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SCHOOL ICT RESOURCES, TEACHERS, AND ONLINE EDUCATION: EVIDENCE FROM SCHOOL CLOSURES IN JAPAN DURING THE COVID-19 PANDEMIC

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School ICT resources, teachers, and online education: Evidence from school closures in Japan during the COVID-19 pandemic

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Abstract

During the COVID-19 pandemic, schools switched to online education. Using Japan's nationwide administrative data, we examine the impact of schools' ICT equipment and teachers' IT skills on the provision of online classes, communication with students' families, and teachers' working hours in early 2020. To isolate supply-side effects, we exploit differences in ICT resources between public elementary and junior high schools at a municipality level, the level at which ICT resources are decided. We find that basic ICT equipment was critical to implementing online classes, but IT skills were not. However, IT skills were associated with teachers' working hours.

Keywords: COVID-19; remote education; teachers' skills; school resources

JEL classification: I20, J22, H75

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1. Introduction

In early 2020, the COVID-19 pandemic forced many schools worldwide to close, resulting in widespread children's learning loss (UNESCO, 2021; Cortés-Albornoz et al., 2023). During these closures, many countries turned to online tools to secure a degree of continuity in children's education. Related studies have predominantly focused on the demand side, investigating how students' family backgrounds influenced access to remote/online education and the associated educational access gap, generally finding a negative impact (Andrew et al., 2020; Bacher-Hicks et al., 2021; Grewening et al., 2021; Ikeda and Yamaguchi, 2021; Akabayashi et al., 2023). However, many countries also faced supply-side issues in providing high-quality online education given schools' information and communication technology (ICT) resources, namely ICT equipment and teachers' IT skills. Only a few studies have examined how school ICT resources affected online learning provision during the pandemic (Dincher and Wagner, 2021; Akah et al., 2022).

The first reason for this gap in the literature is the lack of data. Very few countries have systematic data on schools' ICT resources or educational practices during the pandemic. The second reason is the difficulty separating the demand and supply sides of ICT resources and access to online education. It is likely that schools in wealthier areas where demand for high-quality education might be higher are better equipped and staffed by more highly qualified teachers, making the effects of the supply side difficult to identify. An equally important concern is the overwork of teachers, as even schools with top-level ICT equipment and skilled staff cannot effectively provide online education if teachers are overwhelmed.

Japan has a very high availability of high-speed Internet connection (OECD 2020a), yet the use of ICT in school education is largely lacking (OECD 2020b, 2020c). During the school closures in the first wave of the pandemic, only a small portion of schools provided live online classes and other forms of digital education. This paper aims to examine how ICT resources at school affected the online education provision and teachers' working hours during the early stages of the pandemic using data on Japanese public elementary and junior high schools, the compulsory stage of schooling. Specifically, the aspects of online education we investigate are the length of the school closures, the provision of live online classes and live online communication with students' families. These three outcomes each describe a different aspect of school closures, yet collectively comprehensively capture the closure experience and the degree of its digitalization. While the first two outcomes are the natural focus of interest, we contribute to the literature by simultaneously investigating the channel schools used to communicate with students' families. Since we analyze online education provided to young children, we also consider it important to document how schools communicated relevant information and monitored students' learning and daily lives during this turbulent period.

Japan is also a country where teachers commonly work unusually long hours (OECD 2019), a problem that could be alleviated by better working conditions. In addition to facilitating students' learning, school ICT resources are expected to improve teachers' work efficiency. Most teachers did not switch to remote work during the closures, making school resources highly relevant. We, therefore, also investigate the impact of teachers' IT skills on their overtime during the school closures and the remainder of the affected school term.

In this study, we use a dataset combining several sets of government administrative data collected in 2020 from the entire Japanese public school system: a survey about schools' response to the COVID-19 pandemic, a survey about school ICT resources, and a survey about teachers' overtime work. The combined dataset includes information for both elementary and junior high schools at a municipality level. Public schools in Japan are operated by municipality-level local boards of education (BoE), which also allocate major resources across schools, including ICT, following strict legal procedures. Utilizing a BoE-level fixed effects model, we exploit the variation in schools' ICT resources within each BoE district to isolate the causal effect of the supply side. Due to the centralized nature of resource allocation, the variation in within-BoE's ICT resources is likely related to BoE's budget implementation process. We run a series of additional analyses to confirm the robustness of our results against several threats to causal interpretation. In addition to this empirical analysis, we conducted an online survey of public elementary and junior high school teachers to further our understanding of the results.

Our results show that better ICT equipment was more relevant than teachers' IT skills to the provision of online education, but neither had any effect on communication with students' families using live online tools. However, weak IT skills resulted in a higher percentage of teachers working extra hours, especially extreme overtime, in the months following schools' reopening. These results suggest that the impact of various ICT resources differs between students and teachers. A bottleneck to implementing online education in Japan was created by a shortage of ICT equipment, distributed at the BoE level, but was not contributed to by teachers' IT skills. However, the persistent overwork of teachers in Japan may be due to a lack of IT skills at the individual level. Therefore, the effect of ICT resources is multi-dimensional, and policymakers should be aware of the importance of matching appropriate policy tools to their targets. Improving the supply-side issues should be a priority in promoting access to online education and teacher welfare in Japan.

By presenting this research, we contribute to the growing literature covering pandemic-related school closures by simultaneously investigating the effect of school ICT resources on both the provision of online education and the choice of communication channel with students' families while also examining teachers' working conditions during and after school closures using Japanese data. Our results shed light on the effects of ICT resources on both students and teachers, allowing causal interpretation. To our knowledge, our paper is the first to comprehensively examine these topics.

2. Previous Literature

Whether ICT technology can improve teachers' teaching styles and, thereby, children's learning outcomes has been a central issue in educational policy in recent years. Many studies have empirically investigated how policies providing computers to students or incentivizing ICT equipment purchases have affected students' learning, yielding mixed results. Angrist and Lavy (2002) conducted the first study formally examining the effects of funding for educational computers in Israeli schools, suggesting that increased teachers' computer use had no or negative effect on children's learning. Goolsbee and Guryan (2006) analyzed the effect of Internet access investment subsidies in US public schools, concluding that students' test scores were unaffected while there was a significant increase in Internet access at treated schools. Machin et al. (2007) examined the effect of a change in policy rules allocating ICT funding to public schools, suggesting an improvement in English and science but not in math outcomes. Using a randomized trial, Barrow et al. (2009) found that assigning computer-aided instructions improved pre-algebra and algebra test scores. Bass (2021) examined the effect of eligibility for ICT vouchers for public schools in California, finding voucher use had a significant effect on student achievement. Most recently, Lomos et al. (2023), using 2018 data from secondary schools in Luxembourg, a country with ample school ICT resources yet a relatively low ICT use in classroom practice, reported that teachers' technological knowledge was an important predictor of ICT classroom use. These studies examined the effects of ICT facilities on learning *at school*; however, during the COVID-19 school closures, the effective use of school ICT was crucially important to providing instruction and supporting learning for students *at home*.

Early in the COVID-19 pandemic, Dincher and Wagner (2021) surveyed German elementary and secondary school teachers, finding that at-school ICT infrastructure did not predict the use of online teaching tools during school closures, while teachers' technical affinity did. The setting of this study is close to our paper; however, the initial level of ICT resources in Germany was vastly different from that in Japan, allowing Dincher and Wagner (2021) to focus specifically on teachers' attitudes. Furthermore, their paper does not attempt to separate the role of supply-side factors at school from the demand-side factors such as student and family characteristics. For evidence from a country with a lower initial level of ICT resources, Akah et al. (2022) examined the availability and use of a wide array of ICT resources during the COVID-19 pandemic at public universities in Nigeria. They concluded that academic staff with good IT skills used ICT in teaching to a higher degree than their lower-skilled counterparts. Collectively, Dincher and Wagner (2021), Akah et al. (2022), and Lomos et al. (2023) show that teachers' IT skills likely play an essential role in the impact of school ICT equipment on both at and out-of-school learning.

In a typical school environment, principals and teachers hold discretion over how the benefits of improved productivity provided by additional ICT resources are distributed. For example, teachers may react to additional ICT resources by reducing the time and effort spent preparing classes.[1] It is important to consider the distributional effects of a productivity increase when interpreting why previous studies on the effects of in-school ICT use produced mixed results. However, only a limited number of studies have directly assessed the impact of ICT resources on teachers' efforts at school, as pointed out in review articles by Bulman and Fairlie (2016) and Escueta et al. (2017).

Our paper contributes to two strains of literature: the provision of online school educational practices during COVID-19 school closures and the impact of ICT on teachers' workstyles. While these topics may seem unrelated, ultimately, it is teachers who facilitate school education. Comprehensively examining the supply side of school education presents a more accurate picture of the issues schools faced during the pandemic and can thus better inform policy makers.

3. Data and Setting

At the end of February 2020, shortly before spring break, Japanese schools were ordered to close to prevent the risk of community transmission of COVID-19. Schools reopened at the beginning of the new school year on April 1, 2020, and closed again after a partial state of emergency declaration on April 7, 2020, and nationwide one on April 16, 2020. This state of emergency was lifted in waves from mid-May to late May 2020, prompting schools to reopen. This was the only period of pandemic-related mandated school closures in Japan, making it the period of our interest.

[1] Reducing teachers' work hours should not necessarily be viewed negatively. Japanese teachers' work the longest hours among developed countries (OECD, 2019). The stagnant use of ICT at public schools resulting in unappealing working conditions may thus have created a difficulty in recruiting high-quality teachers. To the best of our knowledge, no previous research exists on the determinants of teachers' overtime in Japan. The research on teachers' working hours outside Japan typically focuses on absenteeism instead of overtime (Duflo et al., 2012; Nunoo et al., 2023). However, research shows that overtime is a source of mental distress for Japanese teachers (Bannai et al., 2015; Matsushita and Yamamura, 2022), making this topic relevant also outside of the topic of school closures.

During the closures, the Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT) asked BoEs nationwide to report closure details for the public schools in their jurisdiction, typically corresponding to a municipality. We use data collected through the Survey on Learning and Instruction during the COVID-19 Pandemic as of June 23, 2020. Appendix A Table A1 further introduces the surveys used in this study. The summary statistics of the closure-related variables are reported in Panel A of Table 1. The average length of school closures was 24-25 school days, live online classes were held in 8-9% of BoEs, and live online tools were used to communicate with students' families in 9-10% of BoEs. BoEs, on average, reported shorter closures and higher degrees of both remote practices for junior high schools. However, the survey asks a binary question about online education implementation; it does not inquire about its extent.

Regarding schools' ICT equipment, public school resources are customarily determined by the school founding body, the local BoE. BoEs are highly sensitive to an equal provision of resources and teacher assignments to each public school of the same level, elementary or junior high. However, the weights placed on school levels might differ across BoEs. MEXT annually collects information on public schools' ICT resources, specifically ICT equipment and teachers' IT skills, through the Survey on ICT in School Education, of which we use the 2019 school year iteration, collected as of March 1, 2020. While the survey results provide information about each public school separately, we aggregate the data on a BoE level to correspond with the pandemic response data.

Panel B of Table 1 contains the summary statistics of the ICT variables. The ICT survey inquiries about teachers' IT skills in four categories with four subcategories each, rating teachers on a scale of 'lacking,' 'mostly lacking,' 'mostly proficient,' and 'proficient'. The main categories are teachers' ability to use ICT for class preparation, grading, and administrative tasks, the ability to teach classes using ICT, the ability to teach students to use ICT, and the ability to instruct students in the knowledge and attitude needed to utilize information. The English translation of the skill-related questions is available in Appendix C. As the relationship between underlying skills and the MEXT-defined categories is unknown, we run a principal component analysis for proficient and lacking ranks over all 16 items and schools and then aggregate the data by school level to a BoE level. We then standardize these IT skill indices to have a mean of 0 and a standard deviation of 1. On average, junior high school teachers had better IT skills than their elementary school counterparts. Next, within-BoE ICT equipment is described by seven variables defined in Appendix A Table A2. Junior high schools were generally better equipped than elementary schools.

	ELEMENTARY SCHOOL		**JUNIOR HIGH SCHOOL**	
	Mean	**SD**	**Mean**	**SD**
Panel A: Remote education practices				
Days closed (min = 0, max = 61)	24.570	10.304	24.466	10.308
Live online class (dummy)	0.081	0.273	0.089	0.285
Live online communication with family (dummy)	0.094	0.292	0.103	0.304
Panel B: ICT resources				
IT skill index (Proficient)	-0.016	0.975	0.016	1.025
IT skill index (Lacking)	-0.200	0.757	0.200	1.160
High-speed Internet (ratio)	0.674	0.431	0.682	0.444
Wi-Fi (ratio)	0.836	0.336	0.835	0.348
Presentation device (E: min = 0, max = 3) (JH: min = 0, max = 5)	0.958	0.425	0.745	0.506
Digital instructions (ratio)	0.574	0.447	0.643	0.440
Digital textbook (ratio)	0.095	0.230	0.100	0.257
Management software (ratio)	0.765	0.392	0.771	0.399
Security policy (ratio)	0.657	0.431	0.662	0.449

Notes: N = 1,711 for Days closed and ICT resources, corresponding to 19,603 elementary and 9,113 junior high schools. N = 1,693 for online education outcomes.

Table 1: Summary statistics – remote education practices and ICT resources

Next, to examine how ICT resources affected teachers' workloads during school closures and in the months after reopening, we use data collected through the Survey on Reform of Working Conditions in Schools by the Local Boards of Education for 2019 and 2020. For each school term month, MEXT asks BoEs to report the percentage of school staff working 0 to 45, 45 to 80, 80 to 100, and over 100 overtime hours per month. We summarize these categories into two variables: the ratio of teachers working over 45 hours of overtime and over 80 hours of overtime, a threshold recognized by the Japanese government as dangerous to health. The survey does not distinguish between types of staff; however, as the staff is predominantly made up of teachers, we consider the data to be representative of teachers. As Japanese teachers are known to work long hours, we use the 2019 data to establish the baseline rate of overtime.

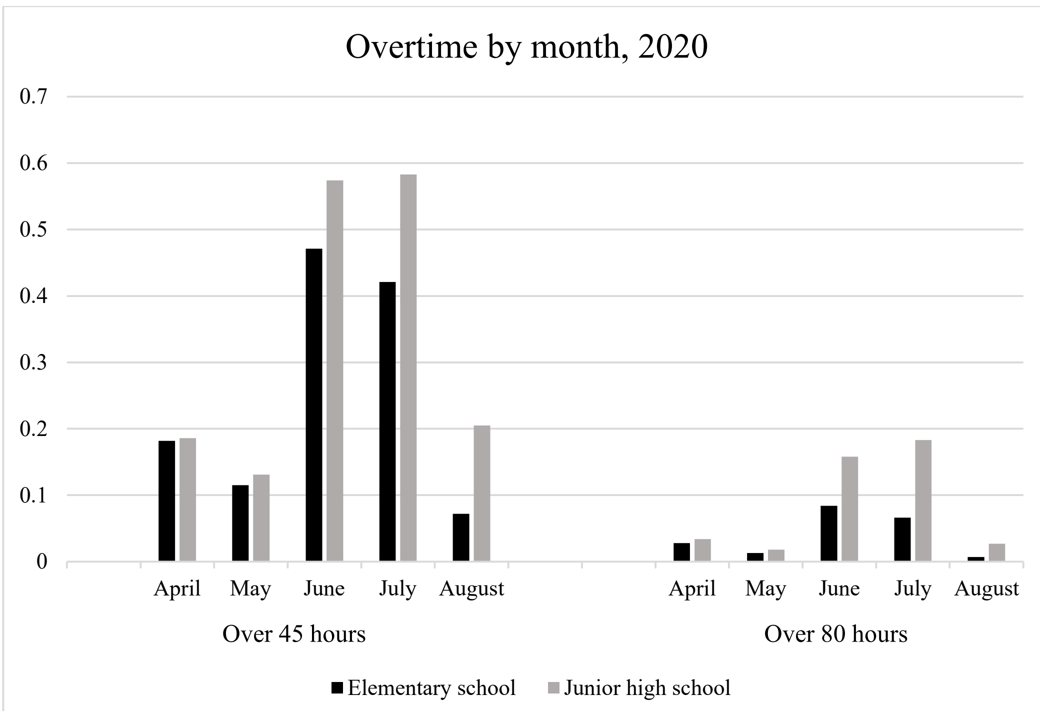

Figure 1: Overtime in 2020

Figure 1 shows the average overtime for 2020, with the full summary statistics in Appendix A Table A3. For all months and thresholds, junior high school teachers worked longer overtime than elementary school teachers. However, the actual amount of overtime hours, especially in 2020, was likely much higher, as the atypical situation likely prevented schools from keeping accurate records. Furthermore, the 2019 survey round, an initial one, suffered from non-respondence.[2] To use all the available 2020 data, we use a single imputation by simple average to fill in the missing 2019 data points.

4. Empirical Strategy

To answer the question of how ICT resources affected schools' pandemic response, we employ the following model as our baseline:

$$Remote\ education_{ij} = \alpha + \beta * ICT\ equipment_{ij} + \gamma * IT\ skills_{ij} + \delta_i + \mu D_j + \epsilon_{ij}, \quad (1)$$

where remote education stands for the length of school closures measured in school days and dummy variables indicating the implementation of live online classes and live online communication with families in BoE i at school level j. The term δ_i is a BoE i fixed effect, D_j is a school-level dummy variable and ϵ_{ij} represents the error term. Standard errors are two-way clustered at a BoE and prefectural level.

Next, we analyze the impact of ICT resources on teachers' overtime hours using the baseline model (2). In this analysis, we focus on teachers' skills only and utilize ICT equipment variables as controls as teachers operate under set conditions.

$$Overtime_{ijkt} = \alpha + \beta * ICT\ equipment_{ijt} + \gamma * IT\ skills_{ijt} + \rho * Overtime_{ijkt-1} + \sigma * Overtime\ imputed_{ijkt-1} + \delta_i + \mu D_j + \epsilon_{ijt}. \quad (2)$$

[2] Unlike ICT survey, this survey is not legally mandated by MEXT, leading to a larger percentage of missing data. The wording of the relevant question also assumes digital record keeping of working hours. We find that relatively smaller BoEs are more likely to be missing; however, whether it affects our estimates based on within-BoE difference is not clear.

The outcome variable $Overtime_{ijkt}$ is the ratio of teachers working over a specific number of overtime hours in BoE i, school level j, month k (April–August) of year t ($t = 2020$). To account for the seasonality in working conditions over a school year, we include the pre-pandemic overtime baseline $Overtime_{ijkt-1}$. As some values of $Overtime_{ijkt-1}$ are imputed, we also include a dummy variable $Overtime\ imputed_{ijkt-1}$ to account for the fact. The definition of the remainder of the terms in Equations (2) is identical to those in Equations (1). All fixed effects models were estimated using Stata 17 *xtreg* command.

For this fixed effect model to identify the causal effect of ICT resources on remote education, the strict exogeneity of explanatory variables conditional on the unobserved effect δ_i must be satisfied (Wooldridge, 2010; p. 304), namely, $E(\epsilon_{ij} \mid ICT\ equipment_{ij}, IT\ skills_{ij}, D_j, \delta_i) = 0$.

We faced three potential issues in the causal interpretation of the effect of ICT resources on remote education and teachers' overtime hours. First, schools in urban areas might be better equipped than schools in remote locations, both in terms of ICT equipment and more skilled teachers. Urban areas were also likely harder hit by the pandemic, possibly resulting in a higher demand for remote education and longer closures.[3] The BoE-level fixed effects model allows us to eliminate these BoE-specific factors common to both school levels. We also use a school-level dummy variable to control for level-specific effects, such as parents of older students likely having a higher income or higher demand for online education.

The second concern is the exogeneity of ICT resources to the pandemic. Because ICT resources were measured before school closures, we believe this concern is negligible. Basic BoE-level funding, including for personnel costs, is determined by a formula based

[3] A major limitation of COVID-19 pandemic-related research in Japan is the lack of detailed epidemiological data, as the Japanese government published the number of infections only on a prefectural level. While many municipalities disclosed their data, these are typically metropolitan areas covering only a portion of our sample. Using a BoE level fixed effect model allows us to work around this problem and thus analyze the full national sample.

on enrollment. BoEs can apply for additional funding for specific purposes, with MEXT deciding the amount and allocation. Given the unexpected nature of the pandemic and the rigidities of the public school system, it is unlikely that more proactive BoEs at the time of the survey equipped schools with ICT resources in expectation of online education, first widely implemented in Japan during the pandemic. The difference in BoE-school-type level ICT resources is thus likely caused by the varying pace of budget implementation.

The third issue is the level of data aggregation. Most of the data are aggregated at the BoE level, making BoE the unit of our analysis and possibly causing our estimates to suffer from attenuation bias due to classical measurement error.

The main underlying assumption of our analysis is that the BoE-level fixed effects control for within-BoE common characteristics affecting the provision of ICT resources to both school levels. The fixed effects approach thus allows us to isolate the supply side effects through the difference in ICT resources between elementary and junior high schools. This strategy is valid only if, first, there is a sufficient within-municipality variation, and second, this variation is not systematically correlated with unobserved factors potentially affecting variation in outcomes. While the national averages of some variables do not have a substantial variation, the within-municipality distribution makes the fixed effects strategy feasible. Next, to test the second condition, we use simple linear regression to examine whether the within-BoE differences in ICT resources are systematically associated with a set of municipality characteristics (population size and per capita income) and the number of COVID-19 cases in April 2020 in the corresponding prefecture. We do not confirm systematic correlation. We further examine the above concerns in the robustness check in Appendix B.

5. Results and Discussion

5.1 Remote Education

In Japan, where telework during the pandemic remained limited even for jobs easily performed remotely, teachers generally continued working from school during the school closures, making the analysis of at-school ICT resources relevant. Better school resources should generally contribute to children's learning, here measured by the provision of remote education, as schools cannot utilize a mode of remote education they are unable to provide. However, our analysis focuses on the differences in the designated variables between school levels on the BoE unit of observation. Thus, it does not determine which factors contributed to the pandemic response if the response or the ICT provision were identical. For completeness, the results from Equation (1) omitting the BoE fixed effect δ_i are presented in Appendix A Table A4.

	School days closed		**Live online class**		**Live online communication**	
	(1)	(2)	(3)	(4)	(5)	(6)
Elementary school	0.102**	0.0942**	-0.0110	-0.0118	-0.00982	-0.00869
	(0.0384)	(0.0399)	(0.00834)	(0.00862)	(0.00710)	(0.00735)
Teachers' IT Skill						
IT skill index - Proficient	0.00461		0.000248		0.00380	
	(0.0162)		(0.00494)		(0.00454)	
IT skill index - Lacking		-0.0188		-0.00219		0.00373
		(0.0311)		(0.00336)		(0.00440)
School ICT Equipment						
High-speed internet	-0.179*	-0.175	-0.0205	-0.0202	-0.00964	-0.0102
	(0.106)	(0.106)	(0.0250)	(0.0249)	(0.0295)	(0.0291)
Wi-Fi	-0.0427	-0.0422	0.0294*	0.0295*	0.0277	0.0276
	(0.0801)	(0.0795)	(0.0161)	(0.0160)	(0.0169)	(0.0171)
Presentation device	0.0133	0.0112	0.0209**	0.0206**	0.00623	0.00739
	(0.0410)	(0.0403)	(0.00954)	(0.00898)	(0.00951)	(0.00908)
Digital instructions	0.00673	0.00469	0.0312*	0.0310*	0.00549	0.00579
	(0.109)	(0.110)	(0.0155)	(0.0155)	(0.0136)	(0.0137)
Digital textbook	0.105	0.104	-0.0220	-0.0220	-0.0185	-0.0192
	(0.182)	(0.182)	(0.0252)	(0.0252)	(0.0215)	(0.0214)
Management software	0.0889	0.0848	-0.0102	-0.0106	-0.0170	-0.0162
	(0.0595)	(0.0605)	(0.0328)	(0.0330)	(0.0335)	(0.0341)
Security policy	-0.0814	-0.0810	-0.0117	-0.0117	0.0349	0.0358
	(0.102)	(0.101)	(0.0302)	(0.0304)	(0.0303)	(0.0307)
N	3,422	3,422	3,386	3,386	3,386	3,386
R^2	0.007	0.007	0.008	0.008	0.005	0.005

Notes: Estimation results from linear fixed effect model at BoE level. Robust standard errors clustered at BoE and prefecture level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table 2: Effect of ICT resources on remote education

Results from Equation (1) are displayed in Table 2. As seen in columns (1) and (2), we do not confirm any consistent link between schools' ICT resources and the length of school closures. As schools were ordered to close, differences in school closure length likely occurred toward the end. The positive and significant estimate of the elementary school dummy suggests that other considerations were made, possibly related to students' age.

Turning to the remaining remote education outcomes, we find no effect of teachers' IT skills on live online classes within BoEs; rather, physical ICT equipment seemed to have enabled schools to transition to online education. The results in Table 2 columns (3) and (4) show that within BoEs, a higher Wi-Fi provision led to a higher likelihood of live online classes; however, this effect is significant only at a 10% level and not significant for live online communication with parents in columns (5) and (6). Likewise, schools better equipped with presentation devices in regular classrooms were at a 5% significance level more likely to provide live online classes. Regarding teaching resources, the availability of commercial digital instructional materials for teachers increased the likelihood of live online classes and, as expected, had no effect on communication with parents. These results are consistent with how online education was typically depicted by the Japanese media: one teacher per empty classroom using a combination of digital presentation tools and a physical board in front of a camera.

Furthermore, we include interaction terms in Equation (1) to explore the impact of school-level specific IT skills and the complementarity of skills and equipment. First, as shown in Appendix A Table A5, we do not confirm any statistically significant effect of school level-specific IT skills on remote education outcomes. Next, we create two dummy variables each for ICT equipment confirmed relevant in Table 2 and IT skills, indicating a value above the sample mean and sample median for each school level. As per Appendix A Table A6, we do not confirm any significant effect of the interaction terms for either definition. This result suggests that the null effect of IT skills on the likelihood of online class implementation was not caused by school-level specific factors or by a shortage of ICT equipment, possibly preventing teachers from manifesting their IT skills.

To further our understanding of these results, we conducted a survey of teachers on a web platform operated by a large Japanese educational company. This platform[4] aims to provide its 73,000 freely registered users with lesson resources and opportunities to exchange ideas. We collected responses for one month in August 2022, receiving 424 answers from public elementary and junior high school teachers, accounting for 83% and 17% of the responses, respectively. The respondents were approximately equally distributed in age from 20s to 50s, and 60% were female.

The survey showed that 32% of the sampled teachers conducted online classes at least once during the pandemic, with over 90% broadcasting lessons from school. This result confirms that it is the school environment, not the teachers' home environment, that should be examined. Moreover, teachers with experience of online classes selected presentation devices as the main equipment used, while only a small percentage responded that they used PCs or tablets only. Furthermore, 25% of the sampled teachers considered presentation devices the key equipment to a future smooth implementation of online education, in addition to basic ICT infrastructure. As this survey was conducted over two years after the initial school closures, it likely overstates the extent of online education. However, these findings are in line with our results.

To summarize, during the early days of the COVID-19 pandemic, the differences in the pace at which schools reopened and in the provision of remote education within a BoE were likely unrelated to teachers' IT skills. Rather, ICT equipment essential for accessing the Internet in a socially distanced environment (Wi-Fi) and the tools necessary to hold an online class (digital materials for teachers and presentation devices to project them) seemed to be the factors that increased the supply of online classes. These results suggest, and a supplemental teachers' survey reinforces, that one obstacle to providing remote education during school closures was a lack of basic ICT infrastructure in schools. We also confirm that using live online tools for classes and communication with students' families is different in nature, with the latter being less equipment-dependent. Considering the presence of measurement error, these results are likely lower bounds of the actual effects; on the other hand, potential omitted variable bias would lead to our

[4] "Foresta Net" owned by Sprix, Ltd. https://foresta.education/

results being overestimated. Although the issue of the potential bias remains, we confirm the robustness of our results in the discussion in Appendix B. Our findings stand in contrast with Dincher and Wagner (2021) and Akah et al. (2022), who reported an association between teachers' IT skills and the increased use of online teaching and ICT tools in elementary and secondary schools in Germany and universities in Nigeria. While these studies, unlike the present one, did not provide a causal discussion, this difference also likely stems from the difference in their settings and an overall digitalization of education in the respective countries, highlighting the need for country-specific research and policies.

5.2 Overwork

The expected impact of ICT resources on teachers' work hours is not theoretically clear. Better ICT resources might enable teachers to perform their jobs, possibly increasing work hours, yet teachers with better IT skills might be able to prepare more efficiently, possibly reducing the time required. It should be noted that teachers with weak IT skills might also be deficient in other skills, lowering the relevance of IT skills specifically. Further, considering the data limitations, the following result likely underrepresent the actual situation.

The results using Equation (2) are displayed on a timeline in Figure 2 and fully in Appendix A Table A7. To arrive at the effect size, we divided the standardized coefficient estimates by the average ratio of teachers working over the specific threshold of overtime. Teacher IT skill proficiency had only a limited impact on overtime hours in terms of statistical significance. However, regardless of significance, proficiency decreased the percentage of teachers working overtime for nearly all months and thresholds except for August, a summer break month used for supplementary classes. Focusing on the significant effects, 1 standard deviation improvement in IT skill proficiency would result in a 14% decrease in teachers working over 80 overtime hours in May and a 4.7% decrease in July. Both months were transitional—from closures to in-person classes for May and to summer break with supplementary classes for July—suggesting a beneficial role of IT skills when adapting to a changing situation. However, the impact for April, the month with the most dramatic transition, is not statistically significant.

Conversely, the effect of the overall lack of IT skills was more pronounced after schools reopened, especially for extreme overtime. During school closures, in April, the lack of IT skills at a 10% level of significance increased the percentage of teachers working over 45 hours of overtime by 3.8% per standard deviation. For all months after reopening, the lack of IT skills had a statistically significant impact on extreme overtime. The effect size of 1 standard deviation deterioration in IT skills stood at 6.9% and 5.7% for June and July, respectively, and 27.8% for August. As the percentage of BoEs reporting implementation of live online classes during school closures stood at just 8–9%, working hours during closures in most BoEs would not have been spent preparing or providing online education, thus lowering the importance of IT skills. However, teachers in all BoEs were tasked with compensating for learning loss after reopening, making IT skills pertinent. Regardless of significance, lack of skills increased overtime for both thresholds and all months.

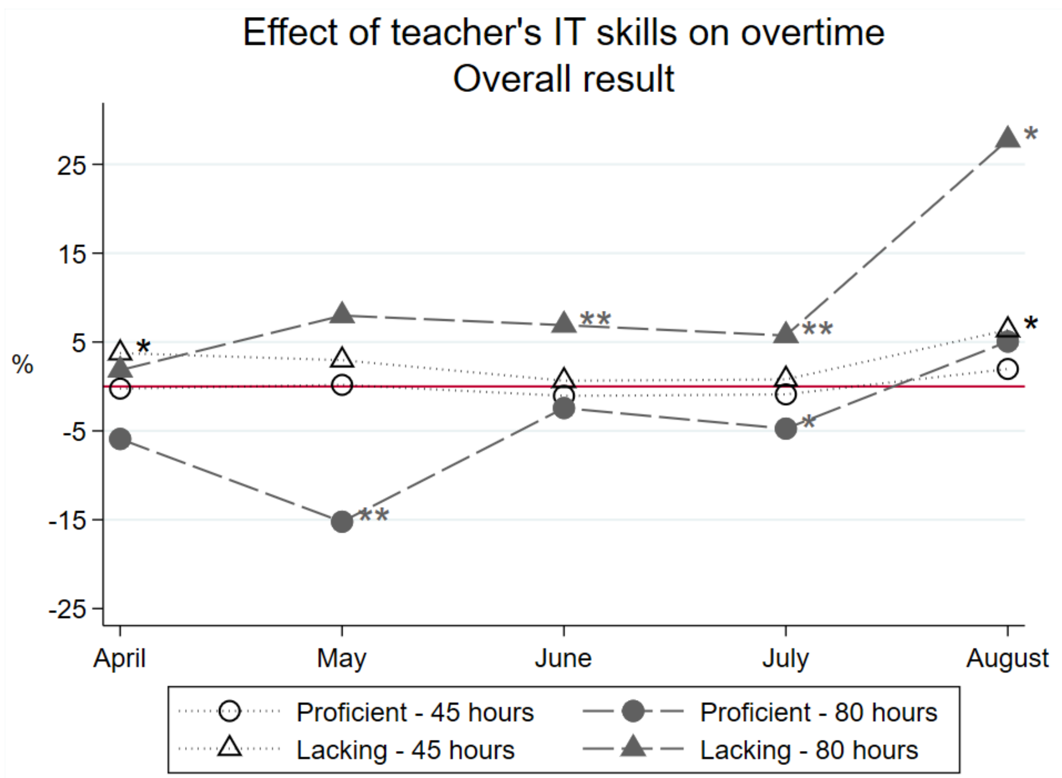

Figure 2: Effect of teachers' IT skills on overtime

To confirm whether these results are driven by IT skills, as opposed to other more general skills, we include teacher characteristics as additional controls in Equation (2). Specifically, we utilize information about teacher's educational attainment, average age, and male-to-female ratio from the School Teachers Survey of the 2019 school year as a proxy for general skills. The results in Appendix A Tables A8 to A10 show that our main results for either measure of IT skills are robust to controlling for teacher characteristics.

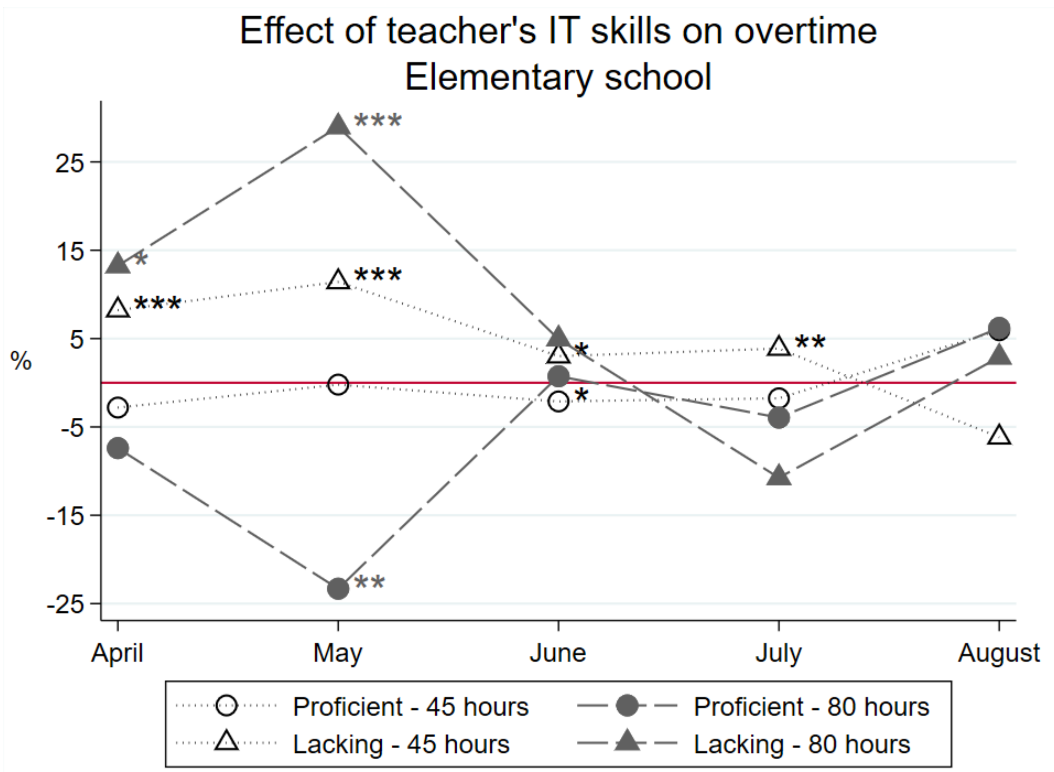

Figure 3: Effect of IT skills on overtime – elementary school

Next, to investigate the role of school level-specific IT skills, we add school-level and IT skills interaction terms to Equation (2). The results are presented in Figures 3 and 4. For elementary schools, IT skill proficiency in general reduced overtime at both thresholds, although the effects lack statistical significance. Conversely, a lack of IT skills significantly increased the percentage of teachers working over 45 extra hours in all months except August and those working over 80 extra hours in April and May, likely reflecting the difficulty of providing education to very young students during a pandemic.

For junior high schools, proficiency showed a similar trend, decreasing overtime but largely missing statistical significance. Compared to elementary schools, the significant detrimental effect of lack of IT skills materialized later, concentrating largely in the post-closure period. This result is consistent with the above interpretation that IT skills are more relevant when teachers actually teach.

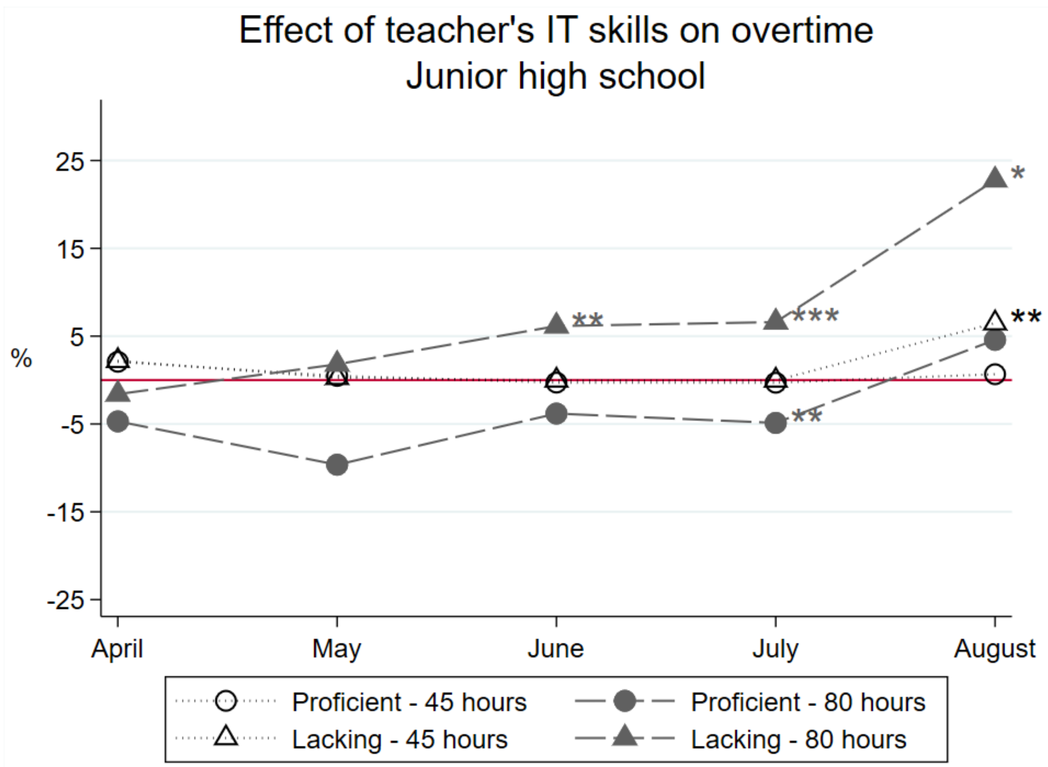

Figure 4: Effect of teachers' IT skills on overtime – junior high school

The teachers' survey provides anecdotal evidence as to how the lack of IT skills affected teachers' overtime. After schools reopened, in addition to conducting face-to-face classes, teachers were required to get accustomed to providing online education to prepare for possible subsequent closures. On top of that, teachers were required to set up devices newly provided to students and teach them how to use them, while following information security regulations. Teachers also cited insufficient BoE-provided IT training and a lack of IT support, limited to several days a month. Teachers, therefore, likely spend more time than usual in schools, especially after reopening, and the lack of IT skills might have severely affected their work hours.

Overall, our analysis suggests that overtime hours are associated with a lack of teachers' IT skills rather than proficiency. This result again demonstrates the importance of removing supply-side bottlenecks, and the supplemental teacher survey supports these findings. We also confirm a heterogeneous effect of IT skills based on school level and timing, indicating the complex nature of the pandemic response. These results are robust against a variety of robustness checks discussed in Appendix B. Nevertheless, it is important to stress that IT skills might be representative of a broader skill set, making a possible intervention difficult to design. Additionally, our results suffer from limitations due to data restrictions and the consequently adopted empirical strategy, and more research into the topic is needed to help alleviate the burden teachers in Japanese schools face.

6. Conclusion

The COVID-19 pandemic forced schools in many countries, including Japan, to close, turning to online education. Many studies analyzing school closures have focused on the demand side, as investigating the impact of the supply side on the provision of remote education is challenging due to the lack of appropriate data and the difficulty of separating the effects of the supply and demand sides.

The percentage of boards of education reporting the implementation of online classes during mandated school closures in their municipality at the start of the pandemic stood at less than 10% nationwide. The paper aims to empirically isolate the effect of school ICT resources on the provision of online education and teachers' work hours early in the pandemic, using nationwide administrative data and a BoE-level fixed effects model. The unique point of our analysis compared to the currently available literature is that we simultaneously investigate the effect of school ICT resources on both the provision of online education and the choice of communication channel with students' families while also examining teachers' working conditions during and after the closures. Under the assumptions discussed in Section 4, our results allow for a causal interpretation of the effect of ICT resources on both students and teachers.

We find no significant effect of teachers' IT skills, whether proficient or lacking, on the provision of live online classes. Rather, physical ICT equipment, such as Wi-Fi access, presentation devices in regular classrooms, and commercial digital instructional materials for teachers, seemed to have enabled schools to transition to online education, suggesting a technological bottleneck to implementing online education in Japan. We also confirm that live online communication with students' families is less equipment-dependent than online classes. Moreover, we find that teachers' extra work hours are associated with a lack of IT skills, while the beneficial effect of IT skill proficiency is weak. Additionally, we identify a heterogeneous effect of IT skills on teachers' overtime by school level and timing, likely reflecting the complex nature of the pandemic response. A supplemental survey of public elementary and junior high school teachers lends support to our results.

These results suggest that the impact of various ICT resources differs between students and teachers. The obstacle to implementing online education in Japan on the supply side was schools' inadequate basic ICT equipment, determined at a BoE level, not teachers' IT skills, developed at an individual level. However, the persistent overwork of teachers in Japan may result from a lack of IT skills. Therefore, the effect of ICT resources is multi-dimensional, which is an important point to consider when drafting a relevant policy.

However, our results have several limitations due to data availability and structure limiting our empirical strategy options. Although we used a wide array of variables describing schools' ICT resources and robustness checks, other unobserved school resources and teachers' skills may also be relevant in determining remote education practices and teachers' work hours. Likewise, it is possible that some measures that do not vary much between school levels may affect both outcomes, yet they are not considered in our analysis, given our analytical framework. It is also clear that our results are specific to the context of the public school system during the early stages of the COVID-19 pandemic in Japan, which lagged in ICT use for education. More research is needed to generalize our findings to a broader context of other societies and circumstances. However, as ICT is a convenient tool to ensure children's continued education in times of crisis in general, such as during conflicts or in case of natural disasters, we believe our results are informative beyond the context analyzed in this study.

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Declaration of interest

None.

Data accessibility statement

The data that support the findings of this study are available from the Japanese Ministry of Education, Culture, Sports, Science and Technology. Restrictions apply to the availability of these data, which were used under license for this study.

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Appendix A: Additional tables

	Survey	Conductor	Respondent	Date	Details
2018-19	Survey on ICT in School Education 2018 School Year (Heisei 30 Nendo Gakko ni okeru Kyoiku no Johoka ni kan suru Chosa)	MEXT	School (nationwide)	March 1, 2019	This survey is conducted as of March 1 every year by the Financial Support and Teaching Materials Division, MEXT. All public elementary, junior-high, senior-high, and special-needs schools are mandated to respond. BoEs enforce compliance.
2019-20	Survey on Reform of Working Conditions in Schools by the Local Boards of Education 2019 School Year (Reiwa Gannendo Kyoiku Iinkai ni okeru Gakko no Hatarakikata no tame no Torikumi Jokyo Chosa)	MEXT	BoE (nationwide)	July 1, 2019	This survey is conducted as of September 1 every year (July 1 for initial year) by the Financial Affairs Division, MEXT. BoEs report the work hours and conditions of teachers in the public elementary, junior-high, senior-high, and special-needs schools in their districts. Responding to this survey is not mandatory.
	School Teachers Survey 2019 School Year (Reiwa Gannendo Gakko Kyoin Tokei Chosa)	MEXT	School (school questionnaire nationwide, teacher questionnaire in selected schools)	October 1, 2019	This survey is conducted as of October 1 every year by the Analytical Research Planning Division, MEXT. All public elementary, junior-high, senior-high, and special-needs schools are mandated to respond to the school questionnaire, including the teacher questionnaire for randomly selected schools. BoEs enforce compliance.
	Survey on ICT in School Education 2019 School Year (Reiwa Gannendo Gakko ni okeru Kyoiku no Johoka ni kan suru Chosa)	MEXT	School (nationwide)	March 1, 2020	This survey is conducted as of March 1 every year by the Financial Support and Teaching Materials Division, MEXT. All public elementary, junior-high, senior-high, and special-needs schools are mandated to respond. BoEs enforce compliance.
2020-21	**MANDATED SCHOOL CLOSURES (April–May 2020)**				
	Survey on Learning and Instruction during the COVID-19 Pandemic (Shingata Korona Uirusu Kansensho no Eikyo wo Fumaeta Gakushu Shido nado ni kan suru Jokyo Chosa)	MEXT	BOE (nationwide)	June 23, 2020	This survey was conducted by the School Curriculum Division, MEXT. BoEs reported pandemic response for all public elementary, junior-high, senior-high, and special-needs schools in their districts. Responding to this survey was not mandatory.
	Survey on Reform of Working Conditions in Schools by the Local Boards of Education 2020 School Year (Reiwa 2 Nendo Kyoiku Iinkai ni okeru Gakko no Hatarakikata no tame no Torikumi Jokyo Chosa)	MEXT	BOE (nationwide)	September 1, 2020	This survey is conducted as of September 1 every year by the Financial Affairs Division, MEXT. BoEs report the work hours and conditions of teachers in public elementary, junior-high, senior-high, and special-needs schools in their districts. Responding to this survey is not mandatory.

Table A1: Survey overview

Variable	Definition
High-speed Internet	Ratio of schools in BoE equipped with the Internet faster than 100 Mbps
Wi-Fi	Ratio of schools in BoE equipped with Wi-Fi
Presentation device	Average number of presentation devices (projector, digital whiteboard, digital TV) per normal classroom in BoE
Digital instructions	Ratio of schools in BoE equipped with commercial digital instructional materials for teachers (e.g., lesson presentation slides)
Digital textbook	Ratio of schools in BoE equipped with commercial digital materials for students
Management software	Ratio of schools in BoE using software to store and manage information
Security policy	Ratio of schools in BoE with a set policy regarding storing and handling information

Table A2: ICT equipment variables definition

Month	N	ELEMENTARY SCHOOL Mean	ELEMENTARY SCHOOL Imputed %	JUNIOR HIGH SCHOOL Mean	JUNIOR HIGH SCHOOL Imputed %
		> 45 HOURS			
Year 2020					
April	1,220	0.182	-	0.186	-
May	1,227	0.115	-	0.131	-
June	1,280	0.471	-	0.574	-
July	1,268	0.421	-	0.583	-
August	1,203	0.072	-	0.205	-
Year 2019					
April	1,220	0.546	35.4	0.644	35.4
May	1,227	0.545	34.6	0.642	34.6
June	1,280	0.558	31.6	0.650	31.6
July	1,268	0.390	23.4	0.531	23.5
August	1,203	0.041	25.9	0.109	24.9
		> 80 HOURS			
Year 2020					
April	1,220	0.028	-	0.034	-
May	1,227	0.013	-	0.018	-
June	1,280	0.084	-	0.158	-
July	1,268	0.066	-	0.183	-
August	1,203	0.007	-	0.027	-
Year 2019					
April	1,220	0.149	35.4	0.255	35.4
May	1,227	0.138	34.6	0.250	34.6
June	1,280	0.158	31.6	0.259	31.6
July	1,268	0.076	23.4	0.166	23.5
August	1,203	0.009	25.9	0.026	24.9

Table A3: Summary statistics – ratio of staff working over 45 or 80 overtime hours a month

	School days closed		Live online class		Live online communication	
	(1)	(2)	(3)	(4)	(5)	(6)
Elementary school	0.258	0.808***	-0.0124	-0.0183**	-0.0100	-0.0153*
	(0.220)	(0.298)	(0.00857)	(0.00796)	(0.00847)	(0.00869)
Teachers' IT Skill						
IT skill index – Proficient	-0.389		0.0107*		0.0155***	
	(0.453)		(0.00565)		(0.00566)	
IT skill index - Lacking		1.444***		-0.0136***		-0.0104**
		(0.393)		(0.00364)		(0.00492)
School ICT Equipment						
High-speed internet	3.051***	2.856***	0.0228**	0.0241**	0.0263*	0.0267*
	(0.823)	(0.790)	(0.0112)	(0.0113)	(0.0138)	(0.0143)
Wi-Fi	-0.580	-0.289	0.0235	0.0223	0.0152	0.0157
	(1.127)	(1.072)	(0.0168)	(0.0172)	(0.0197)	(0.0202)
Presentation device	-0.528	-0.320	0.0307*	0.0310*	0.0206	0.0231
	(0.983)	(0.967)	(0.0167)	(0.0170)	(0.0188)	(0.0191)
Digital instructions	0.349	0.430	0.0215	0.0203	0.0304*	0.0290*
	(0.844)	(0.837)	(0.0149)	(0.0148)	(0.0152)	(0.0155)
Digital textbook	-1.791	-1.844	0.0431*	0.0437*	0.0441*	0.0447*
	(1.204)	(1.190)	(0.0242)	(0.0241)	(0.0256)	(0.0254)
Management software	3.317***	3.249***	0.00217	0.00129	0.000285	-0.00191
	(1.146)	(1.095)	(0.0180)	(0.0179)	(0.0176)	(0.0172)
Security policy	-1.360**	-1.229**	0.0129	0.0122	0.0226*	0.0223*
	(0.607)	(0.576)	(0.0127)	(0.0126)	(0.0120)	(0.0123)
N	3,422	3,422	3,386	3,386	3,386	3,386
R^2	0.045	0.062	0.013	0.013	0.013	0.012

Notes: Estimation results from linear regression. Robust standard errors clustered at BoE and prefecture level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table A4: Effect of ICT resources on remote education – linear regression

	School days closed	Live online class	Live online communication
Proficient			
Elementary school	-0.0191	-0.00590	-0.00506
	(0.0301)	(0.00866)	(0.00467)
Junior high school	0.0246	0.00536	0.0112
	(0.0326)	(0.00548)	(0.00684)
Lacking			
Elementary school	0.0450	0.00539	0.0105
	(0.0375)	(0.00739)	(0.00701)
Junior high school	-0.0367	-0.00438	0.00177
	(0.0351)	(0.00372)	(0.00449)

Notes: Coefficient estimates from Equation (1) with added school-level dummy and IT skill indices interaction term. The coefficients are produced using Stata command "lincom" for the respective linear combination of the baseline IT skill effect and the school-level specific effect. Robust standard errors clustered at BoE and prefecture level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table A5: Effect of teachers' IT skills on remote education – linear fixed effects model with interactions

	Live online class													
	Skill continuous ICT continuous		Skill continuous ICT mean		Skill mean ICT continuous		Skill mean ICT mean		Skill continuous ICT median		Skill median ICT continuous		Skill median ICT median	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Teachers' IT Skill														
IT skill index - Proficient	-0.00176		0.00162		0.00349		0.00481		0.00237		0.00388		0.0134	
	(0.0140)		(0.00994)		(0.0345)		(0.0231)		(0.00901)		(0.0323)		(0.0190)	
IT skill index - Lacking		0.00146		0.00348		-0.00878		-0.00354		-0.00130		-0.00369		-0.0137
		(0.00945)		(0.00841)		(0.0228)		(0.0198)		(0.00818)		(0.0240)		(0.0185)
School ICT Equipment														
Wi-Fi	0.0292*	0.0301*	0.0137	0.0143	0.0303	0.0258	0.0133	0.0109	0.0157	0.0165	0.0344	0.0319*	0.0225	0.0187
	(0.0169)	(0.0162)	(0.0179)	(0.0175)	(0.0201)	(0.0177)	(0.0214)	(0.0192)	(0.0157)	(0.0154)	(0.0216)	(0.0170)	(0.0198)	(0.0167)
Wi-Fi * IT skill index -	0.00256		0.00142		-0.00340		-0.000432		-0.000321		-0.00938		-0.0139	
Proficient	(0.00750)	-0.000537	(0.00698)		(0.0179)		(0.0206)		(0.00700)		(0.0152)		(0.0165)	
Wi-Fi * IT skill index -		(0.00584)		-0.00350		0.00816		0.00695		-0.000459		-0.00269		-0.00246
Lacking				(0.00945)		(0.0162)		(0.0194)		(0.00704)		(0.0128)		(0.0156)
Presentation device	0.0211**	0.0207**	0.00459	0.00491	0.0223	0.0162*	0.00924	0.000490	-0.000795	-0.000797	0.0144	0.0178*	-0.00746	-0.0125
	(0.00994)	(0.00918)	(0.00917)	(0.00907)	(0.0176)	(0.00870)	(0.0143)	(0.00898)	(0.0102)	(0.0101)	(0.0191)	(0.00904)	(0.0155)	(0.0131)
Presentation device * IT skill	-0.00468		-0.00619		-0.00377		-0.0110		-0.00403		0.0128		0.0133	
index - Proficient	(0.0110)		(0.00831)		(0.0285)		(0.0186)		(0.00746)		(0.0250)		(0.0176)	
Presentation device * IT skill		0.00306		0.00246		0.0117		0.0109		0.00854		0.00538		0.0240
index - Lacking		(0.00737)		(0.00817)		(0.0161)		(0.0158)		(0.00730)		(0.0191)		(0.0202)
Digital instructions	0.0311*	0.0309*	0.0167	0.0165	0.0322**	0.0376*	0.0185	0.0243	0.0234*	0.0229*	0.0382**	0.0415*	0.0336**	0.0332*
	(0.0164)	(0.0161)	(0.0121)	(0.0118)	(0.0144)	(0.0206)	(0.0113)	(0.0159)	(0.0131)	(0.0130)	(0.0150)	(0.0216)	(0.0150)	(0.0176)
Digital instructions * IT skill	0.00768		0.00342		-0.00265		-0.00396		0.00288				-0.0197	
index - Proficient	(0.0115)		(0.0110)		(0.0229)		(0.0192)		(0.0114)				(0.0212)	
Digital instructions * IT skill		-0.00948		-0.0125		-0.0165		-0.0184		-0.00969	-0.0152	-0.0235		-0.0234
index - Lacking		(0.00781)		(0.00949)		(0.0181)		(0.0164)		(0.00689)	(0.0235)	(0.0198)		(0.0184)
N	3,386	3,386	3,386	3,386	3,386	3,386	3,386	3,386	3,386	3,386	3,386	3,386	3,386	3,386
R^2	0.009	0.009	0.005	0.005	0.008	0.009	0.005	0.005	0.005	0.006	0.009	0.011	0.006	0.009

Notes: Coefficient estimates from Equation (1) with added ICT equipment variables and IT skill indices interaction terms. Robust standard errors clustered at BoE and prefecture level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table A6: Effect of ICT resources on remote education – linear fixed effects model with interactions

PANEL A	April 2020		May 2020		June 2020		July 2020		August 2020	
Overtime threshold	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Teacher ratio	0.184	0.031	0.123	0.015	0.522	0.121	0.502	0.125	0.138	0.017
IT skill index	-0.000446	-0.00184	0.000215	-0.00233**	-0.00552	-0.00294	-0.00447	-0.00592*	0.00272	0.000855
Proficient	(0.00421)	(0.00185)	(0.00451)	(0.00105)	(0.00512)	(0.00385)	(0.00549)	(0.00344)	(0.00448)	(0.00147)
Effect size	-0.24%	-5.91%	0.17%	-15.23%	-1.06%	-2.43%	-0.89%	-4.75%	1.96%	5.05%
N	2,440	2,440	2,454	2,454	2,560	2,560	2,536	2,536	2,406	2,406
R^2	0.035	0.017	0.059	0.030	0.332	0.320	0.534	0.525	0.462	0.154

PANEL B	April 2020		May 2020		June 2020		July 2020		August 2020	
Overtime threshold	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Teacher ratio	0.184	0.031	0.123	0.015	0.522	0.121	0.502	0.125	0.138	0.017
IT skill index	0.00691*	0.000571	0.00364	0.00122	0.00337	0.00834**	0.00401	0.00714**	0.00880*	0.00470*
Lacking	(0.00370)	(0.00138)	(0.00338)	(0.000928)	(0.00443)	(0.00355)	(0.00456)	(0.00281)	(0.00472)	(0.00260)
Effect size	3.75%	1.83%	2.96%	7.97%	0.65%	6.90%	0.80%	5.73%	6.36%	27.75%
N	2,440	2,440	2,454	2,454	2,560	2,560	2,536	2,536	2,406	2,406
R^2	0.038	0.016	0.061	0.027	0.332	0.324	0.534	0.526	0.464	0.162

Notes: Estimation results from linear fixed effect model at BoE level. Robust standard errors clustered at BoE and prefecture level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table A7: Effect of teachers' IT skills on overtime – linear fixed effects model

PANEL A: Teacher's characteristics controlled

	April 2020		May 2020		June 2020		July 2020		August 2020	
Overtime threshold	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Teacher ratio	0.183	0.034	0.133	0.018	0.528	0.127	0.510	0.132	0.136	0.018
IT skill index Proficient	-0.00535	-0.000381	0.00426	0.000421	-0.00639	-0.00558	-0.00672	-0.00932	-0.00685	-0.00129
	(0.00617)	(0.00231)	(0.00801)	(0.00190)	(0.0128)	(0.00843)	(0.0125)	(0.00837)	(0.00997)	(0.00212)
Graduate school ratio	0.00407	0.0279	0.0383	0.0251**	-0.0848	-0.0492	-0.0320	-0.0106	0.0378	-0.00985
	(0.0359)	(0.0202)	(0.0610)	(0.0114)	(0.0819)	(0.0489)	(0.0714)	(0.0374)	(0.0621)	(0.0151)
2-year college ratio	-0.00165	0.0166	-0.0407	0.00998	0.00909	-0.0224	-0.0149	-0.0442	0.0733	0.00389
	(0.0369)	(0.0158)	(0.0525)	(0.0160)	(0.0533)	(0.0347)	(0.0476)	(0.0351)	(0.0638)	(0.0133)
IT skill: Effect size	-2.92%	-1.12%	3.20%	2.34%	-1.21%	-4.39%	-1.32%	-7.06%	-5.04%	-7.17%
N	1,222	1,222	1,225	1,225	1,284	1,284	1,262	1,262	1,190	1,190
R^2	0.070	0.067	0.094	0.109	0.454	0.466	0.660	0.650	0.545	0.265

PANEL B: Teacher's characteristics not controlled

	April 2020		May 2020		June 2020		July 2020		August 2020	
Overtime threshold	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Teacher ratio	0.183	0.034	0.133	0.018	0.528	0.127	0.510	0.132	0.136	0.018
IT skill index Proficient	-0.00532	-0.000256	0.00448	0.000625	-0.00701	-0.00601	-0.00699	-0.00947	-0.00640	-0.00137
	(0.00612)	(0.00227)	(0.00779)	(0.00189)	(0.0134)	(0.00858)	(0.0127)	(0.00838)	(0.0101)	(0.00215)
IT skill: Effect size	-2.91%	-0.75%	3.37%	3.47%	-1.33%	-4.73%	-1.37%	-7.17%	-4.71%	-7.61%
N	1,222	1,222	1,225	1,225	1,284	1,284	1,262	1,262	1,190	1,190
R^2	0.070	0.058	0.091	0.100	0.451	0.464	0.659	0.649	0.542	0.264

Notes: Estimation results from linear fixed effect model at BoE level. Panel A displays the results with educational controls included. Panel B displays the results from model in Equation (2) in the sample with educational controls available. Robust standard errors clustered at BoE and prefecture level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table A8: Effect of teachers' IT skills on overtime in sample with teachers' educational controls available – IT skill proficiency

PANEL A: Teacher's characteristics controlled

	April 2020		May 2020		June 2020		July 2020		August 2020	
Overtime threshold	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Teacher ratio	0.183	0.034	0.133	0.018	0.528	0.127	0.510	0.132	0.136	0.018
IT skill index Lacking	0.00136	4.07e-05	-0.0134	-0.00274	-0.00131	0.0121	-0.000446	0.0107*	0.0146	0.00322
	(0.00715)	(0.00246)	(0.0114)	(0.00171)	(0.00936)	(0.00779)	(0.00841)	(0.00560)	(0.0122)	(0.00300)
Graduate school ratio	0.00374	0.0278	0.0322	0.0237**	-0.0871	-0.0438	-0.0339	-0.00760	0.0460	-0.00783
	(0.0355)	(0.0199)	(0.0614)	(0.0115)	(0.0816)	(0.0483)	(0.0707)	(0.0375)	(0.0618)	(0.0148)
2-year college ratio	-0.00161	0.0166	-0.0341	0.0113	0.00909	-0.0278	-0.0152	-0.0488	0.0682	0.00267
	(0.0374)	(0.0157)	(0.0512)	(0.0158)	(0.0553)	(0.0360)	(0.0492)	(0.0327)	(0.0615)	(0.0126)
IT skill: Effect size	0.74%	0.12%	-10.08%	-15.22%	-0.25%	9.53%	-0.09%	8.11%	10.74%	17.89%
N	1,222	1,222	1,225	1,225	1,284	1,284	1,262	1,262	1,190	1,190
R^2	0.069	0.067	0.100	0.114	0.453	0.471	0.659	0.651	0.548	0.269

PANEL B: Teacher's characteristics not controlled

	April 2020		May 2020		June 2020		July 2020		August 2020	
Overtime threshold	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Teacher ratio	0.183	0.034	0.133	0.018	0.528	0.127	0.510	0.132	0.136	0.018
IT skill index Lacking	0.00130	-0.000174	-0.0141	-0.00287*	-0.000164	0.0124	-0.000193	0.0103*	0.0145	0.00336
	(0.00698)	(0.00243)	(0.0109)	(0.00159)	(0.00984)	(0.00783)	(0.00858)	(0.00558)	(0.0123)	(0.00302)
IT skill: Effect size	0.71%	-0.51%	-10.60%	-15.94%	-0.03%	9.76%	-0.04%	7.80%	10.66%	18.67%
N	1,222	1,222	1,225	1,225	1,284	1,284	1,262	1,262	1,190	1,190
R^2	0.069	0.058	0.099	0.105	0.450	0.469	0.659	0.650	0.545	0.268

Notes: Estimation results from linear fixed effect model at BoE level. Panel A displays the results with educational controls included. Panel B displays the results from model in Equation (2) in the sample with educational controls available. Robust standard errors clustered at BoE and prefecture level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table A9: Effect of teachers' IT skills on overtime in sample with teachers' educational controls available – lacking IT skills

PANEL A: Teacher's characteristics controlled	April 2020		May 2020		June 2020		July 2020		August 2020	
Overtime threshold	45	80	45	80	45	80	45	80	45	80
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Teacher ratio	0.185	0.031	0.123	0.015	0.523	0.121	0.502	0.124	0.138	0.017
IT skill index Proficient	-0.000781	-0.00191	-0.000503	-0.00251**	-0.00708	-0.00410	-0.00695	-0.00744**	0.00129	0.000847
	(0.00403)	(0.00190)	(0.00429)	(0.00108)	(0.00504)	(0.00374)	(0.00523)	(0.00314)	(0.00410)	(0.00148)
Male-to-female ratio	-0.112**	-0.0599**	-0.104**	-0.0319*	0.000149	0.0451	0.0291	0.0601	0.113**	0.00757
	(0.0422)	(0.0225)	(0.0466)	(0.0185)	(0.0575)	(0.0554)	(0.0678)	(0.0604)	(0.0492)	(0.0144)
Average teacher age	-0.00347*	-0.00135	-0.00566***	-0.00158**	-0.00866***	-0.00566***	-0.0113***	-0.00599***	-0.00600**	-2.38e-05
	(0.00184)	(0.000834)	(0.00201)	(0.000637)	(0.00245)	(0.00200)	(0.00176)	(0.00221)	(0.00242)	(0.000777)
IT skill: Effect size	-0.42%	-6.16%	-0.41%	-16.73%	-1.35%	-3.39%	-1.38%	-6.00%	0.93%	4.98%
N	2,404	2,404	2,418	2,418	2,524	2,524	2,500	2,500	2,372	2,372
R^2	0.048	0.030	0.088	0.052	0.351	0.335	0.554	0.533	0.470	0.151

PANEL B: Teacher's characteristics not controlled	April 2020		May 2020		June 2020		July 2020		August 2020	
Overtime threshold	45	80	45	80	45	80	45	80	45	80
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Teacher ratio	0.185	0.031	0.123	0.015	0.523	0.121	0.502	0.124	0.138	0.017
IT skill index Lacking	0.00810**	0.00105	0.00535*	0.00167*	0.00569	0.00983***	0.00703*	0.00882***	0.0101**	0.00477*
	(0.00365)	(0.00147)	(0.00301)	(0.000845)	(0.00453)	(0.00356)	(0.00402)	(0.00281)	(0.00448)	(0.00254)
Male-to-female ratio	-0.115***	-0.0609**	-0.106**	-0.0334*	-0.00528	0.0400	0.0233	0.0537	0.111**	0.00681
	(0.0426)	(0.0229)	(0.0466)	(0.0188)	(0.0584)	(0.0565)	(0.0691)	(0.0616)	(0.0502)	(0.0147)
Average teacher age	-0.00374*	-0.00135	-0.00583***	-0.00159**	-0.00873***	-0.00593***	-0.0114***	-0.00615***	-0.00634**	-0.000193
	(0.00187)	(0.000842)	(0.00199)	(0.000625)	(0.00241)	(0.00193)	(0.00174)	(0.00217)	(0.00239)	(0.000730)
IT skill: Effect size	4.38%	3.39%	4.35%	11.13%	1.09%	8.12%	1.40%	7.11%	7.32%	28.06%
N	2,404	2,404	2,418	2,418	2,524	2,524	2,500	2,500	2,372	2,372
R^2	0.053	0.030	0.090	0.050	0.351	0.340	0.554	0.534	0.473	0.160

Notes: Estimation results from linear fixed effect model at BoE level in the sample with teacher average teacher age and male-to-female ratio variables available. Robust standard errors clustered at BoE and prefecture level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table A10: Effect of teachers' IT skills on overtime with male-to-female ratio and average teacher age controls

Appendix B: Robustness check

To address the potential concerns raised in Section 4 regarding the validity of our approach, we run a series of checks to investigate the robustness of our results. This follow-up analysis, which also uses the fixed effects framework, systematically confirms our results.

To start with, we investigate the validity of the BoE-level fixed effects approach in addressing unobserved common local factors that simultaneously influence both ICT resources and the schools' pandemic response. We adopt two approaches—splitting the full sample into subsamples of interest and adding interaction terms.

First, our approach assumes that the within-BoE difference in outcomes is uncorrelated with unobserved BoE-specific factors once the differences in schools' ICT resources are controlled for. However, this assumption might not hold universally. One possible case is the difference between urban and rural areas. The demand for ICT resources in junior high schools might be higher in urban areas as opposed to rural areas, possibly due to competition with private junior high schools that are typically located in urban areas. Private schools are generally better equipped than public schools, possibly skewing the local demand for ICT resources or remote education at public schools in favor of one school level. To address this concern, we divide the sample based on an urban or rural location and the presence of private junior high schools. First, an urban location indicator is assigned to BoEs in municipalities designated as cities and city districts, and rural location is assigned to the remaining BoEs (towns, villages, and unions of villages), thus roughly splitting the sample in half. Second, although the BoEs that house at least one private junior high school, representing less than 20% of the sample, are typically urban, we consider this analysis separately. For remote education outcomes, the results displayed in Table B1 and Table B2 closely resemble the main ones for all subsamples. The only exception is the negative impact of presentation devices in regular classrooms on live online communication with parents in the subsample of BoEs with private junior high schools. However, considering the sample size and the remainder of the results, we do not regard it as a concern. The results of the overtime analysis are presented in Tables B3, B4, B5, and B6. We find that while the effects of both proficiency and lack of IT skills largely retain their signs in all subsamples, the effect of lack of skills was generally more pronounced in rural areas and correspondingly in areas without private junior high schools.

Second, in all our models, we include a school-level dummy variable in addition to a BoE fixed effect. However, as the state of emergency was declared and ended on a per-prefecture basis, the local response might not be identical across prefectures. If prefectures placed varying weights on school levels in terms of prioritizing online education, the omitted heterogeneity in between-school-level differences across prefectures would be correlated with the outcomes, violating our assumption on the common school-level dummy. To filter this potential effect out, we include school-level and prefecture dummy interaction terms in Equations (1) and (2) for remote education and overtime analysis, respectively. Adding these interaction terms does not qualitatively alter the results of either of these analyses, as presented in Table B7 and Table B8, supporting our assumption about school-level dummy. Although it is not possible to prove the validity of the BoE-level fixed effects approach completely, a series of robustness checks above suggest that the potential concern with our approach largely does not seem to affect our main results.

Next, we focus on the potential endogeneity of ICT resources. To assess the robustness of the link of ICT equipment to remote education outcomes, we replaced the 2020 ICT equipment variables in Equation (1) with their 2019 levels.[8] Possible endogeneity of the 2020 level would likely create a positive bias in the effect of ICT equipment on the provision of remote education. BoEs with a higher unobserved forecasting ability would have in expectation of the educational disruption equipped schools better by the survey date of March 1, 2020. The results presented in Table B9 for the available variables are consistent with the main results, supporting our interpretation that the challenge to implementing online education in Japan was insufficient physical ICT equipment. Although neither the model specification nor the within-BoE difference is identical to the

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[8] The 2018 school year wave of the Survey on ICT in School Education collected in March 2019 contains most of the ICT variables utilized in the main analysis, except for the prevalence of Wi-Fi and digital textbooks for students.

2020 ICT equipment level analysis, we do not confirm a systematic positive bias. The effect of significant variables in the original analysis is larger for the 2019 level of presentation devices, retaining statistical significance, and is smaller for digital instructional materials for teachers, which is now not significant.

Regarding the analysis of overtime hours, we use the 2019 level of ICT equipment as controls in Equation (2), obtaining essentially identical results to the main ones, as displayed in Table B10. After controlling for 2019 ICT equipment, we find that the effect size of IT skills is, on average, 0.35% points smaller than that for 2020 ICT equipment controls, having unchanged direction and one marginal result losing significance. These results suggest that the concern about the possible endogeneity of 2020 ICT equipment is unfounded.

Additionally, for overtime analysis, we looked further into the past, setting 2019 overtime as the outcome and 2018 overtime as the baseline in Equation (2). Schools with, under normal circumstances, chronically overworked teachers could have better ICT resources to help with the workload. This could possibly create a counteractive correlation in the effects of interest. If work hours during the pandemic were subject to a large unexpected exogenous demand shock with the school ICT resources fixed, we expect the effect of teachers' IT skills on overtime to be generally larger than that in normal times. The 2018 overtime data were collected retrospectively in the 2019 wave of the relevant survey; therefore, they cover a shorter period (April–June), and a larger percentage is missing. In this restricted analysis, as presented in Table B11, the 2019 school year IT skill index had a minimal impact on overtime hours, controlling for the 2019 school year level of ICT equipment. IT skill proficiency lowered the percentage of teachers working extreme overtime in April 2019, and the lack of skills had no effect. These results indicate that the 2019 estimated effect size is slightly larger than that of 2020 only for April and IT skill proficiency. Moreover, for 9 out of the 12 coefficient estimates, both levels of IT skills changed the ratio of teachers working overtime by less than 1%. These results lend support to our assumption of the exogeneity of the 2020 level of ICT resources in the main analysis. Furthermore, they strengthen our interpretation of the main findings that IT skill proficiency is advantageous in transitional months (school year beginning), and a lack of IT skills worsens teachers' working conditions in times of crisis.

Finally, one of the major limitations of our analysis is the use of data aggregated at a BoE level. As our implicit decision model is based at school and teacher levels, using BoE-level data likely leads to a typical classical measurement error bias. To gauge the extent of this bias in our main results, we run the analysis using Equations (1) and (2) on a subsample of BoEs containing a single junior high school. The results in Table B12 and B13 are similar to the full sample results. Focusing on the coefficients statistically significant for the full sample, we find that in the restricted sample, the effect sizes are generally larger by factors of 1.1–2. While the characteristics of small BoEs might also be reflected in the effect size differences, we confirm the presence of measurement error bias in the main results. This source of bias may contribute to our results being underestimated. It is also important to note that not finding a statistically significant effect of an ICT resource might not mean that this resource is ineffective in 'absolute' terms, as our results provide guidance on 'relative' importance in the presence of measurement error bias. Our results suggest that among the broad range of ICT resources, teachers' IT skills are relatively less important than ICT equipment in enabling remote education provision, while the former is important for reducing overtime.

In summary, we address the potential concerns related to our analysis and the validity of our results by conducting a series of robustness checks utilizing several approaches. We confirm that our main results are robust.

	URBAN						RURAL					
	School days closed		**Live online class**		**Live online communication**		**School days closed**		**Live online class**		**Live online communication**	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Elementary school	0.0505	0.0272	0.00289	0.00580	0.00371	0.00812	0.128**	0.123**	-0.0220**	-0.0233**	-0.0197**	-0.0192**
	(0.0315)	(0.0358)	(0.00828)	(0.00959)	(0.00762)	(0.00904)	(0.0583)	(0.0582)	(0.0101)	(0.0101)	(0.00842)	(0.00832)
Teachers' IT Skill												
IT skill index - Proficient	0.0320		-0.00913		-0.0110		0.000910		0.00229		0.00674	
	(0.0518)		(0.0125)		(0.0121)		(0.0248)		(0.00471)		(0.00480)	
IT skill index - Lacking		-0.0493		0.00565		0.00883		-0.0164		-0.00340		0.00322
		(0.0576)		(0.00685)		(0.00836)		(0.0396)		(0.00381)		(0.00460)
School ICT Equipment												
High-speed internet	-0.363	-0.384	0.00311	0.00620	-0.00603	-0.00147	-0.174	-0.170	-0.0229	-0.0220	-0.00993	-0.0103
	(0.319)	(0.322)	(0.0419)	(0.0418)	(0.0428)	(0.0433)	(0.126)	(0.126)	(0.0277)	(0.0276)	(0.0325)	(0.0318)
Wi-Fi	-0.245*	-0.266*	0.0302	0.0319	0.0613*	0.0644*	0.0194	0.0228	0.0309	0.0315	0.0179	0.0168
	(0.145)	(0.143)	(0.0359)	(0.0379)	(0.0312)	(0.0329)	(0.0868)	(0.0859)	(0.0192)	(0.0191)	(0.0220)	(0.0223)
Presentation device	0.0992	0.0925	0.0182	0.0191	-0.0118	-0.0105	-0.0212	-0.0235	0.0216**	0.0216**	0.0128	0.0148
	(0.0894)	(0.0900)	(0.0156)	(0.0151)	(0.0167)	(0.0166)	(0.0496)	(0.0481)	(0.0107)	(0.0103)	(0.0108)	(0.0104)
Digital instructions	-0.247	-0.260	0.0666***	0.0678***	0.0174	0.0195	0.130	0.130	0.0161	0.0158	-0.000583	-0.000795
	(0.229)	(0.243)	(0.0243)	(0.0242)	(0.0362)	(0.0359)	(0.116)	(0.116)	(0.0164)	(0.0164)	(0.0106)	(0.0112)
Digital textbook	-0.0423	-0.0402	-0.0585	-0.0579	0.00480	0.00524	0.123	0.122	-0.0162	-0.0166	-0.0196	-0.0207
	(0.285)	(0.291)	(0.0613)	(0.0612)	(0.0722)	(0.0722)	(0.202)	(0.201)	(0.0273)	(0.0271)	(0.0219)	(0.0217)
Management software	0.334	0.329	0.00698	0.00810	0.00917	0.0104	0.0710	0.0671	-0.0152	-0.0160	-0.0212	-0.0203
	(0.230)	(0.227)	(0.100)	(0.0991)	(0.108)	(0.107)	(0.0631)	(0.0646)	(0.0406)	(0.0411)	(0.0384)	(0.0391)
Security policy	0.0783	0.0928	0.0318	0.0283	0.0538	0.0494	-0.112	-0.112	-0.0150	-0.0147	0.0342	0.0358
	(0.210)	(0.210)	(0.0337)	(0.0327)	(0.0386)	(0.0383)	(0.109)	(0.107)	(0.0326)	(0.0330)	(0.0331)	(0.0340)
N	1,628	1,628	1,614	1,614	1,614	1,614	1,794	1,794	1,772	1,772	1,772	1,772
R^2	0.014	0.014	0.012	0.011	0.005	0.005	0.008	0.009	0.014	0.014	0.013	0.012

Notes: Estimation results from fixed effect model at BoE level. Robust standard errors clustered at BoE and prefecture level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table B1: Effect of ICT resources on remote education – urban and rural subsamples

	PRIVATE JUNIOR HIGH SCHOOL						NO PRIVATE JUNIOR HIGH SCHOOL					
	School days closed		**Live online class**		**Live online communication**		**School days closed**		**Live online class**		**Live online communication**	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
Elementary school	0.0643	0.0431	0.00225	0.00118	0.0102	0.00826	0.108**	0.101**	-0.0129	-0.0137	-0.0132	-0.0119
	(0.0472)	(0.0480)	(0.0110)	(0.0109)	(0.00958)	(0.00924)	(0.0416)	(0.0424)	(0.00998)	(0.0102)	(0.00820)	(0.00846)
Teachers' IT Skill												
IT skill index - Proficient	0.0986		-0.0122		-0.00560		-0.000107		0.000721		0.00411	
	(0.0603)		(0.0160)		(0.0213)		(0.0176)		(0.00538)		(0.00457)	
IT skill index - Lacking		-0.0331		-0.00314		-0.00421		-0.0206		-0.00198		0.00468
		(0.0442)		(0.00528)		(0.0115)		(0.0331)		(0.00351)		(0.00462)
School ICT Equipment												
High-speed internet	-0.927	-0.902	0.0103	0.00198	0.0575	0.0517	-0.164	-0.160	-0.0219	-0.0215	-0.0122	-0.0130
	(0.975)	(0.987)	(0.0254)	(0.0256)	(0.0766)	(0.0760)	(0.114)	(0.115)	(0.0257)	(0.0255)	(0.0304)	(0.0298)
Wi-Fi	-0.170	-0.171	0.0191	0.0195	0.0485	0.0488	-0.0327	-0.0322	0.0310*	0.0311*	0.0265	0.0262
	(0.201)	(0.202)	(0.0235)	(0.0246)	(0.0299)	(0.0302)	(0.0843)	(0.0838)	(0.0173)	(0.0172)	(0.0188)	(0.0189)
Presentation device	-0.194	-0.190	-0.00711	-0.00853	-0.0344**	-0.0354**	0.0355	0.0324	0.0250**	0.0248**	0.0121	0.0135
	(0.178)	(0.182)	(0.0182)	(0.0190)	(0.0161)	(0.0163)	(0.0471)	(0.0458)	(0.0105)	(0.00987)	(0.0103)	(0.00971)
Digital instructions	-0.191	-0.185	0.0981*	0.0959*	0.0482	0.0466	0.0339	0.0320	0.0235	0.0233	0.00100	0.00130
	(0.206)	(0.209)	(0.0524)	(0.0524)	(0.0846)	(0.0844)	(0.107)	(0.108)	(0.0154)	(0.0154)	(0.0131)	(0.0132)
Digital textbook	-0.380	-0.439	-0.00144	0.00548	0.0119	0.0149	0.128	0.128	-0.0253	-0.0254	-0.0214	-0.0221
	(0.527)	(0.541)	(0.0536)	(0.0525)	(0.0777)	(0.0814)	(0.190)	(0.189)	(0.0264)	(0.0263)	(0.0219)	(0.0217)
Management software	0.179	0.163	-0.0362	-0.0372	-0.112	-0.113	0.0879	0.0834	-0.0104	-0.0108	-0.0130	-0.0120
	(0.225)	(0.201)	(0.0256)	(0.0245)	(0.0953)	(0.0952)	(0.0622)	(0.0631)	(0.0343)	(0.0346)	(0.0339)	(0.0345)
Security policy	0.878	0.950	0.0378	0.0382	0.0593	0.0631	-0.0944	-0.0954	-0.0123	-0.0122	0.0344	0.0355
	(0.854)	(0.862)	(0.0490)	(0.0524)	(0.0793)	(0.0923)	(0.103)	(0.103)	(0.0309)	(0.0311)	(0.0310)	(0.0313)
N	588	588	588	588	588	588	2,834	2,834	2,798	2,798	2,798	2,798
R^2	0.028	0.026	0.026	0.024	0.012	0.012	0.008	0.008	0.009	0.009	0.007	0.007

Notes: Estimation results from fixed effect model at BoE level. Robust standard errors clustered at BoE and prefecture level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table B2: Effect of ICT resources on remote education – subsamples with and without private junior high school

	URBAN									
PANEL A	**April 2020**		**May 2020**		**June 2020**		**July 2020**		**August 2020**	
Overtime threshold	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Teacher ratio	0.181	0.038	0.122	0.020	0.542	0.135	0.536	0.145	0.154	0.024
IT skill index	-0.00201	-0.000847	-0.00209	-0.00301**	-0.00750	-0.00639	-0.00920	-0.000485	0.000823	0.00203
Proficient	(0.00575)	(0.00159)	(0.00548)	(0.00136)	(0.0117)	(0.00685)	(0.0109)	(0.00767)	(0.00783)	(0.00253)
Effect size	-1.11%	-2.25%	-1.72%	-14.74%	-1.38%	-4.73%	-1.72%	-0.33%	0.54%	8.37%
N	1,314	1,314	1,318	1,318	1,376	1,376	1,352	1,352	1,270	1,270
R^2	0.066	0.043	0.076	0.044	0.419	0.424	0.672	0.652	0.571	0.251
PANEL B	**April 2020**		**May 2020**		**June 2020**		**July 2020**		**August 2020**	
Overtime threshold	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Teacher ratio	0.181	0.038	0.122	0.020	0.542	0.135	0.536	0.145	0.154	0.024
IT skill index	0.00320	0.000432	-0.00504	1.52e-05	0.00476	0.00684	0.00598	0.00756	0.00720	0.00343
Lacking	(0.00409)	(0.00212)	(0.00565)	(0.00114)	(0.00706)	(0.00550)	(0.00787)	(0.00641)	(0.0105)	(0.00460)
Effect size	1.77%	1.15%	-4.14%	0.07%	0.88%	5.06%	1.12%	5.20%	4.68%	14.15%
N	1,314	1,314	1,318	1,318	1,376	1,376	1,352	1,352	1,270	1,270
R^2	0.067	0.043	0.078	0.037	0.419	0.424	0.672	0.653	0.572	0.253

Notes: Estimation results from linear fixed effect model at BoE level. Robust standard errors clustered at BoE and prefecture level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table B3: Effect of teachers' IT skills on overtime – urban subsample

RURAL										
PANEL A	**April 2020**		**May 2020**		**June 2020**		**July 2020**		**August 2020**	
Overtime threshold	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Teacher ratio	0.197	0.029	0.133	0.012	0.503	0.107	0.466	0.102	0.131	0.014
IT skill index	3.01e-05	-0.00203	0.00146	-0.00194	-0.00441	-0.00162	-0.00326	-0.00693*	0.00272	0.000507
Proficient	(0.00545)	(0.00232)	(0.00598)	(0.00121)	(0.00515)	(0.00376)	(0.00614)	(0.00345)	(0.00528)	(0.00149)
Effect size	0.02%	-6.92%	1.09%	-15.67%	-0.88%	-1.52%	-0.70%	-6.77%	2.08%	3.53%
N	1,126	1,126	1,136	1,136	1,184	1,184	1,184	1,184	1,136	1,136
R^2	0.032	0.030	0.068	0.035	0.287	0.247	0.437	0.399	0.383	0.123
PANEL B	**April 2020**		**May 2020**		**June 2020**		**July 2020**		**August 2020**	
Overtime threshold	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Teacher ratio	0.197	0.029	0.133	0.012	0.503	0.107	0.466	0.102	0.131	0.014
IT skill index	0.00734*	0.000544	0.00665*	0.00164	0.00335	0.00850**	0.00397	0.00637*	0.00877	0.00486*
Lacking	(0.00423)	(0.00167)	(0.00357)	(0.00107)	(0.00551)	(0.00381)	(0.00563)	(0.00375)	(0.00550)	(0.00268)
Effect size	3.73%	1.85%	4.99%	13.25%	0.67%	7.97%	0.85%	6.22%	6.70%	33.83%
N	1,126	1,126	1,136	1,136	1,184	1,184	1,184	1,184	1,136	1,136
R^2	0.037	0.029	0.072	0.035	0.286	0.253	0.437	0.399	0.386	0.134

Notes: Estimation results from linear fixed effect model at BoE level. Robust standard errors clustered at BoE and prefecture level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table B4: Effect of teachers' IT skills on overtime – rural subsample

PRIVATE JUNIOR HIGH SCHOOL										
PANEL A	**April 2020**		**May 2020**		**June 2020**		**July 2020**		**August 2020**	
Overtime threshold	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Teacher ratio	0.149	0.045	0.097	0.028	0.514	0.136	0.522	0.155	0.138	0.034
IT skill index	-0.00733	-0.00207	-0.00265	-0.00444	-0.0239	-0.00461	-0.0181	-0.00119	-0.00764	-0.000110
Proficient	(0.00784)	(0.00419)	(0.00713)	(0.00311)	(0.0160)	(0.0116)	(0.0174)	(0.0114)	(0.0111)	(0.00256)
Effect size	-4.91%	-4.58%	-2.72%	-16.14%	-4.65%	-3.38%	-3.47%	-0.77%	-5.54%	-0.32%
N	482	482	484	484	502	502	492	492	468	468
R^2	0.056	0.168	0.050	0.043	0.439	0.445	0.694	0.724	0.605	0.300

PANEL B	**April 2020**		**May 2020**		**June 2020**		**July 2020**		**August 2020**	
Overtime threshold	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Teacher ratio	0.149	0.045	0.097	0.028	0.514	0.136	0.522	0.155	0.138	0.034
IT skill index	0.00239	-0.00124	-0.00757	-0.00180	0.0123	0.0195**	0.00305	0.0249***	0.0218	0.00822
Lacking	(0.00622)	(0.00260)	(0.00833)	(0.00171)	(0.0116)	(0.00907)	(0.0138)	(0.00824)	(0.0134)	(0.00508)
Effect size	1.60%	-2.74%	-7.78%	-6.54%	2.39%	14.31%	0.58%	16.07%	15.81%	24.05%
N	482	482	484	484	502	502	492	492	468	468
R^2	0.052	0.167	0.053	0.031	0.433	0.464	0.691	0.736	0.612	0.319

Notes: Estimation results from linear fixed effect model at BoE level. Robust standard errors clustered at BoE and prefecture level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table B5: Effect of teachers' IT skills on overtime – subsample with private junior high school

NO PRIVATE JUNIOR HIGH SCHOOL										
PANEL A	**April 2020**		**May 2020**		**June 2020**		**July 2020**		**August 2020**	
Overtime threshold	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Teacher ratio	0.198	0.031	0.134	0.014	0.526	0.118	0.499	0.118	0.144	0.016
IT skill index	0.000257	-0.00177	0.000444	-0.00217**	-0.00402	-0.00304	-0.00292	-0.00599	0.00348	0.000833
Proficient	(0.00443)	(0.00187)	(0.00473)	(0.00106)	(0.00493)	(0.00387)	(0.00551)	(0.00363)	(0.00465)	(0.00158)
Effect size	0.13%	-5.73%	0.33%	-15.51%	-0.76%	-2.57%	-0.59%	-5.09%	2.41%	5.22%
N	1,958	1,958	1,970	1,970	2,058	2,058	2,044	2,044	1,938	1,938
R^2	0.038	0.019	0.065	0.033	0.331	0.316	0.517	0.494	0.442	0.145

PANEL B	**April 2020**		**May 2020**		**June 2020**		**July 2020**		**August 2020**	
Overtime threshold	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Teacher ratio	0.198	0.031	0.134	0.014	0.526	0.118	0.499	0.118	0.144	0.016
IT skill index	0.00744*	0.000865	0.00497	0.00159	0.00330	0.00786**	0.00471	0.00547*	0.00764	0.00438*
Lacking	(0.00403)	(0.00148)	(0.00337)	(0.000973)	(0.00463)	(0.00348)	(0.00472)	(0.00302)	(0.00462)	(0.00260)
Effect size	3.77%	2.81%	3.72%	11.36%	0.63%	6.67%	0.95%	4.66%	5.33%	0.0474***
N	1,958	1,958	1,970	1,970	2,058	2,058	2,044	2,044	1,938	1,938
R^2	0.042	0.019	0.067	0.032	0.331	0.320	0.517	0.494	0.444	0.153

Notes: Estimation results from linear fixed effect model at BoE level. Robust standard errors clustered at BoE and prefecture level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table B6: Effect of teachers' IT skills on overtime – subsample without private junior high schools

SCHOOL LEVEL AND PREFECTURE DUMMIES INTERACTION TERMS						
	School days closed		**Live online class**		**Live online communication**	
	(1)	(2)	(3)	(4)	(5)	(6)
Elementary school	0.232***	0.232***	-0.0404***	-0.0404***	-0.0357***	-0.0358***
	(0.0154)	(0.0154)	(0.00278)	(0.00277)	(0.00317)	(0.00314)
Teachers' IT Skill						
IT skill index - Proficient	-0.000862		-5.33e-05		0.00374	
	(0.0171)		(0.00492)		(0.00473)	
IT skill index - Lacking		-0.0117		-0.00233		0.00405
		(0.0282)		(0.00359)		(0.00490)
School ICT Equipment						
High-speed internet	-0.197*	-0.195*	-0.0262	-0.0259	-0.0116	-0.0121
	(0.105)	(0.104)	(0.0241)	(0.0242)	(0.0293)	(0.0290)
Wi-Fi	-0.0425	-0.0419	0.0338*	0.0339*	0.0369**	0.0364**
	(0.0944)	(0.0942)	(0.0174)	(0.0174)	(0.0178)	(0.0180)
Presentation device	0.00736	0.00583	0.0167*	0.0164*	0.00641	0.00747
	(0.0437)	(0.0440)	(0.00982)	(0.00943)	(0.00911)	(0.00884)
Digital instructions	0.0424	0.0400	0.0293*	0.0288*	0.00384	0.00465
	(0.103)	(0.104)	(0.0147)	(0.0147)	(0.0135)	(0.0137)
Digital textbook	0.0811	0.0813	-0.0219	-0.0219	-0.0184	-0.0191
	(0.183)	(0.183)	(0.0243)	(0.0243)	(0.0205)	(0.0204)
Management software	0.0420	0.0404	-0.00853	-0.00884	-0.0135	-0.0129
	(0.0808)	(0.0818)	(0.0317)	(0.0320)	(0.0319)	(0.0324)
Security policy	-0.0676	-0.0683	-0.0136	-0.0137	0.0319	0.0329
	(0.0965)	(0.0961)	(0.0307)	(0.0310)	(0.0311)	(0.0316)
N	3,422	3,422	3,386	3,386	3,386	3,386
R^2	0.038	0.038	0.039	0.039	0.035	0.035

Notes: Estimation results from fixed effect model at BoE level. School level dummy and prefecture dummies interaction terms included (results omitted). Robust standard errors clustered at BoE and prefecture level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table B7: Effect of ICT resources on remote education – school level and prefecture dummies interaction terms

SCHOOL LEVEL AND PREFECTURE DUMMIES INTERACTION TERMS										
PANEL A	**April 2020**		**May 2020**		**June 2020**		**July 2020**		**August 2020**	
Overtime threshold	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Teacher ratio	0.184	0.031	0.123	0.015	0.522	0.121	0.502	0.125	0.138	0.017
IT skill index	-0.000752	-0.00179	-8.74e-05	-0.00218**	-0.00422	-0.00188	-0.00492	-0.00670*	0.00206	0.000858
Proficient	(0.00434)	(0.00189)	(0.00454)	(0.000974)	(0.00503)	(0.00344)	(0.00560)	(0.00340)	(0.00415)	(0.00144)
Effect size	-0.41%	-5.75%	-0.07%	-14.25%	-0.81%	-1.56%	-0.98%	-5.38%	1.49%	5.07%
N	2,440	2,440	2,454	2,454	2,560	2,560	2,536	2,536	2,406	2,406
R^2	0.145	0.076	0.295	0.122	0.418	0.419	0.592	0.593	0.583	0.305
PANEL B	**April 2020**		**May 2020**		**June 2020**		**July 2020**		**August 2020**	
Overtime threshold	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Teacher ratio	0.184	0.031	0.123	0.015	0.522	0.121	0.502	0.125	0.138	0.017
IT skill index	0.00820**	0.000658	0.00622**	0.00135*	0.00326	0.00725**	0.00493	0.00606**	0.00236	0.00237
Lacking	(0.00342)	(0.00114)	(0.00283)	(0.000787)	(0.00403)	(0.00309)	(0.00389)	(0.00287)	(0.00410)	(0.00239)
Effect size	4.46%	2.11%	5.06%	8.82%	0.62%	6.00%	0.98%	4.86%	1.70%	13.99%
N	2,440	2,440	2,454	2,454	2,560	2,560	2,536	2,536	2,406	2,406
R^2	0.150	0.076	0.298	0.120	0.418	0.421	0.592	0.593	0.583	0.307

Notes: Estimation results from linear fixed effect model at BoE level. School level dummy and prefecture dummies interaction terms included (results omitted). Robust standard errors clustered at BoE and prefecture level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table B8: Effect of teachers' IT skills on overtime – school level and prefecture dummies interaction terms

2019 ICT EQUIPMENT						
	School days closed		Live online class		Live online communication	
	(1)	(2)	(3)	(4)	(5)	(6)
Elementary school	0.0920**	0.0842*	-0.0133	-0.0143	-0.0112	-0.00988
	(0.0424)	(0.0437)	(0.00922)	(0.00951)	(0.00744)	(0.00771)
Teachers' IT Skill (2020)						
IT skill index - Proficient	0.00311		0.000717		0.00398	
	(0.0165)		(0.00500)		(0.00460)	
IT skill index - Lacking		-0.0200		-0.00247		0.00404
		(0.0313)		(0.00333)		(0.00442)
School ICT Equipment (2019)						
High-speed internet	-0.139	-0.137	-0.00436	-0.00411	0.0163	0.0164
	(0.0980)	(0.0995)	(0.0251)	(0.0251)	(0.0287)	(0.0287)
Presentation device	0.0466	0.0446	0.0249**	0.0246**	0.0104	0.0110
	(0.0562)	(0.0553)	(0.0119)	(0.0117)	(0.0100)	(0.00981)
Digital instructions	-0.0131	-0.0160	0.0140	0.0137	-0.000786	-0.000166
	(0.0865)	(0.0878)	(0.0142)	(0.0143)	(0.0108)	(0.0108)
Management software	0.0643	0.0644	0.0118	0.0118	-0.0176	-0.0179
	(0.0810)	(0.0788)	(0.0331)	(0.0329)	(0.0314)	(0.0314)
Security policy	0.0200	0.0151	-0.0140	-0.0145	0.0238	0.0255
	(0.0583)	(0.0583)	(0.0250)	(0.0252)	(0.0253)	(0.0262)
N	3,418	3,418	3,384	3,384	3,384	3,384
R^2	0.006	0.006	0.006	0.006	0.004	0.004

Notes: Estimation results based on fixed effect model at BoE level. Robust standard errors clustered at BoE and prefecture level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table B9: Effect of ICT resources on remote education – 2019 ICT equipment

	2019 ICT EQUIPMENT									
PANEL A	**April 2020**		**May 2020**		**June 2020**		**July 2020**		**August 2020**	
Overtime threshold	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Teacher ratio	0.184	0.031	0.123	0.015	0.522	0.121	0.502	0.125	0.138	0.017
IT skill index Proficient	-0.000399	-0.00170	0.000455	-0.00222**	-0.00557	-0.00220	-0.00420	-0.00546	0.00231	0.000603
	(0.00408)	(0.00182)	(0.00437)	(0.00107)	(0.00518)	(0.00381)	(0.00548)	(0.00362)	(0.00451)	(0.00150)
Effect size	-0.22%	-5.46%	0.37%	-14.50%	-1.07%	-1.82%	-0.84%	-4.38%	1.67%	3.56%
N	2,438	2,438	2,452	2,452	2,558	2,558	2,534	2,534	2,404	2,404
R^2	0.030	0.013	0.054	0.022	0.332	0.317	0.534	0.525	0.458	0.148
PANEL B	**April 2020**		**May 2020**		**June 2020**		**July 2020**		**August 2020**	
Overtime threshold	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Teacher ratio	0.184	0.031	0.123	0.015	0.522	0.121	0.502	0.125	0.138	0.017
IT skill index Lacking	0.00725*	0.000511	0.00361	0.00116	0.00360	0.00813**	0.00376	0.00743**	0.00874*	0.00495*
	(0.00370)	(0.00133)	(0.00337)	(0.000940)	(0.00438)	(0.00360)	(0.00463)	(0.00293)	(0.00479)	(0.00260)
Effect size	3.94%	1.64%	2.93%	7.57%	0.69%	6.74%	0.75%	5.97%	6.32%	29.23%
N	2,438	2,438	2,452	2,452	2,558	2,558	2,534	2,534	2,404	2,404
R^2	0.034	0.012	0.056	0.020	0.332	0.321	0.534	0.526	0.461	0.158

Notes: Estimation results from linear fixed effect model at BoE level. Robust standard errors clustered at BoE and prefecture level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table B10: Effect of teachers' IT skills on overtime – 2019 ICT equipment

2019 OVERTIME						
PANEL A	**April 2019**		**May 2019**		**June 2019**	
Overtime threshold	**45**	**80**	**45**	**80**	**45**	**80**
	(1)	(2)	(3)	(4)	(5)	(6)
Teacher ratio	0.595	0.202	0.593	0.194	0.601	0.205
IT skill index Proficient	-0.00222	-0.0134*	-0.00276	-0.0113	-0.000920	-0.00170
	(0.00806)	(0.00746)	(0.00723)	(0.00766)	(0.00839)	(0.00662)
Effect size	-0.37%	-6.63%	-0.47%	-5.82%	-0.15%	-0.83%
N	1,742	1,742	1,776	1,776	1,914	1,914
R^2	0.584	0.624	0.601	0.623	0.558	0.562
PANEL B	**April 2019**		**May 2019**		**June 2019**	
Overtime threshold	**45**	**80**	**45**	**80**	**45**	**80**
	(11)	(12)	(13)	(14)	(15)	(16)
Teacher ratio	0.595	0.202	0.593	0.194	0.601	0.205
IT skill index Lacking	-0.00107	-0.000907	0.00571	0.00313	-0.00151	-0.00169
	(0.00701)	(0.00639)	(0.00644)	(0.00499)	(0.00735)	(0.00605)
Effect size	-0.18%	-0.45%	0.96%	1.61%	-0.25%	-0.83%
N	1,742	1,742	1,776	1,776	1,914	1,914
R^2	0.584	0.622	0.602	0.622	0.558	0.562

Notes: Estimation results from linear fixed effect model at BoE level. Robust standard errors clustered at BoE and prefecture level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table B11: Effect of teachers' IT skills on overtime – 2019 overtime hours

ONE JUNIOR HIGH SCHOOL						
	School days closed		Live online class		Live online communication	
	(1)	(2)	(3)	(4)	(5)	(6)
Elementary school	0.208***	0.200***	-0.0146	-0.0141	-0.0199*	-0.0171
	(0.0645)	(0.0580)	(0.0126)	(0.0130)	(0.0102)	(0.0108)
Teachers' IT Skill						
IT skill index - Proficient	-0.00259		0.00126		0.000166	
	(0.0269)		(0.00454)		(0.00585)	
IT skill index - Lacking		-0.0239		0.00196		0.00878*
		(0.0473)		(0.00405)		(0.00520)
School ICT Equipment						
High-speed internet	-0.219	-0.212	-0.00549	-0.00601	0.00743	0.00487
	(0.158)	(0.157)	(0.0283)	(0.0279)	(0.0342)	(0.0338)
Wi-Fi	0.00875	0.0152	0.0223	0.0215	0.00410	0.00169
	(0.120)	(0.117)	(0.0212)	(0.0221)	(0.0202)	(0.0215)
Presentation device	-0.0169	-0.0217	0.0341**	0.0347**	0.0268**	0.0282**
	(0.0758)	(0.0740)	(0.0149)	(0.0146)	(0.0132)	(0.0125)
Digital instructions	0.113	0.111	0.0361***	0.0361***	0.00860	0.00945
	(0.135)	(0.135)	(0.0114)	(0.0120)	(0.0105)	(0.0110)
Digital textbook	0.152	0.153	-0.0179	-0.0181	-0.0188	-0.0191
	(0.232)	(0.231)	(0.0319)	(0.0313)	(0.0246)	(0.0243)
Management software	0.148	0.142	-0.0214	-0.0208	-0.0231	-0.0207
	(0.0982)	(0.0973)	(0.0452)	(0.0454)	(0.0476)	(0.0477)
Security policy	-0.116	-0.120	-0.0142	-0.0137	0.0369	0.0381
	(0.126)	(0.121)	(0.0365)	(0.0367)	(0.0359)	(0.0370)
N	1,100	1,100	1,088	1,088	1,088	1,088
R^2	0.016	0.017	0.021	0.021	0.017	0.021

Notes: Estimation results based on fixed effect model at BoE level. Subsample of BoEs with one junior high school. Robust standard errors clustered at BoE and prefecture level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table B12: Effect of ICT resources on remote education – subsample of BoEs with one junior high school

ONE JUNIOR HIGH SCHOOL										
PANEL A	**April 2020**		**May 2020**		**June 2020**		**July 2020**		**August 2020**	
Overtime threshold	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)
Teacher ratio	0.198	0.027	0.128	0.013	0.485	0.098	0.442	0.090	0.120	0.015
IT skill index Proficient	0.00678	-0.000274	0.00611	-0.000704	-0.000151	-0.000380	0.00298	-0.00617*	0.00458	0.000883
	(0.00754)	(0.00320)	(0.00828)	(0.00138)	(0.00631)	(0.00444)	(0.00658)	(0.00363)	(0.00710)	(0.00203)
Effect size	3.42%	-1.03%	4.76%	-5.58%	-0.03%	-0.39%	0.67%	-6.86%	3.81%	5.98%
N	678	678	684	684	710	710	716	716	694	694
R^2	0.060	0.040	0.096	0.045	0.299	0.241	0.405	0.369	0.335	0.128
PANEL B	**April 2020**		**May 2020**		**June 2020**		**July 2020**		**August 2020**	
Overtime threshold	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**	**45**	**80**
	(11)	(12)	(13)	(14)	(15)	(16)	(17)	(18)	(19)	(20)
Teacher ratio	0.198	0.027	0.128	0.013	0.485	0.098	0.442	0.090	0.120	0.015
IT skill index Lacking	0.00807	-0.00110	0.00560	0.00176	0.00306	0.0114**	0.00407	0.0106**	0.00799	0.00501
	(0.00527)	(0.00222)	(0.00368)	(0.00136)	(0.00677)	(0.00438)	(0.00696)	(0.00431)	(0.00661)	(0.00315)
Effect size	4.07%	-4.15%	4.36%	13.96%	0.63%	11.64%	0.92%	11.78%	6.64%	33.92%
N	678	678	684	684	710	710	716	716	694	694
R^2	0.062	0.041	0.096	0.047	0.300	0.254	0.405	0.375	0.337	0.139

Notes: Estimation results from linear fixed effect model at BoE level. Subsample of BoEs with one junior high school. Robust standard errors clustered at BoE and prefecture level in parentheses. *** p<0.01, ** p<0.05, * p<0.1

Table B13: Effect of teachers' IT skills on overtime – subsample of BoEs with one junior high school

Appendix C: Teachers' IT skills questionnaire

Status of teachers' ICT utilization and guidance (teachers in charge of classes in 2019)

Skill A: Ability to use ICT for class preparation, grading, and administrative tasks

A–1 Make planned use of computers, the Internet, etc. to increase education efficacy.

A–2 Make use of the Internet and other tools to collect materials used in class or materials needed for administrative tasks, and to share information necessary to coordinate with guardians and the public.

A–3 Make use of word processing, spreadsheet, and presentation software, etc. to prepare materials such as prints or presentations used in class or documents and materials needed for class management and administrative tasks.

A–4 Make use of computers and other tools to record, organize, and evaluate students' work, reports, worksheets, and others in order to comprehend learning status.

Skill B: Ability to teach class using ICT

B–1 Use computers and presentation devices to effectively present materials and others to appropriately summarize learning contents, to clearly explain tasks and raise students' interest and curiosity.

B–2 Have students use computers, presentation devices, etc. to effectively present opinions and others, in order to share and compare opinions, ideas, and works.

B–3 Use learning software and other tools to have students perform repetitive learning tasks and other tasks corresponding to each student's level of learning for the purposes of establishing knowledge and mastering technical skills.

B–4 Have students make effective use of computer software and other tools when summarizing ideas from group discussions or collaboratively preparing reports, materials, works, and others.

Skill C: Ability to teach students to use ICT

C–1 Guide students to gain the basic skills needed to operate computers and other tools necessary to learning (character input, file management, and others).

C–2 Guide students to be able to use computers and the Internet to collect and select relevant and reliable information.

C–3 Guide students to be able to use word processing, spreadsheet, and presentation software, etc. to organize research and ideas and to summarize them in text, tables, graphs, figures, and others in an easy-to-understand manner.

C–4 Guide students to use computers, software, etc. to be able to exchange, share, and discuss ideas with each other.

Skill D: Ability to instruct students in knowledge and attitude needed to utilize information

D–1 Guide students to be able to take responsibility for their own actions participating in information-driven society, to think of and respect others, and to follow rules and manners when collecting and sharing information.

D–2 Guide students to be able to appropriately avoid antisocial and illegal behavior, online crimes, and other risks and to be mindful of their health when using the Internet and other tools.

D–3 Guide students to gain the basic knowledge of information security and to appropriately set and manage passwords to be able to use computers and the Internet safely.

D–4 Guide students to acknowledge the usefulness of computers and the Internet and encourage students' interest in utilizing them for learning and understanding their mechanism.

1) **Reference for answering 1)**

Skill A: Ability to use ICT for class preparation, grading, and administrative tasks

Proficient: Generally skilled in items in question.

(Example A–3: Is able to use word processing, spreadsheet, and presentation software, etc. to prepare materials such as prints or presentations used in class or documents and materials needed for class management and division of school duties.)

Mostly proficient: Knows how to use ICT equipment in question.

(Example A–3: Knows how to operate word processing, spreadsheet, and presentation software.)

Mostly lacking: Unable to operate without receiving in-school or other training.

(Example A–3: Will know how to operate word processing, spreadsheet, and presentation software after receiving in-school or other training.)

Lacking: Unable to operate without receiving step-by-step training (including outside-school training) starting from the basics of operation.

(Example A–3: Largely does not know how to operate word processing, spreadsheet, and presentation software.)

Skill B: Ability to teach class using ICT

Proficient: Is able to use ICT in teaching activities.

(Example B–1: Is able to use computers and presentation devices to effectively present materials and others to appropriately summarize learning contents, to clearly explain tasks, and raise students' interest and curiosity.

Mostly proficient: Using practical examples and guidebooks, is able to use ICT in teaching activities.

(Example B–1: Is able to present materials and others using computers and presentation devices.)

Mostly lacking: Does not know how to teach using ICT without receiving in-school or other training.

(Example B–1: Will be able to present materials and others using computers and presentation devices after receiving in-school or other training.)

Lacking: Does not know how to teach using ICT without receiving step-by-step training (including outside-school training) starting from the basics of operation.

(Example B–1: Largely does not know how to present materials and others using computers and presentation devices.)

Skill C: Ability to teach students to use ICT

Proficient: Generally able to teach items in question.

(Example C–1: Is able to guide students to gain the basic skills needed to operate computers and other tools necessary to learning (character input, file management, and others).)

Mostly proficient: Using practical examples and guidebooks, is able to teach.

(Example C–1: Has and is able to explain the basic skills needed to operate computers and other tools necessary to learning (character input, file management, and others).)

Mostly lacking: Does not know how to teach without receiving in-school or other training.

(Example C–1: Does not know how to teach; in-school training is therefore necessary.)

Lacking: Does not know how to teach without receiving step-by-step training (including outside-school training) starting from the basics of operation.

(Example C–1: Does not know how to teach; step-by-step training (including outside-school training) starting from the basics of operation is therefore necessary.)

Skill D: Ability to instruct students in knowledge and attitude needed to utilize information

Proficient: Generally able to teach items in question.

(Example D–1: Is able to guide students to be able to take responsibility for their own actions participating in information-driven society, to think of and respect others, and to follow rules and manners when collecting and sharing information.)

Mostly proficient: Using practical examples and guidebooks, is able to teach.

(Example D–1: Using practical examples and guidebooks, is able to guide students to be able to take responsibility for their own actions participating in information-driven society, to think of and respect others, and to follow rules and manners when collecting and sharing information.)

Mostly lacking: Does not know how to teach without receiving in-school or other training.

(Example D–1: Does not know how to teach; in-school training is therefore necessary.)

Lacking: Does not know how to teach without receiving step-by-step training (including outside-school training) starting from the basics of operation.

(Example D–1: Does not know how to teach; step-by-step training (including outside-school training) starting from the basics of operation is therefore necessary.)