to say, whether school ICT resources are a boon to students' digital skillfulness to begin with. Empirical work on various aspects of school ICT resources, often examined in

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isolation, have yielded mixed results (Timotheou et al., 2023). Such an approach, while likely due to data limitations, nevertheless assumes that a single school ICT aspect can serve as a proxy of the whole, glossing over their distinct contributions (Pettersson, 2018; Tondeur et al., 2009; Voogt et al., 2013). A simultaneous consideration of key facets of school ICT resources is therefore still needed. In this paper, we address three key forms of school ICT resources – ICT infrastructure, use of ICT in education, and availability of technical expertise, based on extensive scholarly work on school ICT resources (Kim et al., 2021; Tondeur et al., 2009; Wastiau et al., 2013), and congruent with research on school resources more generally (Hanushek & Woessmann, 2017). Firstly, ICT infrastructure concerns the access to digital devices available to students in school, and is generally found to play only a small role. Secondly, use of ICT in education pertains to how integrated ICT is in class activities, often understood as active use of ICT in class by teachers and students; prior research suggests that foremost use by students is almost unanimously found to beneficial to students' digital skillfulness. Thirdly, availability of technical expertise relates to the (sources of) technical know-how students can tap into, and this has hardly been featured. The overarching expectation here is that students embedded in school environments rich in these three types of ICT resources are more digitally skilled. However, empirical work bringing all three aspects together is scarce. We do so in this paper, which additionally affords an examination of which aspect is most pertinent to students' digital skillfulness. Along the first line of investigation, we pose the following research question: *To what extent do school ICT resources benefit students' digital skillfulness (RQ1, Fig. 1: Path A)?*

Our second line of investigation relates to the *social differentiation* of school ICT resources and its consequences. Students' family background firstly may be related to the *uneven distribution* of school ICT resources, and secondly to *uneven benefits* derived from these resources. On the former, prior research shows that in general, school (ICT) resources are unevenly distributed along socioeconomic lines as well-to-do parents give their children the upper-hand by imparting advantages, with the aim of predisposing them towards success (Bridge & Wilson, 2015). This partly takes place through school selection, where parents of higher socioeconomic status (SES) are more likely to send their children to highly ICT-resourced schools, thereby heightening their digital skillfulness. We therefore expect that high-SES background students are more digitally skilled because they tend to attend schools that are more greatly endowed with the three types of school ICT resources. This line of argument points at social reproduction processes, and is summarized by our second research question: *To what extent is digital skills inequality among students explained by differences in school's ICT resources?* (RQ2, Fig. 1: Path B-A).

Next, students may also *unevenly benefit* from school's ICT resources, contingent on their family SES background. Students, after all, enter the school with varying foundations in digital skills owing to differences in digital resources in the family home (Scherer & Siddiq, 2019). As such, the utility of school ICT resources might vary for students from different SES families. By this token, school ICT resources might be more valuable for students from low-SES backgrounds, compensating for a lack of ICT resources in the family home. A lack which their high-SES counterparts face less of, if at all, and for whom school ICT resources and the skills developed in school add comparatively little to their already richly ICT-resourced home environment and their existing high digital skillfulness. Such an argument, where schools play a compensatory role, points at social mobility processes; schools would be especially advantageous for children from less well-to-do backgrounds. Our third line of investigation is thus guided by the research question: *To what extent are the digital skills benefits from school ICT resources dependent on students' socioeconomic background* (RQ3, Fig. 1: Path C).

Our paper and association pathways are summarized in Fig. 1.

To address our research questions, we analyze data on 14,183 students from 751 schools across seven OECD countries from the International Computer and Information Literacy Study (ICILS) 2018 (henceforth ICILS 2018). ICILS 2018 contains an assessment of students' ICT skills, as well as information on schools' ICT resources from students', teachers', principals' and ICT coordinators' perspectives. By including students and schools from a number of OECD countries, we are better equipped to draw conclusions that are generalizable to post-industrialized societies. It further serves as a springboard for future country-comparative studies.

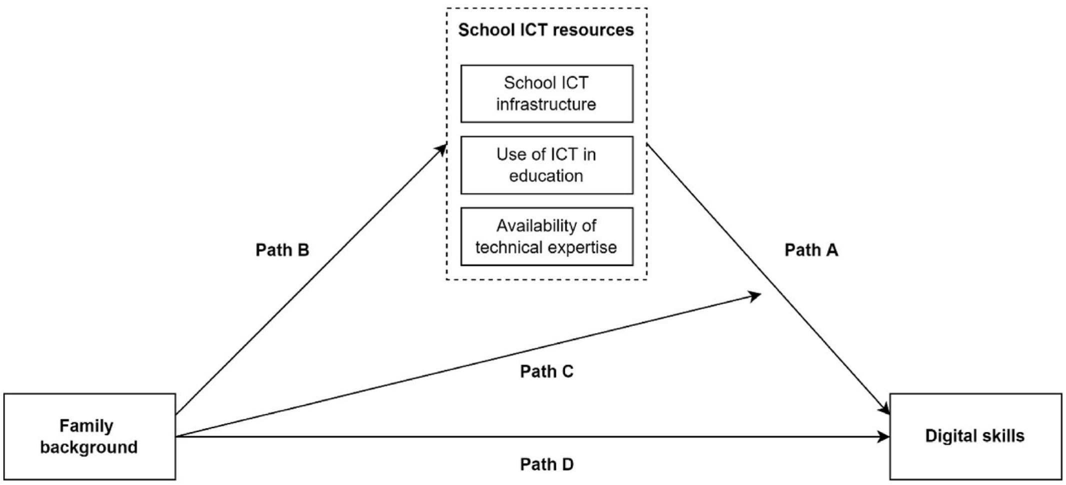

Fig. 1. Conceptual model: overview of association pathways.

Our efforts undertaken in this paper make two key contributions. The first stems from our simultaneous examination of all three aspects of schools' ICT resources. This approach provides a more comprehensive investigation and additionally presents the opportunity to identify which facet of school ICT resources is most advantageous towards the development of students' digital skills. The second contribution is made through our examination into whether the relationship between school ICT resources and students' skills development is related to social differentiation along socioeconomic background. We therefore advance an interdisciplinary foundation of social inequality, media and communication, and education insights integrated in the theoretical elaborations penned down. Taken together, this paper is among the first to theoretically elaborate and empirically examine the role of school ICT resources for students' digital skillfulness and in the augmentation or alleviation of social inequalities in the digital age. In doing so, we add to a growing discussion on social inequality, digital skills inequalities, and the digitalization of education – a discussion that has grown more salient in light of the COVID-19 pandemic.

2. Theory

Our theory section follows the three research questions. We begin firstly with the *general effect* of school ICT resources, focusing on whether and which type of school ICT resources contribute to students' digital skills. Next, we delve into the *uneven distribution* of school ICT resources among students from different socioeconomic backgrounds. Lastly, we turn our attention to the *uneven benefits* students from different SES family backgrounds derive from similar school ICT resources.

2.1. General effect: school ICT resources and students' digital skills

According to educational scholarship, school resources can be distilled into three core forms: (1) financial aggregates of resources, pertaining to expenditure or a proxy of it, (2) the resources in the classroom, relating to in-class resources such as teacher experience and quality, and (3) other resources such as administrative inputs and support (Hanushek, 1997; Hanushek & Woessmann, 2017; Wößmann, 2003). These aspects taken together constitute a conducive learning environment by providing opportunities for students to learn through appropriately challenging and engaging tasks with guidance from qualified teachers with the necessary expertise, promoting student learning as a result (Hattie, 2009). Indeed, considerable work has illustrated how students do better in resource-rich schools over a range of learning outcomes (Hanushek & Woessmann, 2017; Hattie, 2009).

A similar delineation and argument is mirrored in school ICT resources and its consequences for students' digital skillfulness. The three above mentioned forms of school resources dovetail nicely with three facets of ICT resources – a school's ICT infrastructure, use of ICT in education, and availability technical support (Kim et al., 2021; Olszewski & Crompton, 2020; Tondeur et al., 2009; Voogt et al., 2013). These firstly embody the opportunity structure in which students engage in learning using ICT, and therefore develop digital skills. Concurrently, the social interactions embedded within such school environments further adds to this growth by teaching students what is expected, inculcating a set of values and standards of behaviors, and providing guidance (Rafalow, 2020; Wentzel & Looney, 2007). Indeed, pedagogical insights highlight that nurturing digital skills calls for technology-rich settings and opportunities to use technology in meaningful purposeful ways, and adult facilitation and support is called for when it comes to children (Ilomäki et al., 2016).

As with general school resources, the types of school ICT resources do not work in isolation, and should be taken into simultaneous account. Empirical work that does so, as far as we are aware, is lacking when it comes to examining whether students' digital skills are nurtured by school ICT resources. Three studies stand out, nevertheless. Olszewski and Crompton (2020) are one of the few who studied multiple facets of ICT resources, in U.S. schools, and how they contribute to providing opportunities for students to learn with digital tools. They found digital access, use of digital tools by students, and support from teachers to be instrumental. Meneses and Mominó (2010) and Pöntinen and Räty-Záborszky (2020) also account for multiple aspects of school ICT resources, and additionally make the link to student's digital skills. The former study finds that, in Spain, in-school Internet access and use were both important to students' basic digital skills. The latter illustrates how, in Finland, use of ICT in education and availability of technical support promote digital skillfulness. However, neither study accounted for all three aspects of school ICT resources. An examination of all three school ICT resources aspects is therefore still needed to understand if these resources do, as purported, translate to students' digital skills. In the following sections, we lay out the theoretical mechanisms through which each facet – ICT infrastructure, use of ICT in education, and availability of technical expertise, supports students in their development of digital skills.

2.1.1. School ICT infrastructure

School ICT infrastructure is the ICT access available in school, and is conventionally measured as the computer-to-student ratio in school. The provision of sufficient computers for the student body most evidently relates to the provision of opportunities, as it is a necessary condition for both teachers and students' ICT utilization (Kim et al., 2021; Olszewski & Crompton, 2020). The mere exposure to opportunities to use ICT technology has the potential to incite students' use, thereby providing fertile grounds on which digital skills could be developed through usage and experimentation afforded by having ICT at school (Livingstone, 2012; Zheng et al., 2016). Additionally, being embedded in a school environment that has ICT readily available also signals that ICT is a learning tool and should be used and valued as such, therefore prompting usage and further development of students' digital skills (Rafalow, 2020).

While the importance of school ICT infrastructure is theoretically acknowledged, empirical evidence that it helps students develop their digital skills is scarce. In their meta-analysis, Zheng and colleagues (2016) conclude that evidence on access promoting digital skillfulness is limited (see also Gil-Flores et al., 2017; Lomos et al., 2023). The educational technology advocacy principle, that access is a means to an end and it is how technology is used that matters, might explain this finding (Livingstone, 2012). Its diminished empirical impact may likewise be due to decades-long ICT integration efforts having minimized differences in school ICT infrastructure (Hatlevik et al., 2015). And while access does not guarantee the provision of digitalized learning opportunities (Lomos et al., 2023; Olszewski & Crompton, 2020), an absence of ICT infrastructure certainly renders it an improbability. Indeed, prior research emphasizes that a lack of ICT infrastructure is often cited as a barrier to other forms of school ICT resources, particularly usage (Bingimlas, 2009; Fu, 2013; Lawrence & Tar, 2018). Lending support, Kim and colleagues' (2021) evaluation of school ICT environments indicates that a well-developed ICT infrastructure at school is a key condition for use of ICT for learning and technical support. In that spirit, we emphasize access' role as a foundational scaffolding for learning opportunities and setting the expectations for digital skills development.

2.1.2. Use of ICT in education

The use of ICT in education provides active opportunities for students to engage in meaningful scholastic tasks using technology (Ilomäki et al., 2016). This aspect could be construed in terms of teachers' use of digital tools in class lessons, as is typically done when it comes to ICT integration research. However, when it comes to digital skills development, it is students' own use of ICT in educational tasks that is emphasized (Ilomäki et al., 2016; Pöntinen & Räty-Záborszky, 2020). Such use by students facilitates their digital skillfulness as in school it is supervised and under direction, providing purpose, and guiding their navigation through risks, opportunities and potential pitfalls (Ilomäki et al., 2016). Furthermore, when students use ICT in educational tasks, they are inculcated with the association of ICT and digital skillfulness with learning. It therefore sets the tone and prompts development of digital skills in the context of education and learning (Rafalow, 2020). Prior empirical work highlights that students' use of ICT in education, under teacher facilitation and guidance in class increases digital learning opportunities, encourages exploration of digital tools, consequently boosting students' digital skills, particularly for younger students, in European countries (Kalmus et al., 2012; Pöntinen & Räty-Záborszky, 2020; Schmid & Petko, 2019).

2.1.3. Availability of technical expertise

The availability of technical expertise concerns the availability of support from (warm-)experts in school. Such expertise could come from designated professionals such as ICT facilitators, or warm-experts such as teachers. Most evidently, having professional experts who can address technical problems which impede the smooth delivery and set up of learning activities is important in providing for digital learning opportunities (Bingimlas, 2009). These (warm-)experts further play a key role in engaging youths in ICT and developing their skills (Eynon, 2021; Hammer et al., 2021). Not only do they provide assistance, they also define the value of developing digital skills as they become the basis of social connection and working together, thereby motivating students to further their digital skills (Kalmus et al., 2012). As such, in schools with more sources of technical support, teachers are better able to provide learning opportunities that serve as avenues for students to build digital skills (Bingimlas, 2009; Olszewski & Crompton, 2020), and students are better supported and motivated to do so (Eynon, 2021; Pöntinen & Räty-Záborszky, 2020).

It is hard to come by empirical evidence on whether students develop digital skills thanks to the availability of technical expertise as the focus has predominantly been on how it encourages teachers' use of ICT in their teaching practices (Tondeur et al., 2009). Nevertheless, two studies point to how it is a potential aid towards students' digital skillfulness. Pöntinen and Räty-Záborszky (2020) find that students were more engaged and developed their digital skills better with immediate help and feedback from teachers and peers. Looking at learning outcomes more broadly, Means (2010) found that schools who had regular on-site technical support report, in qualitative studies, higher gains in students' learning.

Our overarching expectation that all three aspects of school ICT resources are beneficial to the development of students' digital skills is reflected in our first hypothesis: *Students in schools with (a) higher computer-to-student ratio, (b) higher use of ICT in education, and (c) greater availability of technical expertise, are more digitally skilled.*

2.2. Uneven school ICT resources and students' digital skills: a social reproduction perspective

Research into social background differences in school choice and its underlying mechanism has a rich history spanning decades. It points to how SES disparities in children's educational performance, in combination with how parents of different SES have varying priorities and considerations, drive social differentiation in school choice (Bridge & Wilson, 2015; Van Zanten, 2015). High-SES students are consequently more likely to attend more richly resourced schools, situating them in advantageous learning environments, and predisposing them towards success in education (Bridge & Wilson, 2015; Musset, 2012). Such intergenerational transmission of advantage – harking from social reproduction notions (Bourdieu, 1973; Collins, 2009), can also be observed in the uneven distribution of school ICT resources along SES lines.

Firstly, SES disparities in previous performance, for instance in primary school, influences the range of schools available to students picking their successive school. Low-SES students tend to do less well in school, and are often on the backfoot when it comes to digital skillfulness (Loh et al., 2023; Tzanakis, 2011). Such disparities drive SES differences in subsequent school choice as low-SES students are then less likely to attend high-performing schools which tend to be more richly resourced – including in school ICT resources. Indeed, schools that are endowed with more resources overall also tend to be richer in ICT resources (Anthony & Clark, 2011; Tawfik et al., 2016). As Anthony and Clark (2011) illustrate, richly resourced schools often also have the means to provide ICT access and use technology more in education, and acknowledge the importance of in-school technical expertise (see also Rafalow (2020)).

Secondly, SES also colors parental decision making, with higher-SES parents typically being more strategic and active in school choice as they have accumulated greater amounts of knowledge about the (education) system and possess the (financial and cultural) resources to act on these strategies (Breen & Goldthorpe, 1997; Lareau, 2015; Van Zanten, 2015). Among other school characteristics, such as teaching caliber, reputation, and SES-composition, ICT access and usage in school are deemed important markers of school quality (Mayer et al., 2000). Even if it was not a salient marker of quality to parents, schools that are better resourced in general also tend to be richer in ICT resources, (Anthony & Clark, 2011; Tawfik et al., 2016), which still suggests that high-SES students will have more school ICT resources available to them. Additionally, low-SES parents are also under pressure to prioritize logistics more – such as distance between home and school (Rohde et al., 2019). As such, while all parents might be mindful of what constitutes a "good" school, and vie to send their children there (Johnson, 2012), not all schools are viable options, nor are parents equally equipped to act upon the intention to send their children to a good school (Bridge & Wilson, 2015).

Taken together, students from high-SES backgrounds are more likely to attend schools with more ICT resources, and consequently gain more digital skillfulness compared to their peers from lower-SES families. Such social reproduction processes in school ICT resources and digital skills inequalities has received little empirical attention, but Kim and colleagues' (2021) evaluation of schools' digital resources does indicate that higher-SES students tend to enroll in schools that are more highly ICT-resourced. As such, we posit our second hypothesis: *Students from high-SES backgrounds are more digitally skilled because they attend schools with (a) higher computer-to-student ratio, (b) higher use of ICT in education, and (c) greater availability of technical expertise, compared to students from low-SES backgrounds.*

2.3. Uneven benefits from school ICT resources: a social mobility perspective

Importantly, schools can also play a compensatory role in providing a broad pallet of ICT resources and making them available to all their students. By supplementing ICT resources that students may lack in their family home, school ICT resources may prove especially valuable towards the digital skills of low-SES students, compared to their high-SES peers. On this score, school ICT resources may thus unevenly benefit students of different SES backgrounds, but in the favor of low-SES students, in line with social mobility notions (DiMaggio, 1982).

Students from low-SES families often experience a lack in ICT resources in their family home (Hammer et al., 2021; Livingstone & Blum-Ross, 2020; Passaretta & Gil-Hernández, 2023). Prior work shows that low-SES students often report having fewer digital devices at home (Lim & Loh, 2019; Livingstone & Blum-Ross, 2020), tend to use ICT more for entertainment (Lim & Loh, 2019; Micheli, 2015), and are themselves the warm digital expert of the family (Correa, 2014; Livingstone & Blum-Ross, 2020). The ICT opportunities and guidance available in their school, through school ICT infrastructure, the use of ICT for educational activities, as well as the technical expertise available, could therefore be more valuable to low-SES students than for high-SES students. In contrast, high-SES students often originate from well ICT-resourced family homes, they use ICT more often for learning, and their parents can offer technical expertise. Therefore, a well-equipped ICT support system in school adds marginally little for high-SES students, and activities even may strike as mundane, but prove valuable for low-SES students (Eynon & Geniets, 2015; Micheli, 2015; Rideout & Katz, 2016; Scherer & Siddiq, 2019).

Prior research on whether students from different SES families unevenly benefit in their digital skillfulness from school ICT resources is scarce. On learning more broadly, however, there have been various school-based technology interventions efforts targeting disadvantaged and under-privileged groups of students that have boosted learning and achievement (Freeman, 2012; Suppes et al., 2014). Our third hypothesis thus reads: *Students from low-SES backgrounds gain more in digital skills from schools with (a) higher computer-to-student ratio, (b) higher use of ICT in education, and (c) greater availability of technical expertise, compared to students from high-SES backgrounds.*

3. Data

This study utilizes data from the second round of the International Computer and Information Literacy Survey (ICILS) conducted in 2018. ICILS is designed to survey the contexts and outcomes of ICT-related educational resources, particularly the role of schools in supporting students' digital capability development among 8th graders (approximately 14 years of age). ICILS 2018 provides information on the digital capabilities of 46,561 students, from 2,226 schools across 12 countries and one city.[1] ICILS 2018 also holds information from 26,530 teachers across all schools, as well as the ICT coordinators and principals from each school. ICILS is one of the few, if not the only, international surveys that measures students' digital skills through an assessment that also contains school and teacher information. To maintain generalizability of results, we limited the sample to only OECD countries which implemented the necessary questionnaires, leaving us with seven countries (N = 23,000).[2] We further only included schools[3] (N = 15,207), and students with complete information on all key variables (N = 14,183).[4] Our final sample therefore includes 14,183 students from 751 schools, across seven OECD countries. A list of the countries and their respective Ns is provided in Appendix A.

[1] Moscow was the one city, and was subsequently excluded from the sample as Russia is not an OECD member.

[2] United States is a OECD member, but is excluded as they did not implement the ICT coordinator questionnaire.

[3] The computer-to-student ratio caused the most significant loss in number of schools included – 149 schools across the 7 countries, amounting to 6,344 students excluded from the analytical sample. This is because computer-to-student ratio calls for two pieces of information provided in two separate questionnaires. The number of students is questioned in the principal questionnaire, and number of devices available for student use is recorded in the ICT coordinator questionnaire.

[4] Descriptive statistics (Appendix B) of samples prior (N = 23,000) and after (N = 14,183) selection were highly similar, indicating that the analytical sample largely preserves representativeness.

As ICILS 2018 is cross-sectional, ruling out reverse causality is not feasible as students' were not tested over multiple years. We therefore do not have information on students' digital skills prior to the testing in ICILS. We are assured, however, that measures of school ICT resources capture information that precedes that of students' digital skills. This is particularly true because the establishment and changes to school ICT resources is not something that happens overnight, or within the short period of a survey. It is therefore most likely that the establishment of school ICT resources represent a durable situation well before students' digital skills were assessed. Nevertheless, our results should be taken, in the strictest sense, as associations and relationships rather than as causal effects.

4. Measures

4.1. Student's digital skills

Student's digital skills are measured with plausible values provided by ICILS 2018. Students were assessed on their Computer and Information Literacy (CIL), defined as "an 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 the community" (Fraillon et al., 2019).[5] Through assessment tasks that mimic real tasks, students were tested on their understanding of computer use, gathering of information, production of information, and digital communication.[6] Five plausible values were then derived using Item Response Theory (IRT).

4.2. School characteristics

School ICT infrastructure is indicated by the computer-to-student ratio, based on the information provided by the ICT coordinator on the number of devices (desktop, laptops, tablets) available and information on the number of students in the school provided by the principal at the school level. ICILS 2018 provided this student-to-computer ratio, which we reversed coded such that higher numbers indicates greater access.

Use of ICT in education is a count of the number of activities students within school engage with using digital technology. Teachers indicated the frequency that students in their reference class uses ICT for each of the 14 activities listed, including "work on extended projects", "working individually on learning materials at their own pace", evaluate information resulting from a search" and "create visual products or videos". The frequency categories were: (1) students do not engage, (2) never use ICT, (3) sometimes use ICT, (4) often use ICT or (5) always use ICT in that activity. A scale was constructed using a count of respondents' scoring sometimes, often, and always, ranging from 0 to 14.

Availability of technical expertise is indicated by a count of the number of seven possible sources students could turn to for day-to-day technical support, reported by the ICT coordinator. The sources spanned professional sources such as "ICT technical staff at the school" and warm-experts such as "teachers". The final scale runs from 0 till 7.

All school characteristics were aggregated at the school level and subsequently centered on the country-level grand-mean – where the average over all schools is deducted such that the grand-mean now takes on the value of 0. A list of items used is provided in Appendix C.

4.3. Student characteristics

Family SES background is indicated by parents' highest ISCED bracket. Students were presented with five options about their parent's educational level. The options were examples that corresponded with (1) He/she did not complete [ISCED level 2], (2) ISCED level 2, (3) ISCED level 3, (4) ISCED level 4 or 5, and (5) ISCED level 6,7, or 8. From this, ICILS 2018 generated a variable indicating the highest level of both parents. The variable ranged from 1 to 5 and was recoded to 0 to 4 for a meaningful zero.

We also controlled for the students' sex and age. Student's sex is indicated by a dummy variable *Girl*, where (1) indicates a girl, and (0) a boy student. Student's *Age* was provided by ICILS 2018 based on the student's birth month and year. Age originally ranged from 11.25 to 17.92 (i.e. 11 years and 3 months old, to 17 years and 11 months). We bottom-coded it by deducting 11 from all students' ages for a more meaningful and interpretable zero.

Descriptive statistics are provided below (Table 1), along with the correlation matrix of key variables (Table 2).

5. Analytical method

For the analyses, we fitted three-level country fixed-effects structural equation models, with students nested in schools, nested in counties to ascertain the general impact of schools' ICT resources on students' digital skills for all students in seven OECD countries. We used R (version 4.3.0) and Mplus (version 8.4) in this study. Conclusions drawn using all five plausible values for digital skills did

[5] ICILS 2018 also assessed students' Computational Thinking (CT), which pertains to "an individual's ability to recognize aspects of real-world problems which are appropriate for computational formulation and to evaluate and develop algorithmic solutions to those problems so that the solutions could be operationalized with a computer" (Fraillon et al., 2019). We opted to examine their CIL scores, instead, as that relates more to skills pertinent to education, rather that CT's focus on algorithmic or systems thinking.

[6] For further information on assessment items, refer to the ICILS 2018 Assessment Framework (Fraillon et al., 2019).

Table 1
Descriptive statistics.

	N	Mean	S.D.	Min	Max
Student variables					
Digital skills	14183	511.185	80.545	137.302	747.875
Parental education	14183	2.676	1.194	0	4
Girl (1 = girl)	14183	.494	.500	0	1
Age (0 = 11)	14183	3.250	.762	.250	6.920
School variables					
Computer-to-student ratio	14183	.014	.313	−.291	2.405
Use of ICT in education	14183	−.147	2.314	−5.985	5.747
Availability of technical support	14183	.016	1.343	−2.830	4.170

Note: Digital skills values are averages of 5 plausible values. School variables have been centered on the overall mean across schools.

Table 2
Correlation matrix of key variables.

	Digital skills	Parental education	Computer-to-student ratio	Use of ICT in education	Availability of technical support
Digital skills	1.000				
Parental education	.207	1.000			
Computer-to-student ratio	.105	.093	1.000		
Use of ICT in education	.174	.131	.373	1.000	
Availability of technical support	.061	.067	.146	.127	1.000

Note: Correlations with digital skills are based on one plausible value.

not differ from the conclusions based on one plausible value. The interclass correlations (ICC) for students' ICT skills was .137 at the school-level and .356 at the country-level, illustrating the need for multilevel analysis. To gauge model fit, we examined primarily the Akaike Information Criteria (AIC).

Table 3
School and country fixed-effect SEM regression of student digital skills on school ICT resources and parental education (mediation model).

					B		β		
Constant					537.322	(13.065)	16.570	(4.518)	***
Direct effects of parental education									
Par. Educ.	→	Digital skills			7.803	(.541)	.135	(.009)	***
Par. Educ.	→	Infrastructure			.024	(.002)	.093	(.008)	***
Par. Educ.	→	Use of ICT in edu.			.254	(.016)	.131	(.008)	***
Par. Educ.	→	Tech support			.075	(.009)	.066	(.008)	***
Direct effects of school ICT resources									
Infrastructure	→	Digital skills			2.056	(4.868)	.009	(.022)	
Use of ICT in edu.	→	Digital skills			3.528	(.920)	.118	(.030)	***
Avail. tech expertise	→	Digital skills			.509	(1.026)	.010	(.020)	
Indirect effect of parental education via school ICT resources									
Par. Educ.	→	Infrastructure	→	Digital skills	.050				
Par. Educ.	→	Use of ICT in edu.	→	Digital skills	.897				***
Par. Educ.	→	Avail. tech expertise	→	Digital skills	.038				
Decomposition of effect									
Total effect									
Par. Educ.	→	Digital skills			8.788				
Total indirect									
Par. Educ.	→	School ICT resources	→	Digital skills	.985				
Proportion indirect					.112				
Individual-level residual variance					4373.632	(69.320)			
School-level residual variance					944.629	(65.659)			
Country-level residual variance					1050.976	(571.417)			
Fit statistics									
Log-likelihood					−156193.696				
df					21				
AIC					312429.392				

Includes control variables— girl, age (not displayed here).
Standard errors provided in parenthesis. ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

6. Results

6.1. General effect: school ICT resources and students' digital skills

The focus of our first research question was on the general effect of the three types of school ICT resources on students' digital skills. We expected that students who attend schools that were rich in ICT resources would be more highly digitally skilled (hypothesis 1).

Our results in Table 3, and summarized in Fig. 2, indicate that of all three forms of school ICT resources – school ICT infrastructure, use of ICT in education, and availability of technical expertise, only the use of ICT in education emerged as a boon specifically to students' digital skills (B = 3.528 S.E. = .920). This indicates that students in schools where they experience a broader application of ICT in educational activities for students are more digitally skilled. The association is substantial, with a one standard deviation increase on the measure use of ICT in education (approx. 2 activities in our sample) students would gain 7.056 test points in digital skills, corresponding to 8.76% of a standard deviation in digital skills. The difference is more drastic when comparing both ends of the scale. Students in schools with the lowest use of ICT in education (−5.985 in our sample) scored, on average, 41.390 test points lower in digital skills than their peers in schools with the highest usage (5.747 in our sample). Looking also at the standardized coefficients, we see that the effect of use of ICT in education (ß = .118) is largely comparable to that of students' parental education (ß = .135).

We therefore accept hypothesis 1b, and reject 1a and c. Analyzing the three forms of school ICT resources separately did not change the conclusions, merely that the magnitude of school ICT infrastructure and availability of technical expertise's coefficients were larger when analyzed in isolation.

6.2. Reproduction: uneven distribution of school ICT resources and students' digital skills

Table 3 and Fig. 2 in combination present the results pertaining to our second research question relating to school ICT resources mediating the relationship between students' family background and digital skills. We expected that students from high-SES backgrounds were more digitally skilled because they attended schools that were more richly ICT-resourced (hypothesis 2).

Our results first indicate that there is indeed a SES digital skills divide, with higher-SES students being more digitally skilled than their lower-SES peers (B = 7.803, S.E. = .541). Comparing students from the lowest and highest SES categories, there emerges a 31.212 points gap (7.803*4) – within the range of score gaps found among countries participating in ICILS 2018 (Karpinski et al., 2021). The results also show that high-SES students more often do attend schools that have more ICT resources on all three fronts. Among the three forms of school ICT resources, parental education is most strongly associated with the use of ICT in education (ß = .131). The results here confirm a selection process, but only to a modest extent. Taking a closer look at use of ICT in education, the difference between the lowest and highest level of parental education is 1.016 (.254*4) test points, which is just over 40% of a standard deviation on a range of −5.985 to 5.747. It would take a gap of about 8 ISCED brackets to account for one standard deviation on student's digital skills. This pattern might have been more fleshed out if the ISCED categories were not collapsed into brackets in ICILS 2018. That said, students' use of ICT in education did emerge as most pertinent to digital skills, and a minute advantage in this aspect could have a strong influence down the road. Indeed, by examining the decomposition of parental education effect on skills into its direct and indirect effects (Table 3), we show that even a slight selection effect matters. We observe that school ICT resources accounts for 11.2% of the association between parental education and students' digital skillfulness. Comparing the three school ICT resources, it is use of ICT in education that is most important in terms of effect size and statistical significance, which net of all other school ICT resources, accounts for 10.2% of the association between parental education and student digital skills. Our results therefore support hypothesis 2b, and not 2a and c. Together, our results on this front indicate that high-SES students do attend schools in which students use ICT in a wider range of activities. This advantage facilitates, in turn, the social reproduction processes underlying SES inequality in digital skills.

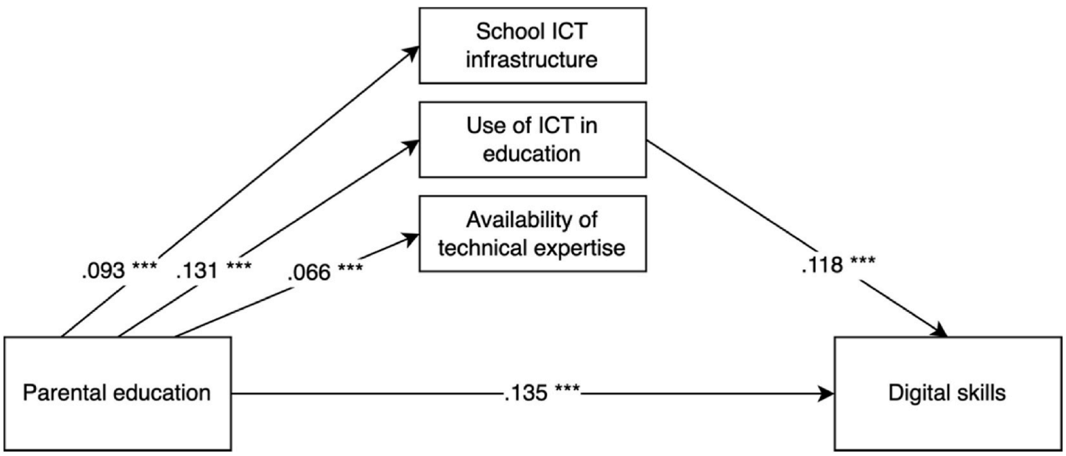

Fig. 2. Results from mediation analyses (only significant standardized coefficients featured).

6.3. Moderation: uneven benefits in digital skills from school ICT resources

Our third and final research question pertains to the moderation of school ICT resources' impact on student digital skills. We expected that low-SES students would profit more in terms of digital skillfulness from school ICT resources than high-SES students (hypothesis 3).

The results, presented in Table 4 and summarized below in Fig. 3, lend partial support to our expectations. Notably, while availability of technical expertise did not bolster the digital skills of all students, its impact was brought to the fore when differentiation by parental education was considered. Our results indicate that students from low-SES backgrounds benefit more in digital skills than students from high-SES backgrounds do from the availability of technical expertise in school (B = −1.140, S.E. = .425). A low-SES student who was in a school with more sources of technical expertise, stood to gain about 4.56 (1.140*4) test points more in digital skills than a high-SES student in a school with the same number of sources. This difference is notable, and its implications for social mobility are obvious when plotted (Fig. 4). On this score, our results therefore indicate that social mobility processes in schools are facilitated by the availability of technical expertise in schools. We therefore accept hypothesis 3c, and reject 3a and b.

6.4. Robustness checks

We performed several additional analyses to assure the robustness of our findings. Firstly, we split the sample up into younger adolescents (aged 11.25 to 14.92) and older adolescents (aged 15.00–17.92). In both groups, and in-line with the main analyses, use of ICT in education emerged as the main and only statistically significant contributor to digital skills (Appendix D). As to social reproduction processes, we note that the SES disparities in digital skills is more pronounced among younger adolescents (B = 8.293, S.E. = .589) than in the older group (B = 7.166, S.E. = 1.394), which is congruent with prior research (Passaretta & Gil-Hernández, 2023). In both groups, it remains that high-SES students attend schools that are more ICT-resourced and are subsequently more digitally skilled. The results relating to the social mobility processes are nuanced (Appendix E). Among the younger group, availability of technical support in school did benefit the lower-SES students more than it did their high-SES peers (B = −1.117, S.E = .461). However, among the older group, that avenue of social mobility diminishes to statistical insignificance. In contrast, among the older students, it was the high-SES students who gained more from the use of ICT in a larger range of school activities when compared to their lower-SES peers (B = 1.438, S.E. = .601). This evinces that, should schools hope to play a role in narrowing social background digital skill inequalities, this must start early in education. We also analyzed boys and girls separately (Appendix F), concluding likewise that use of ICT in education remained the only statistically significant contributor to digital skills, though more strongly so for boys (B = 4.202, S.E. = 1.060) than for girls (B = 2.826, S.E. = .966). However, it is only among that girls that low-SES students gain more from the availability of technical expertise in school (B = −1.870, S.E. = .533), while high-SES students gain more from use of ICT in school activities (B = 1.001, S.E. = .352) (Appendix G). One could speculate on how it relates to the socioeconomic digital skills inequality being slightly wider among girls (B = 9.337, S.E. = .754) than among boys (B = 8.158, S.E. = .809). However, to fully understand why this might be would call for intersectional research.

We also set a higher cut-off point in deriving the use of ICT in education. In the main analyses, we considered an activity when it used ICT sometimes, often, and always. To be sure, we applied a stricter cut-off point, including only activities when ICT is often or always used. This brought the mean down from about 8 to 3 activities, indicating that not many schools often or always use ICT in their range of class activities. Nevertheless, this set of robustness checks led to the same conclusions as the main analyses. This suggests that

Table 4
School and country fixed-effect SEM regression of digital skills on school ICT resources and parental education, and their interactions (moderation model).

			B		β		
Constant			716.459	(20.073)	22.225	(6.047)	***
Direct effects of parental education							
Par. Educ.	→	Digital skills	8.019	(.560)	.139	(.010)	***
Direct effects of school ICT resources							
Infrastructure	→	Digital skills	.238	(7.226)	.001	(.033)	
Use of ICT in edu.	→	Digital skills	2.239	(1.187)	.075	(.040)	
Avail. tech expertise	→	Digital skills	3.595	(1.492)	.070	(.029)	*
Interaction terms							
Par. Educ.	x	Infrastructure	.701	(1.997)	.009	(.027)	
Par. Educ.	x	Use of ICT in edu.	.466	(.268)	.047	(.027)	
Par. Educ.	x	Avail. tech expertise	−1.140	(.425)	−.066	(.025)	**
Individual-level residual variance			4370.642	(69.488)			
School-level variance			941.009	(65.644)			
Country-level variance			1039.403	(565.213)			
Fit statistics							
Log-likelihood			−96445.389				
df			15				
AIC			192920.778				

Includes control variables— girl, age (not displayed here).
Standard errors provided in parenthesis. ***$p < 0.001$, **$p < 0.01$, *$p < 0.05$.

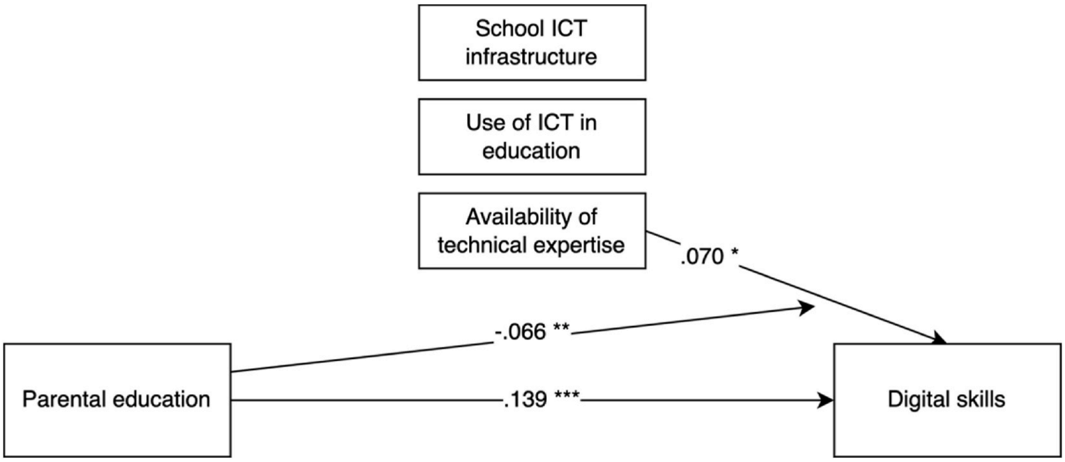

Fig. 3. Results from moderation analyses (only significant standardized coefficients featured).

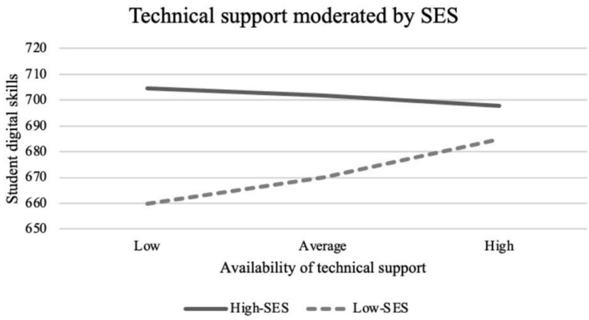

Fig. 4. Effect of availability of technical expertise on student's digital skills moderated by family SES.

students gain digital skills from the use of ICT in education, be it in spades or not. Lastly, additional analyses with parental education as a categorical variable, and with computer-to-student ratio as a binary variable did not yield different conclusions.

7. Discussion and conclusion

Fervent digitalization has made digital skillfulness indispensable and digital skills inequalities among youth a more pressing issue than ever (Helsper, 2021; Wilkin et al., 2017). Research into the avenues of digital skill development of youths, and how digital skills inequalities could be narrowed are therefore paramount. In this paper, we focus on the school – a key socialization site for youths, and a key venue of digitalization efforts. Drawing on social inequality, media and communications, and educational scholarship, we investigate whether school ICT resources in terms of school ICT infrastructure, use of ICT in education, as well as availability of technical expertise contribute to students' digital skills. We further examine the uneven distribution and uneven benefits of these school ICT resources. In doing so, we investigate the role school ICT resources play in social reproduction and social mobility processes – a nascent area of research. Our efforts are focused on seven OECD countries, using available ICILS 2018 data. As such, the results of this study are generalizable only to post-industrialized countries.

From our results, we glean that students do gain digital skills in school, and this is done primarily through students' use of ICT in educational tasks. Thereby, our work aligns with research which has shown that schools do have an added value to students' digital skillfulness, on top of the digital skills they acquire in the family home and out-of-school environments (Bjørgen & Erstad, 2015; Pöntinen & Räty-Záborszky, 2020). Our findings are also congruent with research that used observational data, which has large found that active use of digital technology for defined tasks benefits digital skillfulness and use of ICT in education by students does nurture digital skills (Ilomäki & Rantanen, 2007; Pöntinen & Räty-Záborszky, 2020). This echoes the adage that it is not merely the provision of ICT that matters, but how it is being used. That we did not find that a schools' ICT infrastructure and availability of technical expertise are important to students' development of digital skills does not discount them completely. Firstly, the three aspects work in tandem, and use of ICT in education is hardly possible without ICT infrastructure or the support of on-site technical expertise. Indeed, research on ICT integration in school highlights this symbiotic relationship (Lawrence & Tar, 2018; Tondeur et al., 2009). Secondly, ICT infrastructure has conventionally been measured as computer-to-student ratio. This reflects only the provision of ICT hardware, and markers of quality and accessibility such as hard- and soft-ware versions and locality are often overlooked (Lomos et al., 2023). The quality of ICT access and any supplementary resources such as software have remained understandably difficult to quantify, given how fast paced technological advancement can go and how slow school-wide implementation can sometimes be. There are hardly any large-scale data that capture this nor claim to do so in an up-to-date manner. However, if possible, future research examining the different components that make up ICT access in quantity and quality and how they influence digital skillfulness of students would be greatly insightful. Nevertheless, the findings from this prong of our investigation shows that students do glean digital skills in school, mainly via their use of ICT in educational tasks.

Following this, we drew on social stratification and social mobility literature, buttressed by media and communications insights, to investigate the socially differentiated role of school ICT resources. We first found that school ICT resources were unevenly distributed along students' social background. Students hailing from high-SES families attended schools with more ICT resources compared to those from low-SES families. In other words, our results highlight that higher educated parents send their children more often to well ICT-resourced schools. We found that this subsequently benefits their children's digital skill development. This suggests that school ICT resources indeed facilitate social reproduction processes. Alongside this, we also found uneven benefits of school ICT resources which ring true to social mobility notions. More specifically, we find that the availability of technical expertise – that is, from teachers, ICT coordinators and the like, was particularly fruitful for low-SES students' digital skills, compared to the limited benefit their high-SES counterparts derived from the same technical expertise. With the aim of narrowing digital skills inequalities, future research could thus examine what manner of technical expertise show greater utility. For example, are they more helpful if these are individualized help or consultations in reaction to students' digital skills, available around campus, or some other permutation? Future research on this front calls additionally for pedagogical scholarship, and for longitudinal data.

Indeed, a key limitation of our study is the lack of longitudinal data, without which we were unable to account for prior digital skills, or reflect the dynamic nature of digital skill development as highlighted by Ilomäki et al. (2016), and by McNiff and Whitehead (2012) on learning more generally. With longitudinal data, one might also account for how students' digital skills prior to school affects their school choice, as well as the extent to which they benefit from school ICT resources. Furthermore, with ICILS 2018 data, we were not able to distinguish between types of digital skills, or between basic and advanced skills. It could very well be that schools beget different types and levels of skills. Bringing these together, future studies with longitudinal data and afforded the chance to delineate types and levels of skills could illuminate on the nuances within students' digital skill development in school and the socio-digital inequalities therein.

What is clear from our findings is that schools can and do play a role in nurturing digital skills in today's youths. Students' own use of digital tools in educational tasks in class emerged as most pertinent to their digital skill development. As to whether school ICT resources exacerbate or alleviate digital skills, our results paint a nuanced picture. On one hand, school ICT resources are mostly enjoyed by the students from high-SES backgrounds, which augment existing digital skills inequalities. On the other hand, the technical expertise available in school is more valuable a resource to students from less well-off families, thus narrowing the disparities in digital skills, particularly in early education. Our results therefore suggest that both social reproduction and social mobility processes are facilitated by school ICT resources. This presents a conundrum when it comes to addressing digital skill inequalities through school ICT resources. In continuously digitalizing and upgrading, schools can better ensure students are vested with relevant and current digital skills, but this also shifts the benchmark of digital skills higher and higher. How can schools then boost its ability to alleviate, rather than augment, the existing digital skills inequalities while continuously pushed to digitalize further? Additional research is required to answer these questions, hopefully encouraged by our finding that school ICT resources do matter in youths' digital skillfulness and in efforts to close digital skills disparities.

CRediT authorship contribution statement

Renae Sze Ming Loh: Writing – review & editing, Writing – original draft, Visualization, Validation, Methodology, Formal analysis, Conceptualization. **Gerbert Kraaykamp:** Writing – review & editing, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization. **Margriet van Hek:** Writing – review & editing, Supervision, Methodology, Conceptualization.

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Appendix. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.compedu.2024.105195.

Data availability

The data used in this study is publicly available at https://www.iea.nl/studies/iea/icils/2018.

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