**The Digital Divide in Online Education. Inequality in Digital Preparedness of Students
and Schools before the Start of the COVID-19 Pandemic**

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Abstract

The COVID-19 pandemic has disordered the educational process across the globe, as schools suddenly had to provide their teaching in an online environment. One question that raised immediate concern is the potential effects of this forced and rapid digitalization on inequalities in the learning process by social class, migration background and sex. Elaborating on the literature on the digital divide, we study inequalities in digital preparedness of students and schools, before the pandemic took place. Using data from the International Computer and Information Literacy Study (ICILS) on seven countries, and the Teaching and Learning International Survey (TALIS) on 45 countries, both from 2018, we demonstrate that schools and students vary in their preparedness for digital education, but that school variation is not systematically related to the student composition by socioeconomic and migration background. More important drivers for a digital divide in corona-times are the ICT skills students have, which are strongly related to socioeconomic background (known as the second level of the digital divide). We found little evidence for a hypothesized ‘fourth level’ of the digital divide, which would result from social gradients in the preparedness of school environments for digital education.

BACKGROUND AND RESEARCH QUESTION

The corona crisis resulting from the COVID-19 disease disordered the educational process of millions of children. Distance education through online communication channels has become the practice in many societies during the months of March till June 2020 (UNESCO 2020¹). School exams have been cancelled in many societies. While schools slowly reopen in some societies, and despite the great efforts that schools and teachers make to deal with the immediate change of life, it is likely that the corona-crisis keeps affecting the educational process for some time to come.

¹ <https://en.unesco.org/covid19/educationresponse>, accessed 11 May 2020

One question that swiftly received attention of scholars and policy makers is whether sociodemographic inequalities in educational progress will be enlarged by the school closures (Bol 2020). For distance education to work, it takes a good study place with digital equipment, sufficient digital skills, involved parents, and a well-prepared school, and these circumstances are likely to be socially stratified. While the impact of the COVID-19 pandemic on inequalities in educational progression can only be studied later, it is important to examine whether children are well-prepared for the immediate change to online education. It will inform the future study of educational inequalities resulting from the pandemic.

Importantly, we consider both student and school readiness for dealing with online education, in terms of the access to computers and digital skills. Current efforts of (local) governments are to increase digital provisions for families, for instance by lending computers to children who need one. But as research on the ‘digital divide’ shows, access to computers and internet are not the main drivers of digital inequalities these days. A second, and currently more important source of digital divisions are the skills to use technology (DiMaggio et al. 2004; Hargittai and Hinnant 2008). In the context of education, the distinction between access and skills is even more relevant as the two requirements are plausibly applicable to both the student and the school. Not only the student, but also the school needs the necessary equipment and skills to work with online education technology.

We study inequality in corona-preparedness in two different ways. First, we use the International Computer and Information Literacy Study (ICILS) of 2018, for seven countries (Chile, Denmark, Finland, France, Germany, Italy, and South Korea). This comparative student assessment of 8th graders investigates students, school principals, ICT coordinators, and teachers. Second, we use the Teaching and Learning International Survey (TALIS) of 2018, a teacher and school principal survey, covering a much larger set of countries but without information on student-level digital skills. While these data were gathered before the pandemic took place, it helps us to see the extent to which students and schools are well-prepared for online education, by socioeconomic and migration background and composition. While schools or policy makers have sometimes taken immediate action to increase the availability of digital equipment to households during the school closures, it is likely that the combination of student skills, equipment and school readiness is much harder to address with the same immediacy.

We examine the extent to which students are ready for online teaching, defined as having sufficient skills and facilities themselves and going to a school that is well-prepared

for online instruction, and whether this readiness varies by socioeconomic, migration background and sex.

Our results indicate that there are strong inequalities by socioeconomic and migration background in who is well-prepared for online education. However, most of the inequalities are resulting from the skills that students have, and much less from the infrastructure and digital preparedness of schools that students attend. Policies aimed at reducing the digital divide among school children would then best be concerned with teaching digital skills more equally.

THEORIZING THE DIGITAL DIVIDE IN CORONA TIMES

Since the early days of the internet, the ‘digital divide’ has been of concern to social scientists. The literature has proposed three levels of the digital divide (Castells 2001; DiMaggio et al. 2004; Hargittai and Hinnant 2008; Ragnedda and Muschert 2013; Scheerder et al. 2017). A first layer is *access* to computers and the internet. While access was originally an important source of variation between citizens, currently it is not accounting for a big cleavage between social groups, at least not in highly developed economies. Yet, even today access varies across socioeconomic groups in the material availability of devices, software, subscriptions, and secondary equipment like printers and external hard-drives (Van Deursen and Van Dijk 2019). In less developed economies access is still limited and unequal (Lavery et al. 2018; Ragnedda and Muschert 2013; Rotondi et al. 2020).

A second level of the digital divide concerns the *skills and usage* of technology (Büchi et al. 2016; Castells 2001; Hargittai 2001). Skills are crucial determinants of use of technology and the internet, especially for more creative uses (Hargittai and Walejko 2008). Determinants of skills and usage are usually similar to those of access, including socioeconomic status, age, gender, location, and ethnicity. The literature distinguishes between various forms of internet usage and skills, where predominantly information seeking and engaging in commercial transactions are stratified by educational attainment, and information seeking is strongly stratified by being a student or not (Büchi et al. 2016). Using the internet for social interaction and entertainment are less stratified by education or other socioeconomic indicators (Büchi et al. 2016; Van Deursen et al. 2016).

The third level of digital divide is concerned with the *effects* of technology access, skills and usage on various outcomes (such as employment, education, social and political connectedness, and health, Van Deursen and Helsper 2015). In the context of education,

research shows that digital skills enhance educational performance, particularly among students from less advantaged backgrounds (Pagani et al. 2016).

Scholarship has also widened the theoretical scope of digital inequalities, by proposing a *resources and appropriation theory* of inequality in the diffusion, acceptance and adoption of advanced technologies (Van Dijk 2005; 2013). According to this relational theory, it is not sufficient to describe inequalities in new technologies by examining correlations with individual predictors. Instead, we should understand digital inequalities from the appropriation of technology use by elites. “The dominant category is the first to adopt the new technology. It uses this advantage to increase power in its relationship with the subordinate category” (Van Dijk 2005: 11).

These three perspectives of the digital divide all focus on the users of technology; focusing on whether they have access, have the skills, use technology, and experience benefits from all this in other life domains. Yet, the extent to which digital inequalities emerge in and through education is also dependent on the context in which students are educated: the schools. Existing studies have sometimes placed the available infrastructure under the access mechanism (Wei et al. 2011), and schools could similarly vary in the infrastructure they have to provide digital education (e.g. by the availability of computers in the school). However, the contextual environment may not only vary in the infrastructure that is necessary to have access to digital learning, but also in the skills that teachers have to offer the education necessary in an online environment (Sipilä 2014). The skills available in the context within which students learn can be seen as a fourth level of digital divide. This fourth level emphasizes that it is not only the readiness and skills of individuals that determine the outcomes of internet use, but also the extent to which external parties create environments conducive of the realization of personal goals. In the light of resources and appropriation theory, schools can be seen as environments where the provision of computers and the importance attached to digital learning function as strategies to advance students over students in other schools. Attending resource-full schools thus not only offers the opportunity to learn to study in a digital environment, but places the acquired skills and knowledge in a power relationship against schools and students who are less able to learn in a digital way. A coincidental, but nevertheless highly influential byproduct of the corona crisis is, then, that inequalities in digital skills and usage are enlarged.

According to this line of reasoning, digital divides are of a multilevel nature. To the extent that the fourth level of the digital divide exists, policies to reduce digital inequalities should not only consider the access, skills and uses at the individual level, but also at the

contextual level. On the other hand, if the contexts are not unequally equipped with digital preparedness, policies to reduce digital inequalities can primarily focus on the individuals in question (i.e. the students).

Analyzing the Digital Divide

Following the digital divide literature, we make a distinction between access and skills. In line with our suggested elaboration of a fourth level of digital divide, we furthermore consider ICT resources of both the focal person (i.e. student) and the environment (i.e. school) he or she attends. Thus, in order to understand student stratification in the readiness to be educated in a digital environment, we consider the extent to which students of various backgrounds have the skills and experience to use digital technology, attend schools that have a supportive infrastructure, and attend schools where teachers have sufficient digital skills to enable the digital educational process. Inequality in readiness for digital education is examined by socioeconomic background, migration background, and sex.

We examine digital inequalities in two different designs. The first design employs student-level and school-level data for seven countries, and studies student and school-level dimensions of the digital divide. The second design only focuses on school-level data but a larger set of countries, and incorporates student composition data to elaborate on digital inequalities by socioeconomic and migration background. Moreover, the second study includes more direct measures of teachers' digital skills as a potential source for a digital divide.

STUDY I: STUDENTS AND SCHOOLS IN SEVEN COUNTRIES

Methodology

For Study I, to examine students' and schools' degree of readiness for online education, we use data from the International Computer and Information Literacy Study (ICILS) from 2018. This cross-country survey measures how well 8th-grade students are prepared for the digital age, combined with data about their schools' and teachers' ICT-related resources. Specifically, we look at students in seven countries across three continents, selected because rich student- as well as school-level data is available for these countries²: Chile, Denmark,

² By rich we mean that all relevant questions were included in the survey, and there were few missing observations

Finland, France, Germany, Italy and South Korea. We argue that readiness for online education is a function of both a student's individual ICT resources as well as the student's school ICT resources. Despite combining student- and school-level data, students thus serve as our unit of analysis (N=18,882).

To measure students' individual preparedness, we look at students' experience in ICT use as well as at students' digital skills; we do not look at students' access to ICT since we study OECD countries where this is no longer a prominent level of the digital divide. To measure ICT use, we use a factor score of 12 manifest variables that pertain to the frequency of students' school-related ICT use. These include, for instance, data about how often the student uses ICT to write a document or to prepare a presentation. Since we are interested in students' readiness for online education, students' ICT use for school-related tasks is arguably of prime relevance. For this reason, manifest variables that pertain to the frequency of students' ICT use for non-educational activities, such as playing games, using social media or listening to music, are not included. Moreover, since the objective of the factor analysis is the construction of a valid measurement tool, all included items have relatively few missing values, reasonably strong loadings on the emerging factor (≥ 0.35 ; Fabrigar & Wegener, 2012). The scale created is internally consistent (Cronbach's alpha is 0.86 across countries; average inter item correlation is 0.35). The resulting latent variable provides a valid and reliable measure of students' experience with using ICT for educational purposes.

Students' digital skills are measured using a factor score of five plausible values of a student's score on a Computer and Information Literacy Achievement scale. These estimated scores are summary statistics of students' skills, derived from students' results on test modules that were specifically designed to assess a person's "ability to use computers to investigate, create, and communicate in order to participate effectively at home, at school, in the workplace and in society" (Fraillon, Schulz & Ainley, 2013, p.17). These test modules consist of comprehensive, real-world tasks such as creating a webpage about a school band competition, or designing an infographic to raise awareness about waste reduction. A student's test results thus combine information about their level of proficiency in various ICT-related activities, ranging from information-gathering to digital communication (Fraillon, Ainley, Schulz, Friedman & Duckworth, 2019). Hence, the emerging digital skills score taps into students' ability to competently and effectively use ICT broadly.

School's preparedness is measured by two dimensions: the school's infrastructure (availability of internet, software, devices), and the ICT competencies (usage, skills, encouragement) prevalent in the school setting. These two dimensions of school preparedness

emerge from a factor analysis of 40 manifest variables that pertain to the evaluation by school principals and ICT coordinators of their school's ICT provision. Again, since the objective of the factor analysis is to develop a valid measurement instrument, manifest variables are included that clearly and strongly load on one and only one of the emerging factors (≥ 0.35), selected in an iterative process (Fabrigar & Wegener, 2012). The first latent variable comprises data about the school's technology and software infrastructure, for example internet access at the school or the availability of digital learning resources, a learning management system or email accounts for school-related use. One could think of such variables as promoting *access* to digital learning. The second latent construct encompasses indicators about the importance the school attaches to digital learning outcomes of students (e.g. the development of proficiency in processing information with ICT) and digital teaching competences of instructors, for instance the extent to which teachers are expected to integrate ICT into their lessons, are encouraged to participate in ICT-related professional development, and are provided with resources to prepare lessons in which ICT is used. The resulting scale can be seen as indicative of the ICT *competencies* available in the school context. Both measurement instruments are internally consistent (Cronbach's alpha is 0.85 for infrastructure and 0.89 for competencies; average inter-item correlations are 0.24 for infrastructure and 0.28 for competencies). Hence, the resulting factor scores provide valid and reliable measures of two distinct dimensions of school preparedness for online education, tapping into the 'access' to respectively the 'skills and usage' of digital resources at the school.

In sum, we construct four continuous indicators of digital readiness that account for the multi-level structure of the digital divide: students' ICT use, students' ICT skills, the ICT infrastructure of students' schools, and the ICT competencies of students' schools. All four indicators are based on standardized Bartlett factor scores that are estimated after an exploratory factor analysis using maximum likelihood estimation and an oblique factor rotation. Missing values for the factor scores are imputed by using the row-mean of the non-missing manifest variables as a predictor. We argue that all four dimensions increase a student's digital preparedness since having experience in using ICT, possessing the skills to competently handle ICT, going to a school that has a well-developed ICT infrastructure, as well as attending a school that encourages high-quality digital teaching and learning all facilitate the transition to online schooling. But although these four dimensions are distinct, they may not be fully independent, meaning students may be (dis-)advantaged in several dimensions at the same time. To examine students' overall preparedness for online education,

we lastly construct a combined indicator by taking the average of the four separate indicators discussed above, giving equal weight to all dimensions of readiness.

To analyze the divide in digital readiness, that is the extent to which digital readiness differs between students, we look at three dimensions of stratification therein: students' socio-economic background, migration background and sex. Student socioeconomic origin is measured using the National Index of Socio-economic Background (NISB) that takes into account students' parental occupational status, their parental education level and the number of books at home. On that basis, within-country quartiles of socioeconomic status are constructed, resulting in an ordinal variable of low, medium-low, medium-high and high socioeconomic status.

Students' migration background is measured using a dichotomous variable whereby a student is defined as a migrant if either both parents were born abroad or if the student and the parents were born abroad. Finally, with respect to sex, we distinguish between boys and girls. On the basis of these data, we conduct multivariate regression analyses separately for each country, and compare the predicted outcomes across sociodemographic groups. The four indicators of digital readiness serve as the respective dependent variables, while the three stratification dimensions serve as the independent variables. By country, we thus analyze the differences in four dimensions of digital readiness between students that a) come from different socioeconomic origins; b) have a migration background or not; and c) are boys or girls. If there is a digital divide in students' preparedness for online education along these sociodemographic lines, we hypothesize that there should be a significant association between the stratification variables and students' digital readiness.

Table 1 shows the descriptive statistics of the variables used in Study I. The first five variables are the indicators of digital readiness; the latter three variables are the dimensions of stratification. As latent variable scores are standardized, all ICT-related indicators have their mean around zero. What is interesting, however, is that they vary in their degree of dispersion: whereas students diverge in terms of their ICT skills by up to 8.3 standard deviations, dispersion in students' ICT use and their schools' ICT provision is considerably smaller (5.4 to 6.4 standard deviations). The overall readiness indicator takes an intermediate position with a range of 7.5 standard deviations. Concerning their socioeconomic background, the students in the sample are moderately dispersed, ranging from 3.7 standard deviations below to 2.6 standard deviations above average socioeconomic status. Boys and girls are equally represented in the sample, and 10 percent of the students have a migration background.

Table 1: Descriptive statistics of the data for Study I

	mean	sd	min	max
Student ICT use	0	1	-2.044	3.391
Student ICT skills	0	1	-4.994	3.337
School ICT infrastructure	0	1	-3.023	3.330
School ICT competencies	0	1	-4.138	2.043
Overall digital readiness	0	1	-3.674	3.819
Socioeconomic background	0	1	-3.720	2.567
Immigration status	0.1	0.3	0	1
Sex	0.5	0.5	0	1
Observations	18882			

Results

To study the extent to which students are ready for online teaching and how this readiness varies by students' sociodemographic background, we conduct multivariate linear regression analyses (including all three predictors socioeconomic background, migration background and sex).³ To examine the net effects of students' socioeconomic background, migration background and sex, we compare different student groups' predicted outcomes on the four indicators of digital preparedness. Starting with students' usage of ICT, these predicted outcomes are visualized in Figure 1. A first notable finding is that students' predicted level of ICT usage for school-related activities varies by country, with especially high values in Denmark. Inequality in ICT usage by SES quartile is relatively small in Chile, Denmark and France, but larger in Finland, Germany, Italy and Korea. While pointing in the expected direction – i.e. the higher a student's socioeconomic background, the more they tend to use ICT for educational purposes – SES differences are modest, amounting to less than half a standard deviation. Likewise, inequality in ICT usage by migration background is small in most countries. In fact, after controlling for students' SES and sex, students with and without migration background do not differ statistically significantly in terms of their ICT usage in Denmark, Finland and Korea. In Chile, France, Germany and Italy, there are statistical differences but again of modest magnitude, not exceeding 0.2 standard deviations.

³ The tables with the detailed regression coefficients can be found on www.socarxiv.org (precise link will follow after peer review).

Interestingly, if there are differences, they indicate that students with a migration background tend to use ICT more frequently for educational purposes, meaning they are *better* prepared for online education than students without a migration background (and similar SES). With regard to students' sex, differences in students' school-related ICT usage are similarly small but statistically significant in all countries except for Germany and Italy. Where there are differences, girls tend to use ICT for educational purposes more frequently than boys, most distinctly in Korea where girls' lead amounts to 0.33 standard deviations. Overall, while the degree to which students use ICT for school-related tasks varies along sociodemographic lines, the divergences are modest.

Figure 1: Predicted student ICT use, by country and group

Figure 2: Predicted student ICT skills, by country and group

Turning towards students' ICT skills, Figure 2 displays predicted gaps in the ICT skills as assessed in the ICILS student assessment. The lowest levels of ICT skills are found in Chile and Italy, the highest in Denmark and Korea. Chilean students coming from the highest SES quartile have ICT skills at a similar level as Danish students of the lower half of the SES distribution. The gaps in ICT skills by SES groups are sizeable and statistically significant in all countries, with students from socioeconomically advantaged backgrounds possessing considerably better ICT skills than students from less advantaged backgrounds. The strongest gaps are found in Chile, where the digital skills of students from the highest SES quartile are 1.3 standard deviations higher than those of students from the lowest SES quartile. By contrast, in Denmark, the difference in skills between students from the highest and lowest SES quartiles 'only' amounts to 0.48 standard deviations. With regard to students' migration background, the gaps in ICT skills vary across countries: while there are no statistically significant differences in Chile, Italy and Korea, students with a migration background are significantly disadvantaged in their ICT skills in all other countries, scoring up to 0.54 standard deviations lower than students without migration background. In contrast to the first indicator, ICT usage, migrants thus appear to be *less* prepared for online education than non-migrants in terms of their ICT skills. Considering students' sex, the pattern

indicated by their ICT usage is confirmed for ICT skills: again, girls tend to be better prepared for online education; their skills are statistically and substantively significantly better than those of boys, by up to 0.44 standard deviations. Students' ICT skills, therefore, vary to a considerable extent, especially by socioeconomic background but also between migrants and non-migrants as well as between boys and girls.

Based on the results concerning students' ICT usage and skills, it appears that students in Denmark have the highest averages, and among the lowest inequalities, in ICT usage and skills. Following these statistics, one would conclude that Danish students are best prepared for digital education. However, these findings do not yet take the multi-level nature of students' readiness into account. Figure 3 presents findings on students' schools' ICT infrastructure, by student SES quartile, migration background and sex. There are large differences across countries in the provisions of internet, email addresses and other infrastructural elements that promote access to digital education. In Denmark, Finland and Korea, schools are generally well-equipped; the ICT infrastructure is less generous in France, Germany, and Chile, and intermediate in Italy. An important finding is, however, that statistically and substantively significant inequality by socioeconomic background is only found in Chile, where high-SES students score 0.59 standard deviations above low-SES

students. Inequality by migration background only occurs, to a small extent, in Finland where migrants tend to go to schools whose ICT infrastructure is 0.16 standard deviations higher than that of non-migrants' schools. Inequality by sex occurs in none of the countries, meaning boys and girls go to schools that are equally well equipped in terms of their ICT infrastructure. Hence, students' schools' ICT infrastructure hardly varies along sociodemographic lines, with notable exceptions being the socioeconomic divergence among Chilean students, and the migration divergence among Finnish students.

Figure 4 shows the predicted differences between schools' ICT competencies for students of different SES quartiles, migration background and sex. Generally, countries differ in the importance schools attach to digital learning and teaching: ICT competencies of schools are relatively low in Germany and France, countries that also scored relatively low on infrastructural provisions. Comparatively well-resourced are schools in Chile, Finland and Korea, whereas Denmark and Italy take intermediate positions when it comes to schools' skills and usage of digital learning. In none of the countries, there is an SES or sex gap in the ICT competencies available in students' schools. A migration gap in school-level ICT competencies only occurs in Finland, where migrants' schools are modestly better skilled

than non-migrants' schools, by 0.33 standard deviations. This confirms the results with regard to schools' infrastructure, where a migration gap also only occurs in Finland. Overall, the ICT competencies of the schools that students attend hardly vary according to students' sociodemographic characteristics, except for a modest migration gap in Finland.

Interestingly, the school-level indicators of students' preparedness for online education thus differ considerably from the individual-level indicators: while students' individual ICT usage and especially their digital skills are characterized by significant sociodemographic gaps in all countries, ICT resources of students' schools hardly vary by sociodemographic background in the countries under study. Moreover, the indicators also differ in their absolute level: while, as previously mentioned, Danish students seem to be best prepared for online education on the basis of the individual-level indicators, they are no longer in the lead when considering the school-level ICT resources. Hence, the question emerges which students in which countries 'have it all' or, at least, 'most of it'? Arguing that readiness for online education hinges on all four indicators, that is on students' individual experience and skills with ICT as much as on students' schools' access to and usage of ICT, we analyze in the next step which students are digitally prepared multidimensionally, using the combined indicator of readiness.

Figure 5: Predicted digital readiness, by country and group

Figure 5 visualizes predicted gaps in students' overall digital readiness, by SES quartile, migration background and sex. Students are overall best prepared in Denmark, followed by Finland and Korea. Students are least prepared in Germany and France, and slightly better off in Italy and Chile. Inequality in digital readiness is highest among students of different SES quartiles, and this socioeconomic divergence is most pronounced in Chile (0.84 standard deviations) and least distinct, yet still considerable, in Denmark (0.23 standard deviations). In all countries under study, therefore, high-SES students are statistically significantly and substantively better prepared for online education than low-SES students.

Inequalities by migration background and sex are smaller in magnitude, but significant gaps nevertheless occur. With regard to students' migration background, the four separate indicators did not indicate a clear pattern, with migrants appearing sometimes better and sometimes worse prepared. Consequentially, when controlling for SES and sex, in most countries migrants and non-migrants are overall approximately equally prepared for online education, with the only exception being Denmark where migrants are disadvantaged by 0.19 standard deviations. This is a notable gap, but even Danish students with a migration background are much better prepared than students in all other countries. Finally, with respect to students' sex, girls are overall significantly better prepared for online education than boys in all countries except for Germany. The magnitude of girls' premium varies, however, ranging from 0.31 standard deviations in Korea to less than 0.1 standard deviations in Chile and Italy. With regard to the multiple dimensions in which students are (not) prepared for digital education, we thus conclude that both a student's country matters but also their sex as well as their socioeconomic status within the country. The students that 'have it all', that are multidimensionally prepared for online teaching, tend to come from Denmark, but being socioeconomically advantaged and a girl helps in all countries under study.

To conclude, students vary significantly in the extent to which they are prepared for online education, both between and within countries. Looking at four dimensions of digital readiness, a general pattern emerges that girls are better prepared than boys, and children from socioeconomically advantaged backgrounds are better prepared than children from disadvantaged backgrounds. Students' migration background, by contrast, does not seem to have a systematic impact on students' digital readiness. These gaps between students of different SES quartiles and sex add up over the various dimensions of readiness, resulting in modest yet considerable inequalities in students' overall digital preparedness. By far the largest inequalities, however, arise from students' ICT skills where students' differential

preparedness for online education is most pronounced. Especially students' school-level digital readiness, by contrast, hardly diverges along sociodemographic lines.

STUDY II: TEACHERS IN 45 COUNTRIES

Methodology

In Study II, we further examine students' degree of readiness for online education but take a different approach, focusing specifically on students' school-level preparedness and a larger sample of countries, including more direct measures of teachers' ICT skills. We use data from the Teaching and Learning International Survey (TALIS) of 2018. This international survey is organized by the OECD and held among teachers and school principals to study teachers' working conditions and students' school learning environments. We select the data of teachers in lower-secondary schools in 45 countries and subnational regions, thereby covering a similar time frame as well as student age group as in Study I⁴ while including considerably more countries. The countries under study are spread across all continents, and they are as economically, politically and socially diverse as Sweden, Saudi Arabia, Colombia and Vietnam. This does justice to the global nature of the COVID-19 pandemic during which online education has rocketed: since school closures are a worldwide phenomenon, it is relevant to examine students' preparedness in diverse societies. Moreover, the teacher data allow us to zoom in on the multi-level structure of the digital divide. To the extent that a fourth level of the digital divide exists and students' readiness for online education is also shaped by the differential ICT resources of students' schools, this should be reflected in teachers' varying ICT-related behavior, as measured by TALIS.

The TALIS data cover many aspects of teaching and professional development, and some of the questions address the use of ICT. We distinguish four indicators of the digital preparedness of teachers: the attention to ICT use in teacher education and training, attention to ICT use as part of the professional development while being a teacher, students' use of ICT during the teacher's classes, and the teacher's use of ICT to support student learning. The first indicator, ICT in teacher education, is a standardized continuous scale that incorporates both whether ICT use was addressed as well as how well the teacher was trained in ICT use. The second indicator, ICT during professional development, is a dummy variable,

⁴ TALIS matches with the PISA student assessments of 15-year old students, while ICILS studies grade-8 studies with a modal age of 14.

measuring whether ICT skills for teaching were part of the teacher's professional development activities during the last 12 months. The third, ICT for classwork, and fourth, ICT for student support, indicators are standardized categorical variables that indicate respectively a) how often the teacher lets students use ICT for classwork, and b) the extent to which the teacher supports student learning through the use of ICT. These four variables tap both into teachers' ICT *skills*, as acquired during their teacher training and professionalization activities, as well as into teachers' ICT *usage*, as evidenced by their use of digital technology in class. Hence, these four indicators are complementary, together providing a valid measure of teachers' ICT competencies. We argue that if teachers score high on these variables, that is they are digitally prepared, this implies that also their students' school-level readiness for online education is high.

Our objective is to analyze whether there is a divide along sociodemographic lines in how digitally prepared students are at the school level, yet the TALIS data do not contain information on individual students. Hence, we use information on school composition instead. In the survey, school principals estimate the proportion of students in their school that a) come from a socioeconomically disadvantaged home, and b) are migrants or have a migration background. In doing so, principals are asked to judge a student as 'disadvantaged' if they "lack the basic necessities or advantages of life" (OECD, 2018, p.8), and as a migrant if either the student or the parents were born abroad. The data are categorized (none, >0-10%, >11-30%, >30-60%, >60%).

We fit multi-level models, separately for each country, whereby teachers serve as our unit of analysis (N=135,169) but are nested in schools. The four indicators of teachers' digital readiness serve as the respective dependent variables, while the student composition measures function as the main independent variables. We fit linear models for all dependent variables except for ICT during professional development, for which we fit a linear probability model to accommodate its binary nature while maintaining our focus on (un-)explained variances. If there is a digital divide in students' school-level preparedness for online education along sociodemographic (SES and migration background) lines, we hypothesize two outcomes for the regression models:

1. There should be a negative association between the school composition variables (proportion migrants and proportion low-SES) and teachers' digital preparedness;
2. The between-school variance in teachers' digital preparedness should be (partially) explained by schools' student composition measures.

To render the models more robust, we include several teacher characteristics as control variables since these could influence both how digitally apt a teacher is as well as at what kind of school the teacher works. These encompass a teacher's experience in years, the experience squared, whether they are a STEM-teacher (mathematics, science or technology), whether the teacher has a Master degree, and the teacher's sex. With the exception of the experience measures, all control variables are dichotomously coded. Where data was missing for either of the independent or control variables, the corresponding observations were dropped. For 45 countries separately, we thus analyze the differences in four indicators of school-level digital readiness among schools that a) have different percentages of students from socioeconomically disadvantaged backgrounds; and b) have a varying proportion of students with [a](#) migration background.

Table 2 shows the descriptive statistics of the variables used in Study II. The first four variables are the measures of teachers' digital readiness, the next two indicate the school's student composition, and the last variables refer to the teacher characteristics that we include as controls. 70% of teachers have recently participated in ICT-related professional development activities; the other three indicators of teachers' digital readiness are standardized and have their mean at zero. ICT attention in teacher education and ICT use for classwork are approximately equally dispersed, whereas the dispersion in ICT use for student support is comparatively higher. The overwhelming majority of schools in the sample have no (45.4%) or less than 11% (39.1%) of students who are migrants or have a migration background. The largest group of schools have some but less than 11% of students from socioeconomically disadvantaged backgrounds (44.6%), with schools estimated to have 11-30% of disadvantaged students scoring second (27.7%). The teachers in the sample have widely varying degrees of experience, averaging 16.6 years. 40% of them are STEM teachers, 40% have a Master degree and 70% of them are female.

Table 2: Descriptive statistics of the data for Study II

	mean	sd	min	max
ICT in teacher education	0	1	-1.624	1.712
ICT in professional development	0.7	0.5	0	1
ICT for classwork	0	1	-1.698	1.563
ICT for student support	0	1	-2.187	1.183
% low-SES students in school	1.5	1	0	4
% migration background students in school	0.8	0.9	0	4
Teaching experience in years	16.6	10.8	0	58
STEM teacher	0.4	0.5	0	1
Master degree	0.4	0.5	0	1
Teacher sex	0.7	0.5	0	1
Observations	135169			

Results

To examine the inequalities in students' school-level readiness for digital education, we conduct multi-level, multivariate regression analyses, and compare the results across the 45 countries under study. We expect that if there is a fourth, school level of the digital divide, the percentages of students from socioeconomically disadvantaged and migration backgrounds at a school should be negatively related to the ICT competencies of the teachers at that school. The corresponding coefficients are displayed, for the respective indicators of teachers' digital readiness and controlling for other teacher characteristics, in Figures 6, 7, 8 and 9. Regarding the attention to ICT in teacher education (Figure 6), the expected negative relationship with the percentages of students from low-SES and migration backgrounds significantly applies in only one case: Mexico. Here, at schools where more than 60% of students come from socioeconomically disadvantaged respectively migration backgrounds, teachers have been 0.2 respectively 0.12 standard deviations less well trained in ICT use during their teacher education than teachers in schools with no students from these backgrounds. In most other cases, these effects are even weaker and not statistically different from zero, whereas in some countries, they even point in the opposite direction. In Lithuania, for instance, teachers at schools where more than 60% of students are socioeconomically disadvantaged have been 0.28 standard deviations better trained in ICT use during their teacher education than teachers in schools with no disadvantaged students.

Figure 6: Regression coefficients - ICT in teacher education

Figure 7: Regression coefficients - ICT during professionalization

Regarding the attention to ICT during professional development activities (Figure 7), a similar picture emerges that the proportion of a school's students from low-SES and migration backgrounds tends not to be statistically significantly related to the ICT competencies of the school's teachers. In the overwhelming majority of countries, depending on their schools' student body, teachers are neither more nor less likely to have improved their ICT skills as part of their professionalization activities while being a teacher. There are some noteworthy exceptions in both the positive and the negative direction, however. In England, for example, teachers at schools with more than 60% of low-SES students are 24 percentage points less likely to have attended an ICT-related professionalization activity than teachers at schools with no low-SES students. By contrast, in Norway, teachers at schools with a high percentage (>60%) of disadvantaged students are 28 percentage points more

likely to have upgraded their ICT skills as part of their professional development than teachers at schools without disadvantaged students.

Figure 8: Regression coefficients - ICT for classwork

Moving from teachers' theoretically acquired ICT skills to their practical ICT usage in class, the relationship with the student composition of their school does not substantially change. Regarding students' use of ICT during a teacher's classes (Figure 8), in most countries this does not significantly vary with the perceived proportion of students from socioeconomically disadvantaged or migration backgrounds at the teacher's school. Where there is a significant relationship, however, it is more consistent than with the first two indicators of teachers' ICT competencies, pointing in a negative direction, and the effect sizes are larger. In Australia, for instance, teachers at schools with more than 60% of low-SES students let their students use ICT for classwork 0.6 standard deviations less frequently than

teachers at schools without low-SES students. Likewise, in Italy, at schools with more than 60% of students with migration background, students use ICT during class 0.56 standard deviations less often than at schools without migrants. By contrast, there is no country where teachers at schools with more low-SES students significantly more often let their students use ICT during class than teachers at schools without low-SES students, and for the student composition in terms of students' migration background, such a positive association only applies in the United Arab Emirates as well as in Estonia.

Regarding teachers' use of ICT to support student learning (Figure 9), the relationship with the perceived sociodemographic student composition of teachers' schools is less consistent than with the ICT-for-classwork indicator, but it continues to be insignificant in most cases. That is, in most countries, teachers at schools with many disadvantaged or migrant students are neither more nor less able to support their students via the use of ICT than teachers at schools with less students from these backgrounds. However, there are exceptions in both directions: in Singapore, for example, teachers at schools with more than 60% of socioeconomically disadvantaged students are 0.36 standard deviations less able to support their students by using ICT than teachers at schools with no low-SES students. At the same time, teachers at schools with a comparably high proportion of students with migration background are 0.28 standard deviations better able to support their students via ICT than teachers at schools without migrant students. Hence, while students with a low socioeconomic background tend to be disadvantaged in their school-level digital readiness, students with a migration background tend to be advantaged in Singapore (net of SES composition).

Figure 9: Regression coefficients - ICT for student support

The paradoxical relationship between teachers' ICT competencies and the student composition of teachers' schools in Singapore is no exception: for all four indicators of teachers' digital readiness, the effects of an increase in low-SES respectively migrant students tend to be negatively correlated with each other, meaning where teachers' digital preparedness is positively associated with a larger share of migrant-background students, it is negatively associated with a larger share of low-SES students, and vice versa. Overall, however, these associations between students' sociodemographic backgrounds and school-level digital readiness are very weak, hardly significantly different from 0, and no systematic pattern is discernible. In some cases, teachers are less digitally prepared where many students from socioeconomically disadvantaged or migration backgrounds attend their schools; in other cases, teachers at comparable schools are more digitally prepared. In the overwhelming

majority of countries under study, however, the sociodemographic student composition of a school is not at all statistically related with the digital preparedness of its teachers and, consequentially, with the school-level digital preparedness of its students. No matter their sociodemographic background, students are approximately equally prepared for online education at the school level; their teachers are approximately equally digitally apt.

To further corroborate our conclusion that there hardly is a digital divide at the school level, we analyze the between-school variance in teachers' digital readiness. If there is a school-level digital divide, we expect that the between-school variance in teachers' digital preparedness can be (partially) explained by schools' student composition. Controlling for teacher characteristics, the between-school variances in the respective indicators of teachers' ICT competencies and how they change when additionally controlling for schools' student composition are visualized in Figures 10, 11, 12 and 13. Regarding the attention paid to ICT during teachers' initial teacher training (Figure 10), the unexplained between-school variance generally tends to be low (less than 0.08 standard deviations in all cases), and it is hardly reduced when accounting for schools' student composition in terms of students' SES and migration backgrounds. Without accounting for students' backgrounds, the variance is relatively highest in Kazakhstan (0.071 standard deviations) but it cannot be substantially explained by students' backgrounds. In fact, the only cases where the between-school variance in teachers' attention to ICT during their teacher education can be non-negligibly explained by the student composition of their schools are Buenos Aires/ Argentina, Israel and

South Africa, but even here the variance reduction amounts to less than 0.01 standard deviations.

Regarding the attention paid to ICT not during teachers' initial education but during their professional development activities (Figure 11), the likelihood of ICT-related professionalization likewise hardly varies between schools and is mostly independent of schools' sociodemographic student composition. Without accounting for school composition, the between-school variance is relatively highest in Norway (0.034 percentage points) but schools' student composition can only explain a small part of it (4.5%). School composition can explain the largest proportion of the between-school variance in teachers' ICT attention during their professionalization in Korea (23.0%) but in absolute levels the unexplained variance is reduced by only 0.001 percentage points. In absolute terms, students' sociodemographic backgrounds can best explain this between-school variance in England, but even here the reduction only amounts to 0.003 percentage points.

When considering teachers' digital readiness in terms of their ICT usage instead of their ICT skills, the between-school variances tend to be higher in absolute terms but the explanatory power of schools' student composition remains similarly limited. Regarding students' ICT use during teachers' classes (Figure 12), the total between-school variance amounts up to 0.1 standard deviations in most of the countries under study. It is higher in the Netherlands (0.15 standard deviations) and in Sweden (0.184 standard deviations) but schools' student composition can hardly explain these relatively high between-school

variances. This is not surprising given that neither the proportion of low-SES nor the proportion of migrant-background students at a school significantly correlates with teachers' digital preparedness in these two countries. Instead, in absolute terms, the largest reduction in unexplained between-school variance in teachers' digital readiness when accounting for students' backgrounds is achieved in Australia (by 0.021 standard deviations) where the proportion of low-SES students at a school is highly significantly related to the frequency of ICT-for-classwork use by that school's teachers.

Figure 12: Between-school variance - ICT for classwork

Figure 13: Between-school variance - ICT for student support

Regarding teachers' use of ICT to support student learning (Figure 13), the picture is again similar. In most countries under study, the total between-school variance in teachers' ICT usage for student support is low (below 0.1 standard deviations). There are two notable exceptions: South Africa (0.183 standard deviations) and Belgium (0.261 standard deviations). Students' background characteristics, however, cannot explain more than 0.01 standard deviations of the between-school variance in any of the countries studied.

To conclude, when examining the extent to which the between-school variance in school-level digital readiness can be explained by schools' student composition, the primary finding is that in most cases there is hardly any between-school variance to explain in the first place; oftentimes, it is not significantly different from zero. No matter whether considering teachers' digital preparedness in terms of their ICT skills acquired during their teacher training or professionalization activities or in terms of their ICT usage for classwork or student support, this hardly varies between schools within a country. The between-school variance that does occur can in some cases be explained by schools' sociodemographic student composition but only to a very limited extent. Considering that a school's composition with regard to the socioeconomic and migration backgrounds of its students is in many countries not statistically significantly related to its teachers' ICT competencies, this is not a surprising finding. Instead, it confirms the previous conclusions that the fourth level of the digital divide tends to be minor. At the school-level, students are approximately equally digitally prepared, no matter their sociodemographic background. That is, when inequality arises in how prepared students are for online education, this is not substantially induced by unequal preparedness of the schools that students attend.

CONCLUSION AND DISCUSSION

The COVID-19 pandemic forces schools to rapidly digitalize their educational process, and demands from children to do their class and homework in an online environment. Given the expected inequalities that may come with it, the current study assessed whether there were inequalities in digital preparedness of students and schools, shortly before the pandemic took place. We examined the digital divide in a multilayered framework, by examining student ICT skills, student usage of ICT, and the ICT infrastructure and competencies in the schools that students attend. More precisely, we examined whether socioeconomic background,

migration background and sex were associated to gaps in these different facets of digital preparedness.

We found clear evidence for a digital divide by socioeconomic and migration background, and sex, but mostly with regard to the students' individual ICT skills. Children of more advantaged backgrounds, without a migration background, and girls had higher-level ICT skills than their male peers from disadvantaged, migration backgrounds. These findings point to the second level of the digital divide (Hargittai 2001; the first one being the access to technology).

Other levels of the digital divide were less stratified by student background. Lower SES and migrant children were not less likely to go to schools with a good digital learning environment. Between-school differences in digital infrastructure and teacher competencies, which existed in a number of countries, were hardly related to the share of disadvantaged children or children with a migration background. It should be emphasized that the differences across schools within a country were sometimes quite substantial. This in itself is a fourth-level digital divide as some students go to secondary schools with good ICT provisions while other schools are less well-equipped. But this variation is not strongly related to the student composition in terms of social class or migration background, so these patterns are not likely to form a source of a fourth-level of digital divide in the form of class-based or migration-related inequalities.

Given the educational situation during corona times, it is important to investigate whether the demonstrated digital divides strengthen the third-level digital divide which is concerned with the (educational) outcomes of access and usage of technology. Our study may help educational practitioners, policy makers and scientists to bring focus in dealing with unequal preparedness for the digital educational revolution we were suddenly confronted with. There are two lessons to be drawn in this regard. First, student background is clearly related to the level of ICT skills, while student background was hardly correlated with the school's digital preparedness. Socioeconomic and migration gaps in digitalization should be primary concerned with equalizing the skills. Second, even if between-school differences in digital preparedness were hardly related to the student composition, these between-school differences do exist in many societies. This means that students are confronted with a variability in infrastructure and school-level competencies, which creates inequalities in the learning process. A better understanding of these between-school differences seems crucial to promote equality of educational opportunity in the digital age.

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