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ICT Use in Schools and Students' Non-Cognitive Skills

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Abstract

Over the past few decades, information and communication technology (ICT) has been increasingly integrated in the classroom. Using student panel data and administrative data on ICT use in schools, we analyze whether the increased ICT use in schools relates to students' non-cognitive skills. Fixed effects estimations show that the introduction and use of ICT in the classroom are likely to change students' self-efficacy and grit, but the effects vary by their demographic and socioeconomic characteristics. Overall, the findings attest to the importance of addressing the heterogeneous effects of ICT on students, in order to optimize its use for their personal development.

JEL classification: I21
Keywords: ICT, Self-efficacy, Grit

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1. Introduction

With the rapid development in technology, information and communication technology (ICT) has been increasingly integrated in the classroom over the past few decades.[1] According to the Teaching and Learning International Survey administered by the Organisation for Economic Cooperation and Development (OECD), the percentage of lower secondary school teachers who frequently use ICT for students' projects or class increased from 38% in 2013 to 57% in 2018.[2] Relatedly, students have higher access to computers at school: the average ratio of computers at school to 15-year-old students in OECD countries rose from 0.68 in 2012 to 0.81 in 2022,[3] approaching a one-to-one ratio of digital devices to students (OECD, 2023a). Undoubtedly, the outbreak of the pandemic in 2020 and the subsequent school closures have further accelerated the use of ICT at all levels of schools.

In line with global trends, the Japanese government launched a program in 2019, called the Global and Innovation Gateway for All (GIGA) School Program, to promote the use of ICT in schools. The program, for example, aimed to ensure that every student has access to a digital device at school. There is a large body of literature that examines the impact of ICT on student outcomes (Escueta et al., 2020). However, given the dramatic shift that occurred in the learning environment in recent years, it is now crucial to reconsider how the introduction and use of digital devices may affect students in this new context.

Along with the increasing digitalization of society, the skills demanded in the labor market are also changing. In addition to digital skills, non-cognitive skills, or social and emotional skills, are growing in its importance in the workplace to adapt to fast-changing environments and accompanying uncertainties (European Commission, 2020). Prior research suggests that non-cognitive skills are positively correlated with labor productivity (Morandini, Thum-Thysen, & Vandeplas, 2020). As these skills are relevant for tasks that cannot be easily automated, the returns to these skills are increasingly becoming higher (Deming, 2017).

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[1] In this study, ICT is used to refer to "a diverse set of technological tools and resources used to transmit, store, create, share or exchange information" (UNESCO, 2009), such as computers, software, and the Internet,

[2] The statistics for 2013 are obtained from the following website of the OECD: https://www.oecd-ilibrary.org/docserver/5jrxnhpp6p8v-en.pdf?expires=1711193529&id=id&accname=guest&checksum=85F6F4C08111AFC647FBE09DD5267B7B. The statistics for 2018 are obtained from the OECD.Stat at the following website: https://stats.oecd.org/Index.aspx?QueryId=97203.

[3] The computers available to students at school include both laptops and tablets.

By combining student data collected by the Department of Education in Saitama prefecture with administrative data collected by the Ministry of Education, Culture, Sports, Science and Technology (MEXT), we examine whether the use of ICT in schools has any effects on students' non-cognitive skills. As mentioned previously, non-cognitive skills are increasingly recognized as a key factor in life success (Heckman, Stixrud, & Urzua, 2006; Heckman & Kautz, 2012; Weinberger, 2014). In particular, we focus on two types of non-cognitive skills that are available in our dataset over a long period of time: self-efficacy and grit. Both of these skills are understood to be instrumental in academic success and labor market performance (see, for example, Pajares & Kranzler, 1995, for self-efficacy; Duckworth et al., 2007, for grit). We also expect that the use of ICT is likely to affect these two skills through the mechanisms discussed in Section 2.

The main contribution of this paper is that we shed light on the effect of ICT on non-cognitive skills. Given that ICT has been increasingly used in the classroom, previous literature has extensively studied how ICT affects student outcomes, but mostly limited to academic skills. The evidence from developed countries on the impact of increasing ICT investment or infrastructure on cognitive skills is mixed (Escueta et al., 2020): Some studies find positive impacts (Machin, McNally, & Silva, 2007), while others find negative or negligible impacts (Checchi, Rettore, & Girardi, 2018; Leuven et al., 2007). Likewise, a new experience of using ICT in schools could potentially affect children's non-cognitive skills, which are known to change over time as they are influenced by environments (Kautz et al., 2014). By highlighting the potential role of ICT in student acquisition of non-cognitive skills, we aim to fill in the gaps in existing research and deliver new implications for policy related to the use of ICT.

Based on student fixed effects estimations, we find that in general, increased use of ICT in the classroom is likely to foster self-efficacy of students in the older cohort (grades 7-8 in junior high school), but not in the younger cohort (grades 4-5 in elementary school). We also explore heterogeneous effects of ICT across student demographic and socioeconomic characteristics, as the effects may depend on these factors. The results show that in the younger cohort, an increased ratio of computers per student corresponds to an increase in self-efficacy of male students, whereas the use of digital textbooks is negatively associated with that of female students. In the older cohort, we also observe a gender difference that frequent use of ICT in math class is more likely to foster self-efficacy of male students, while female students do not experience the same benefits.

When differences by socioeconomic status (SES) are taken into account, the results indicate that in the younger cohort, the ICT availability and usage appear to negatively influence self-efficacy of low SES students, but this negative effect is alleviated for non-low SES students. In the older cohort, no discernible difference is found with respect to SES. In case of grit, the analysis using the overall sample or gender-specific samples does not yield any significant results, but we do find a difference based on SES. Specifically, the increased availability of computers and digital textbooks is more likely to foster grit in low SES students compared to non-low SES students. These findings collectively suggest that it is important for schools and teachers to consider the potential heterogeneous effects of ICT on student outcomes based on their characteristics and backgrounds to maximize its effectiveness in their personal development.

The rest of the paper is organized as follows. Section 2 discusses the development process of self-efficacy and grit and possible mechanisms through which the use of ICT may affect these skills. Section 3 presents the background information and stylized facts on the ICT use in schools and non-cognitive skills of students in Japan. Section 4 describes the data employed in our analysis. Section 5 presents the empirical framework, followed by regression results in Section 6. The last section concludes with discussions of implications for policy.

2. Mechanism

2.1 Development of Self-Efficacy

The concept of self-efficacy was originally developed by Bandura (1977) and is defined as one's expectation that he or she can successfully perform the behavior necessary to achieve certain outcomes in the face of obstacles. Bandura (1977) proposes that self-efficacy can be enhanced by four factors: performance accomplishments, vicarious experience, verbal persuasion, and physiological states. First, self-efficacy is formed as individuals gain personal mastery experiences. One's own experience of success builds up his or her expectation of further success. Second, when individuals observe the success of others, they may begin to believe that they too can achieve similar results if they put in more and consistent efforts. Third, words influence one's behavior. Words of encouragement can strengthen one's belief in his or her ability to overcome difficulties facing them. Fourth, managing one's emotional and physiological states can lead to fostering his or her expectation of success.

2.2 Development of Grit

The concept of grit was first proposed by Duckworth et al. (2007) and is defined as "passion and perseverance for long-term goals" (Duckworth et al., 2007). Duckworth (2016) identifies four sources of grit: interest, practice, purpose and hope. First, when individuals find a strong interest in what they are working on, they can continue to pursue their goals when faced with difficulties. Second, commitment and consistent efforts in practice are key to achieving success in one's endeavors. Third, when individuals work with a higher sense of purpose, they can stay motivated and persevere through challenges. Fourth, grit is fostered when people are able to feel hopeful and optimistic about the future.

2.3 ICT, Self-Efficacy, and Grit

Given the above factors that develop self-efficacy and grit, we propose several possible mechanisms through which ICT use in the classroom may affect students' self-efficacy and grit.[4] First, ICT makes individualized learning possible, for instance, using adaptive learning software and online learning aids. For example, artificial intelligence (AI) is used to analyze exam results and identify areas where students are having difficulty solving problems, and students can deepen their understanding of those areas by re-learning what the AI suggests.[5] Self-efficacy is fostered by personal experience of success, while grit is cultivated when practice and hope are sustained. When students can learn at their own pace, receive targeted support, and complete their tasks, their self-efficacy and grit in academic tasks may be enhanced.

Second, ICT enables teachers to provide more timely and personalized feedback. The timing of feedback is found to influence student performance (Fischer & Wagner, 2023). Without ICT, it is difficult for teachers to keep track of each student's understanding and progress during lessons with class sizes of around 30 students. ICT makes it easier for teachers to grasp students' status and provide individualized support in a timelier manner, for example, by displaying students' work on teachers' screens. Effective feedback and assessment can help students recognize areas

[4] In this section, we focus on explaining how the introduction or use of ICT in the classroom may affect students' self-efficacy and grit. The introduction or use of ICT in schools may also indirectly affect students outside the classroom, for example, reducing other activities that may foster these non-cognitive skills. The estimates we get in the analysis section reflect overall effects of ICT, including these possible indirect effects.

[5] The specific example is available at the following website of the MEXT: https://www.mext.go.jp/content/20210323-mxt_jogai02-100013299_003.pdf

of improvement, which may positively influence their self-efficacy through increased verbal persuasion and grit through a clearer sense of purpose.

Third, the introduction of ICT requires students to develop new skills in using ICT tools. Mastery experience is an important factor in fostering, for instance, self-efficacy (Bandura, 1982). Learning new skills may also stimulate students' interest, thereby motivating students to sustain grit. However, it can also have a negative impact if students fail to master these new skills.

Lastly, ICT tools can facilitate more interactive and collaborative learning in class. For example, students can access a shared document, collaborate on it in real time, and easily share it with other classmates.[6] By working collaboratively with others, students may more easily gain vicarious experiences and alleviate any anxiety they may have, thereby developing confidence in their abilities. When students receive more support from their peers in a collaborative environment, they may also find it easier to maintain hope in their goals and persist in their efforts (Christopoulou et al., 2018).

3. Background

3.1 The Use of ICT in Japanese Education

Innovative technologies, such as artificial intelligence (AI), robotics, the Internet of Things (IoT), and big data, are being increasingly utilized across various sectors of society. In light of the growing digitalization and societal changes, policymakers in Japan have been discussing the necessary qualities and skills for today's world. For example, the Basic Plan for the Promotion of Education, which outlines the guidelines for educators in Japan, states a goal of nurturing individuals who can contribute to a sustainable society for 2040 and beyond.[7] To achieve this goal, one of the policies listed in the plan is the promotion of digital transformation in education. In another example, the Central Council for Education emphasizes the importance of fostering individuals who can positively embrace changes and enrich society and themselves by utilizing

[6] Examples of using ICT to facilitate interactive learning are available at the following website of the MEXT: https://www.mext.go.jp/content/20210713-mxt_kyoiku01-000016371.pdf.
[7] The details are available at the following website of the MEXT: https://www.mext.go.jp/content/20230615-mxt_soseisk02-100000597_01.pdf.

their unique human sensibilities.[8,9] Additionally, the Council highlights the importance of cultivating a sense of self-affirmation and self-usefulness, as well as the ability to persevere through challenging circumstances.

With a rapidly changing society in mind, the MEXT has identified "individualized learning" and "collaborative learning," which bring forth the potential of all children, as the keys to ideal school education to be realized in the 2020s.[10] "Individual learning" is achieved through both personalized instruction by teachers and personalized learning by students, while "collaborative learning" involves exploratory learning and experiential activities with peers. The MEXT expects that ICT plays a key role in carrying out individualized and collaborative learning in the classroom.[11]

The introduction and use of ICT in schools, however, had been progressing slowly in Japan. According to the 2018 Programme for International Student Assessment (PISA) survey on ICT use, Japan ranked the lowest among OECD countries in terms of time spent using digital devices in classes, with about 80% of 15-year-old students reporting that they do not use digital devices.[12] That said, as mentioned earlier, ICT use was expected to be a means of developing individuals who can respond to rapid societal changes. Given these circumstances, in 2019, the MEXT announced the Global and Innovation Gateway for All (GIGA) School Program, a policy to accelerate the development of ICT infrastructure in schools. The program aimed to promote the provision of one computer per student and the development of a high-speed, high-capacity communication network for all classrooms over a period of five years.

In the meantime, due to the COVID-19 pandemic in 2020, many schools were temporarily closed to prevent the spread of infection. In response, the MEXT implemented the GIGA School Program ahead of schedule to ensure uninterrupted student learning through online classes during this period. As a result, the penetration rate of educational computers accelerated, such that the ratio of students per computer went down from 4.9 students per computer as of 2020, to 1.4 in

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[8] The Central Council for Education is an organization established under the Ministry of Education, Culture, Sports, Science and Technology (MEXT) to study and deliberate on education policies in Japan.
[9] The details are available at the following website of the MEXT: https://www.mext.go.jp/content/20210126-mxt_syoto02-000012321_2-4.pdf.
[10] The details are available at the following website of the MEXT: https://www.mext.go.jp/content/20210126-mxt_syoto02-000012321_1-4.pdf.
[11] The details are available at the following website of the MEXT: https://www.mext.go.jp/content/20210126-mxt_syoto02-000012321_2-4.pdf.
[12] The details are available at the following website of the National Institute for Educational Policy Research: https://www.nier.go.jp/kokusai/pisa/pdf/2018/01_point-eng.pdf.

2021, and 0.9 in 2022.[13] Similarly, the percentage of regular classrooms equipped with wireless local area networks (LANs) increased from 48.9% in 2020 to 78.9% in 2021, 94.8% in 2022, and 95.7% in 2023, indicating that the introduction of ICT in Japanese schools has been achieved at a remarkable pace.

Now that an enhanced ICT infrastructure has been provided, Japanese schools are expected to further improve teachers’ ICT skills, train experts in digital transformation, and promote ICT use in the classroom. Yet, the PISA 2022 survey reveals that the use of ICT in the classroom is still relatively low in Japan. Specifically, 48.5% of the 15-year-old students surveyed reported not using digital resources in Japanese language classes, 53.5% in math classes, and 43.8% in science classes, while the OECD averages of these statistics are 31.2% in language-of-instruction, 36.4% in math, and 25.2% in science.[14] The provision of ICT devices is nearly complete. The next question is how to effectively integrate them into the classroom.

3.2 Japanese Students’ Self-Efficacy and Grit

Low academic self-efficacy and low self-perception of grit are prevalent issues among Japanese students. According to the 2022 PISA survey, Japanese students scored an average of 536 points in mathematics, the highest among the 37 OECD member countries. Nevertheless, their self-efficacy in mathematics is relatively lower. For instance, only 30.0% of students answered feeling “very confident” or “confident” in their ability to find mathematical solutions to real-life problems, which is much lower than the OECD average of 52.5%.[15] Furthermore, the 2015 PISA survey shows that Japan ranked the lowest among participating countries in terms of self-efficacy as a science learner, despite the fact that Japanese students performed strongly on science exams compared to other countries (OECD, 2016; National Institute for Educational Policy Research, 2016).

In addition to academic self-efficacy, the OECD also surveyed general self-efficacy of students in their 2018 PISA survey. The report (OECD, 2019) shows that Japanese students have

[13] The statistics are obtained from the reports published by the MEXT in the respective years, and their surveys cover all public schools from elementary to high schools in Japan. The reports are available at their website: https://www.mext.go.jp/a_menu/shotou/zyouhou/1287351.htm.
[14] It should be noted that the provision of a digital device per student was still in the process of being implemented in upper secondary schools at the time of this survey in 2022. The details are available at the following website of the National Institute for Educational Policy Research: https://www.nier.go.jp/kokusai/pisa/pdf/2022/01_point_2.pdf.
[15] The details are available at the following website of the National Institute for Educational Policy Research: https://www.nier.go.jp/kokusai/pisa/pdf/2022/01_point_2.pdf.

significantly lower self-efficacy compared to other OECD countries when facing difficult situations. Although some of the questions used to measure these indicators of self-efficacy are not directly related to grit, they are still relevant. For example, the survey includes questions that measure the extent to which students agree with such statements as, "I usually manage one way or another," "My belief in myself gets me through hard times," and "When I'm in a difficult situation, I can usually find my way out of it." In all these three questions, Japanese students reported the lowest values among OECD countries. These results suggest that Japanese students may have a low level of grit, as evidenced by their lack of confidence in their ability to accomplish tasks under difficult situations. It is, therefore, important to consider and implement measures to improve these non-cognitive skills of Japanese students.

4. Data

This paper draws on data from two different sources. The first is a panel data set collected by the Department of Education in Saitama prefecture at the beginning of a school year,[16] from which we use student questionnaires to gather information on student characteristics, non-cognitive skills, and the extent of ICT use in the classroom. This survey covers all public elementary and junior high schools from 62 participating municipalities in the prefecture. The second is a school-level data set on the use of ICT and is gathered annually at the end of a school year by the Ministry of Education, Culture, Sports, Science and Technology (MEXT) for all public elementary and junior high schools in Japan.[17] We combine these two data sets to characterize students and schools in Saitama prefecture over the period between 2018 and 2022.

To measure the availability and use of ICT in schools, we use the following four indicators: i) the ratio of computers to students[18]; ii) the use of digital textbooks, which is a binary variable that equals one if digital textbooks have been introduced in schools; iii) the frequency of ICT use in Japanese classes; and iv) the frequency of ICT use in math classes. The last two variables are dummy variables that take the value of 1 if students used ICT, such as personal computers and

[16] The Japanese school year runs from April through March. The survey was conducted either in either April or May, depending on the year, except in 2020 when the survey was administered in June and July due to the pandemic. The questions regarding ICT use in the classroom refer to the situation in the previous year.
[17] This data is collected in March every year.
[18] Any types of devices available for student use, such as desktops, laptops, and tablets, are included.

tablets, at least once a week in the respective classes. The first two variables simply measure the availability of ICT tools, whereas the other two assess the utilization of ICT in the classroom.[19]

Figures 1 through 3 illustrate the trends of the aforementioned ICT measurements over the regression sample period. In line with the national trend discussed in Section 2, the number of personal computers available for student use has significantly increased in 2020 after the GIGA School Program was initiated, and schools, on average, reached one-to-one provision of devices in 2021 (Figure 1). The adoption of digital textbooks has proceeded more slowly and is yet to be fully utilized. In both elementary and junior high schools, less than 10% of the sample introduced digital textbooks in 2020, and still only the half of the sample did so in 2021 (Figure 2). The extent of ICT use varies by school, as shown in Figure 3. The left panels refer to the use in Japanese class, while the right panels refer to that in math class. In general, the figures reveal an increase in the use of ICT over time in both subjects. It is also observed that ICT is used more frequently in Japanese class than in math class. Moreover, we find that ICT is more commonly utilized in elementary schools than in junior high schools.

Data on the ways ICT tools are used in the classroom are only available for latest two years in the sample, but an examination of these data reveal an evolution in how ICT is integrated in the classroom during this period. In 2020 when schools began providing more personal computers to students, the common way to use ICT in Japanese and math classes was video or audio recording in both elementary and junior high schools. In addition, junior high school students commonly used ICT for writing in Japanese class, while they used ICT for searching the Internet in math class. In elementary schools, students also used learning software in both subjects. In 2021 when most schools reached one-to-one provision of personal devices to students, more common ways to use ICT in Japanese class, in both elementary and junior high schools, were searching the Internet and submitting their assignments via ICT tools, rather than video or audio recording. In math class, students in elementary school students most often used ICT for doing drills and submitting their assignments, whereas junior high schools were more likely to use computers for other types of learning software than drills.

In the survey on non-cognitive skills, only one type of skills is measured for each cohort to reduce students' burden. Based on the data availability, we analyze two cohorts for self-efficacy

[19] The first two variables are based on school questionnaires, whereas the last two variables are based on student questionnaires.

and one cohort for grit. Self-efficacy is measured by students' responses to eight questions drawn from Pintrich et al. (1991), and grit is measured by twelve questions based on Duckworth et al. (2007).[20] All questions are rated on a five-point Likert scale. We aggregate these responses to create each index, with higher values indicating higher levels of these skills, and then standardize these values by cohort and year. The sample period varies by cohort and ICT-related variables, and the detailed summary of the sample period is presented in Table 1.

After limiting the sample to those students with two or more observations to have a consistent sample between ordinary least squares (OLS) and student fixed effects estimations, the final sample consists of 351,074 students.[21] The summary statistics of the variables used in regressions are provided for the pooled sample in Table 2. As for students' characteristics, half of the students are male. While our data set contains limited information about students' family backgrounds, their socioeconomic status (SES) is arguably an important determinant of student development. Following convention in the education literature (Heppt, Olczyk, & Volodina, 2022), we use the number of books possessed at home as a proxy for students' SES. More specifically, we define possession of 10 or fewer books as indicative of low SES and observe that approximately 11% belong to low SES families.[22, 23]

5. Empirical Framework

We first conduct a simple ordinary least squares (OLS) estimation using the equation below:

$$Y_{ist} = \alpha_1 + \beta_1 S_{is(t-1)} + \boldsymbol{\gamma}_1 \boldsymbol{X}_{ist} + \mu_t + \varepsilon_{ist} \tag{1}$$

where Y_{ist} represents the standardized value of non-cognitive skill score for self-efficacy or grit of individual *i* in school *s* in year *t*; $S_{is(t-1)}$ denotes an ICT-related variable in the previous year; $\boldsymbol{X}_{ist}$ refers to a vector of student characteristics, including gender and quarter of birth; μ_t represents year effects; and ε_{ist} is an error term. Standard errors are clustered at the school level.

[20] The detailed list of questions is provided in Appendix Table A1.
[21] The annual attrition rate is 2-3%, primarily due to absences on exam days. However, this rate increases to 6-8% when students advance from grade 6 to grade 7, as some students opt for private junior high schools over public schools.
[22] This categorization follows the definition used in Yamaguchi, Ito, and Nakamuro (2023).
[23] In the original question, students are asked how many books there are in their home and choose one of the following categories: none or very few (0-10 books), enough to fill one shelf (11-25 books), enough to fill one bookcase (26-100 books), enough to fill two bookcases (101-200 books), and enough to fill three bookcases (201-300 books).

The estimates from the parsimonious model using equation (1) are likely to be biased due to omitted variables, including unobserved student characteristics that are potentially correlated with both the ICT-related variables and non-cognitive skills. For example, parents may play an important role in affecting both school efforts to integrate ICT into the classroom and their children's non-cognitive skills, if they are actively engaged in school activities. Another possible factor that can be correlated with both the use of ICT and students' non-cognitive skills is teacher quality. A teacher who effectively integrates ICT in the classroom may also have a teaching style that can foster students' non-cognitive skills. In consideration of these possibilities, we exploit the panel nature of the data set and within-student variation in exposure to ICT use. The following equation serves as the main equation to be estimated:

$$Y_{ist} = \alpha_2 + \beta_2 S_{is(t-1)} + \theta_i + \mu_t + \varepsilon_{ist} \tag{2}$$

where θ_i denotes student fixed effects and controls for time-invariant student characteristics. Assuming that parental involvement tends to be relatively constant over time, student fixed effects can control for the innate nature of parents. To the extent that teacher quality is also unlikely to change rapidly in a few short years, fixed effects can account for teacher quality in schools.[24]

As a supplement to our main analysis, we also conduct regressions using sub-samples. The use of ICT may affect students' non-cognitive skills differently according to students' characteristics and backgrounds. For example, prior studies find that there are differences in the level of self-efficacy for ICT skills and academic skills by gender (Cai, Fan, & Du, 2017). In particular, female students tend to have a lower level of self-efficacy in these skills than male counterparts (see, for example, OECD, 2013 for mathematics self-efficacy). There is also a commonly observed tendency worldwide that male students tend to outperform their female counterparts in math tests (Fryer & Levitt, 2010). Such fundamental differences in nature may lead to different impacts of ICT on their non-cognitive skills. We, therefore, explore differential impacts of ICT by gender.

Additionally, we examine whether the relationship between an ICT indicator and non-cognitive skills differs by students' SES by adding an interaction term between the ICT-related

[24] However, fixed effects cannot account for teacher quality if it changes over time, for example, when a student changes her or his school. To take into account teacher's role, we additionally examined whether the relationship between the ICT-related variables and non-cognitive skills depended on teachers' ability to utilize ICT in their teaching. More specifically, we added an interaction term between the ICT-related variables and teachers' ability to integrate ICT into their teaching but found no significant differences.

variable and the proxy for SES to equation (2). Earlier literature finds a negative impact of providing a personal computer on academic performance among low SES students, possibly failing to utilize the device due to less familiarity with it (Hall, Lundin, & Sibbmark, 2021). A similar mechanism may influence non-cognitive skills. Conversely, more equal access to resources may reduce the gap in these skills between low and non-low SES students; therefore, theoretically the effects are ambiguous.

6. Results

6.1.1 Self-Efficacy of Students in the Younger Cohort

We first present the regression results on the relationship between ICT-related variables and self-efficacy of students in elementary schools in Table 3. Based on an ordinary least squares (OLS) estimations, the more frequent use of ICT in Japanese class corresponds to a lower level of self-efficacy (column (3) in Panel A), but the estimated coefficient becomes insignificant after controlling for student fixed effects (column (3) in Panel B). Using an ICT in math class at least once a week is associated with a 0.03 standard deviation increase in the self-efficacy score (although it is marginally significant at the 10 percent level). The results appear to suggest that the availability and use of ICT is not significantly correlated with self-efficacy of students in elementary schools.

Disaggregating the sample of students into gender-specific groups, we find differential relationships between ICT indicators and students' self-efficacy (Table 4). The student fixed effects estimations show that the adoption of digital textbooks is negatively and significantly correlated with self-efficacy of female students (column (2) in Panel A). This result may be partly explained by gender differences in digital navigation skills. Although girls generally perform better than boys in both print and digital reading, they are found to have weaker digital navigation skills, conditional on print reading skills (OECD, 2012). In contrast, an increase in the availability of computers for students is likely to increase self-efficacy of male students (column (1) in Panel B). Previous studies show that male students tend to have higher ICT self-efficacy (Vekiri & Chronaki, 2008), which may account for the observed positive correlation between the availability of computers and their academic self-efficacy.

Next, we take into account students' SES in our analysis (Table 5). The coefficients of ICT are negative and statistically significant for all ICT measurements, ranging from -0.12 to -0.27 standard deviation changes. This result suggests that the increased availability and use of ICT is negatively correlated with self-efficacy of low SES students. This negative effect of ICT on self-efficacy is mitigated or offset when students are from non-low SES backgrounds, as indicated by the positive signs of the interaction term between ICT and non-low SES variables in all specifications. The coefficients of the non-low SES variable are found to be statistically significant and negative, except for column (1), which implies that non-low SES students are more likely to have lower self-efficacy when ICT is used less. These findings are arguably related to other studies that show non-low SES students are more likely to possess a computer at home and have higher ICT self-efficacy (Vekiri, 2010). This background could lead to a more positive perception of the introduction of ICT in schools, enhancing their academic self-efficacy.

6.1.2 Self-Efficacy of Students in the Older Cohort

Slightly different results are obtained for the older cohort in junior high schools. In particular, the frequent use of ICT in both Japanese and math classes appears to increase students' self-efficacy, and the results are consistent between OLS and fixed effects estimations (columns (3) and (4) in Table 6). In contrast to the younger cohort of students in elementary schools, junior high school students may be already familiar with the use of technology at this age, so they may be able to make an effective use of ICT in their learning, which can eventually help build their confidence in their academic ability. Similar to the younger cohort, the mere provision or adoption of ICT itself does not seem to play a significant role in developing self-efficacy (columns (1) and (2) in Table 6).

Turning to gender differences, we observe that while the frequent use of ICT in Japanese class is positively and significantly associated with self-efficacy for both female and male samples (column (3) in Table 7), which is consistent with the analysis based on the whole sample, the more use of ICT in math class is statistically significant only for male students. Bordaldo et al. (2019) find that gender stereotypes significantly affect one's belief in their ability. Jobs in the fields of math and computer tend to be male-dominated in Japan, so gender stereotypes may contribute to producing a gender difference in the impact of ICT on one's self-efficacy. Moreover, West et al. (2020) find that girls tend to have a much lower level of self-efficacy than boys, especially in the middle school ages between grade 6 and grade 8. This trend also holds true for our sample, as shown in Figure 4. These stereotypes and fundamental differences may have led only boys to grow their self-efficacy in the older cohort when ICT is more frequently used in math class.

In general, Table 8 shows that non-low SES students tend to have a higher level of self-efficacy without ICT, as indicated by the positive and significant coefficients for the non-low SES variable. In this cohort in early adolescence, student family backgrounds are less likely to make a difference in the effect of ICT on students' self-efficacy as the interaction term between ICT and non-low SES variable is not statistically significant in all specifications, except for the use of e-textbook in column (2).

6.2 Grit

Table 9 presents the results for grit. In both OLS and fixed effects estimations, the coefficients are statistically insignificant for all ICT measurements, based on the aggregate sample. In the similar vein, the analysis by gender does not produce any significant results.[25] Conversely, students' SES likely plays a significant role in determining the relationship between ICT and their grit. In particular, the results in columns (1) and (2) of Table 10 show that an increase in the provision of computers and the adoption of digital textbooks correspond to a 0.2 standard deviation increase and 0.08 standard deviations increase, respectively, for low SES students. In contrast, non-low SES students have higher grit without ICT, but the introduction of ICT appears to lower their grit, as suggested by the negative coefficient of the interaction term between the ICT and non-low SES variable. The findings appear to suggest that the introduction of ICT reduces the gap in grit between non-low SES students and low SES students. Grit is indeed found to be malleable (Alan, Boneva, and Ertac, 2019), making it an important policy question how such a skill can be fostered in schools.

6.3 Robustness Checks

As robustness checks, we conducted regressions using two alternative proxies for students' SES. First, we use an indicator whether a student attends a cram school. Cram school attendance reflects how much parents invest in their children's education in addition to public education. The decision to attend a cram school is, however, largely influenced by the child's age, as the number of children

[25] The table is not reported for brevity, but available upon request.

attending cram schools naturally increases in the sixth grade and beyond to prepare for entrance exams for junior or senior high school. Thus, our main proxy for SES is the possession of books at home. Additionally, we create a composite index of SES by combining the original proxy of SES (the possession of books at home) with the new proxy (cram school) based on principal component analysis. Both specifications yield qualitatively similar results.[26]

7. Conclusion

The ICT infrastructure in Japanese schools has developed rapidly, facilitated by the GIGA School Program since 2020. Given the increased integration of ICT into the classroom and growing importance of non-cognitive skills in life outcomes, we analyze the effects of ICT use on two kinds of non-cognitive skills, namely self-efficacy and grit. Based on the student panel data and the administrative data on school use of ICT from Saitama prefecture in Japan, our fixed effects estimates reveal that the adoption and use of ICT has the potential to alter students' self-efficacy and grit. This finding, in turn, may suggest that the government's ongoing efforts to improve the ICT infrastructure through the GIGA School Program could have significant implications for student outcomes. The effects, however, vary by age, gender, and socioeconomic status (SES).

At younger ages (grades 4-5 in elementary school), increased availability of personal computers is likely to enhance boys' self-efficacy, while the introduction of digital textbooks is likely to lower girls' self-efficacy. At older ages (grades 7-8 in junior high school), we find that the frequent use of ICT in Japanese class is positively and significantly associated with students' self-efficacy for both girls and boys. Junior high school students may have familiarized themselves with ICT tools, so frequent use may drive further confidence in their ability to handle ICT and ultimately, academic self-efficacy. In contrast, this positive relationship is found in math class only for boys. Generally, male students perform better on math exams, as evidenced across countries (OECD, 2023b). The findings from our results point to the importance of considering gender differences when using ICT in the classroom, so as to avoid widening the gender gap in this field.

Furthermore, when considering SES, it appears that the use of ICT is likely to have a detrimental effect on self-efficacy of those from low SES backgrounds in the younger cohort, but this negative effect is less pronounced among those from non-low SES backgrounds. This result

[26] The tables are not reported brevity, but available upon request.

may be possibly due to the difference in familiarity with computers between low SES and non-low SES students. Such a difference may be particularly significant at younger ages, but the gap may dissipate at older ages after students gain more equal access to and experience with computers in school. In contrast to the results for self-efficacy, we find that the increased availability of personal computers and digital textbooks are likely to enhance the grit of low SES students, compared to non-low SES students.

The heterogeneous effects across these characteristics may be attributable to the third mechanism discussed in Section 2. Mastery experience fosters self-efficacy, but failure to master new digital skills can lower self-efficacy levels. As previous studies suggest, female students, students from low SES backgrounds, and younger students may be at a disadvantage in using ICT tools, compared to their respective counterparts, due to lower skills or familiarity with digital devices. This difference may lead to a decrease in their self-efficacy. In comparison, the introduction of ICT tools may spark greater interest among low SES students, who tend to have less access to these tools than non-low SES students, thereby enhancing their grit. Overall, these findings underscore the importance of recognizing the heterogeneous effects of ICT on student skills based on their demographic and socioeconomic backgrounds, in order to optimize the use of ICT in their personal growth. One possible benefit of integrating ICT in schools is that it allows for individualized learning. Educators may take advantage of such property of ICT to address potential differential impacts on students in their teaching.

One limitation of this paper is that we do not have information on other relevant factors that comprise SES, such as parents' income and education. We used a proxy of SES and attempted alternative measures for robustness checks, but provided that SES is generally understood to influence students' educational outcomes, future studies can complement our analysis by gathering other relevant SES factors. Another possible limitation is the measurements of self-efficacy and grit. The measurements used in the questionnaire are based on Pintrich et al. (1991) and Duckworth et al. (2007), respectively, and students are asked questions in the translated version. The validity of the translated version and the appropriateness of its use with school-aged children may need to be considered in future research. In addition, our paper focuses on the quantitative aspect of ICT use and its effect on students. As our sample period contains only the initial years of the GIGA program, the results should be interpreted with the caveat that the use of ICT may not have been fully optimized. Now that the availability of ICT equipment is ensured in most schools in Japan, future analysis may highlight the qualitative dimensions, such as the effect of the way in which teachers use ICT in the classroom.

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Table 1. The Sample Period by Cohort

Cohort	Non-Cognitive Skill Measured	Period Covered for Non-Cognitive Skill	Corresponding Grades	Period Covered for ICT Variables			
				(i) Ratio of PC to students	(ii) Digital Textbook	(iii) ICT use in Japanese class	(iv) ICT use in math class
A	Self-Efficacy	2021–2022	Grade 4–5	2020-2021	2020-2021	2020-2021	2020-2021
B	Self-Efficacy	2020–2022	Grade 6–8	2019-2021	2019-2021	2020-2021	2020-2021
C	Grit	2019–2022	Grade 6–9	2018–2021	2019-2021	2020-2021	2020-2021

Table 2: Summary Statistics

Variable	Obs	Mean	SD	Min	Max
Non-cognitive skills					
Self-efficacy (standardized)	187,880	0.00	1	-2.59	2.41
Grit (standardized)	163,194	0.00	1	-3.43	3.13
Student characteristics					
Male (=1 if a student is male)	351,074	0.50	0.50	0.00	1
Non-low SES (=1 if more than 10 books at home)	346,834	0.89	0.32	0.00	1
ICT measurements					
Ratio of PC to students	332,650	0.66	0.50	0.01	3.82
E-textbook for students (=1 if introduced in school)	289,218	0.28	0.45	0.00	1
ICT use in Japanese class (=1 if used at least once a week)	224,895	0.28	0.45	0.00	1
ICT use in math class (=1 if used at least once a week)	227,115	0.20	0.40	0.00	1

Source: Author's calculations based on the student surveys collected by Saitama prefecture (2019-2022) and the administrative data collected by the Ministry of Education, Culture, Sports, Science and Technology (2018-2021). The statistics are presented for the pooled sample.

Notes: 1. Month of birth is used in OLS regressions but not reported for brevity. The observations are roughly equally distributed across months.

2. Ratio of PC to students and e-textbook are obtained from school questionnaires, while ICT use in Japanese and math classes are obtained from student questionnaires. ICT refers to digital devices such as PCs and tablets.

Table 3. ICT Use and Self-Efficacy (Cohort A: Grade 4 in 2021 to Grade 5 in 2022)

Dependent variable: Self-Efficacy (standardized)	**ICT Variable**			
	(1)	(2)	(3)	(4)
	Ratio of PC to students	E-text for students	ICT use in class (Japanese)	ICT use in class (math)
Panel A.				
OLS Estimations	0.009	-0.025	-0.026 ***	0.007
	(0.017)	(0.015)	(0.010)	(0.011)
Panel B.				
FE Estimations	0.020	-0.028	0.018	0.030 *
	(0.024)	(0.019)	(0.014)	(0.016)
Observations	56,086	56,086	58,474	60,954

Notes: 1. Robust standard errors, clustered at the school level, are in parentheses.
2. * significant at 10%; ** significant at 5%; *** significant at 1%.
3. Month of birth, gender, year effects, and a constant are included in OLS estimations, while year effects, student fixed effects and a constant are included in FE estimations, but not reported for convenience.
4. ICT in columns (3) and (4) refers to digital devices such as PCs and tablets.

Table 4. ICT Use and Self-Efficacy Differences by Gender (Cohort A: Grade 4 in 2021 to Grade 5 in 2022)

Dependent variable: Self-Efficacy (standardized)	**ICT Variable (Fixed Effects Estimations)**			
	(1)	(2)	(3)	(4)
	Ratio of PC to students	E-text for students	ICT use in class (Japanese)	ICT use in class (math)
Panel A.				
Female students	-0.024	-0.049 **	0.031 *	0.039 *
	(0.030)	(0.024)	(0.017)	(0.021)
Observations	28,383	28,383	29,763	30,847
Panel B.				
Male students	0.066 **	-0.003	0.011	0.027
	(0.031)	(0.024)	(0.019)	(0.021)
Observations	27,703	27,703	28,711	30,107

Notes: 1. Robust standard errors, clustered at the school level, are in parentheses.
2. * significant at 10%; ** significant at 5%; *** significant at 1%.
3. Year effects, student fixed effects and a constant are included in all estimations, but not reported for convenience.
4. ICT in columns (3) and (4) refers to digital devices such as PCs and tablets.

Table 5. ICT Use and Self-Efficacy Differences by Students' Socioeconomic Status (Cohort A: Grade 4 in 2021 to Grade 5 in 2022)

Dependent variable: Self-Efficacy (standardized)	**ICT Variable (Fixed Effects Estimations)**			
	(1)	(2)	(3)	(4)
	Ratio of PC to students	E-text for students	ICT use in class (Japanese)	ICT use in class (math)
ICT	-0.115 ***	-0.265 ***	-0.175 ***	-0.139 ***
	(0.037)	(0.042)	(0.037)	(0.040)
Non-Low SES	0.099 ***	-0.091 ***	-0.107 ***	-0.061 **
	(0.037)	(0.028)	(0.030)	(0.027)
ICT * Non-Low SES	0.137 ***	0.267 ***	0.223 ***	0.191 ***
	(0.037)	(0.043)	(0.038)	(0.042)
Observations	52,578	52,578	55,390	57,684

Notes: 1. Robust standard errors, clustered at the school level, are in parentheses.
2. * significant at 10%; ** significant at 5%; *** significant at 1%.
3. Year effects, student fixed effects and a constant are included in all estimations, but not reported for convenience.
4. ICT in columns (3) and (4) refers to digital devices such as PCs and tablets.

Table 6. ICT Use and Self-Efficacy (Cohort B: Grade 6 in 2020 to Grade 8 in 2022)

Dependent variable: Self-Efficacy (standardized)	**ICT Variable**			
	(1)	(2)	(3)	(4)
	Ratio of PC to students	E-text for students	ICT use in class (Japanese)	ICT use in class (math)
Panel A.				
OLS Estimations	0.020	-0.003	0.038 ***	0.070 ***
	(0.019)	(0.014)	(0.010)	(0.013)
Panel B.				
FE Estimations	0.005	0.007	0.040 ***	0.019 **
	(0.011)	(0.009)	(0.006)	(0.008)
Observations	106,857	106,857	75,766	76,538

Notes: 1. Robust standard errors, clustered at the school level, are in parentheses.
2. * significant at 10%; ** significant at 5%; *** significant at 1%.
3. Month of birth, gender, year effects, and a constant are included in OLS estimations, while year effects, student fixed effects and a constant are included in FE estimations, but not reported for convenience.
4. Due to data availability, the sample period starts at 2021 in columns (3) and (4). ICT in columns (3) and (4) refers to digital devices such as PCs and tablets.

Table 7. ICT Use and Self-Efficacy Differences by Gender (Cohort B: Grade 6 in 2020 to Grade 8 in 2022)

Dependent variable: Self-Efficacy (standardized)	**ICT Variable (Fixed Effects Estimations)**			
	(1)	(2)	(3)	(4)
	Ratio of PC to students	E-text for students	ICT use in class (Japanese)	ICT use in class (math)
Panel A.				
Female students	0.005	0.001	0.044 ***	0.014
	(0.013)	(0.009)	(0.008)	(0.010)
Observations	52,823	52,823	38,026	38,282
Panel B.				
Male students	0.005	0.013	0.038 ***	0.026 **
	(0.014)	(0.011)	(0.009)	(0.010)
Observations	54,034	54,034	37,740	38,256

Notes: 1. Robust standard errors, clustered at the school level, are in parentheses.
2. * significant at 10%; ** significant at 5%; *** significant at 1%.
3. Year effects, student fixed effects and a constant are included in all estimations, but not reported for convenience.
4. Due to data availability, the sample period starts at 2021 in columns (3) and (4). ICT in columns (3) and (4) refers to digital devices such as PCs and tablets.

Table 8. ICT Use and Self-Efficacy Differences by Students' Socioeconomic Status (Cohort B: Grade 6 in 2020 to Grade 8 in 2022)

Dependent variable: Self-Efficacy (standardized)	**ICT Variable (Fixed Effects Estimations)**			
	(1)	(2)	(3)	(4)
	Ratio of PC to students	E-text for students	ICT use in class (Japanese)	ICT use in class (math)
ICT	0.015	-0.021	0.040 **	0.042 ***
	(0.019)	(0.016)	(0.016)	(0.018)
Non-Low SES	0.193 ***	0.068 ***	0.080 ***	0.087 ***
	(0.013)	(0.009)	(0.012)	(0.012)
ICT * Non-Low SES	-0.007	0.032 **	-0.001	-0.026
	(0.015)	(0.015)	(0.018)	(0.019)
Observations	105,697	105,697	74,154	74,866

Notes: 1. Robust standard errors, clustered at the school level, are in parentheses.
2. * significant at 10%; ** significant at 5%; *** significant at 1%.
3. Year effects, student fixed effects and a constant are included in all estimations, but not reported for convenience.
4. Due to data availability, the sample period starts at 2021 in columns (3) and (4). ICT in columns (3) and (4) refers to digital devices such as PCs and tablets.

Table 9. ICT Use and Grit (Cohort C: Grade 6 in 2019 to Grade 9 in 2022)

Dependent variable: Grit (standardized)	**ICT Variable**			
	(1)	(2)	(3)	(4)
	Ratio of PC to students	E-text for students	ICT use in class (Japanese)	ICT use in class (math)
Panel A				
OLS Estimations	-0.001	0.001	-0.004	0.008
	(0.012)	(0.011)	(0.011)	(0.011)
Panel B				
FE Estimations	-0.004	0.005	0.020	0.002
	(0.010)	(0.009)	(0.013)	(0.013)
Observations	156,983	105,753	71,446	72,580

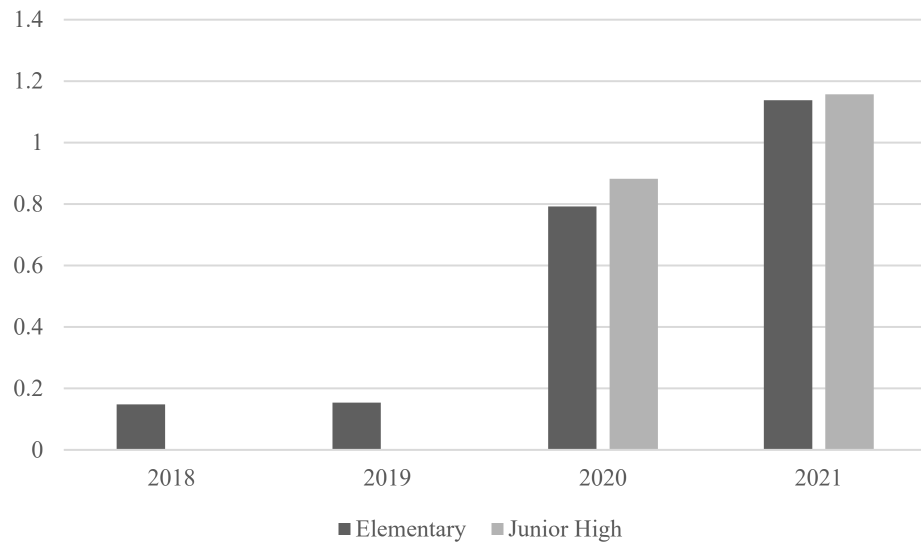
Notes: 1. Robust standard errors, clustered at the school level, are in parentheses.
2. * significant at 10%; ** significant at 5%; *** significant at 1%.
3. Month of birth, gender, year effects, and a constant are included in OLS estimations, while year effects, student fixed effects and a constant are included in FE estimations, but not reported for convenience.
4. Due to data availability, the sample period starts at 2020 in column (2) and at 2021 in columns (3) and (4). ICT in columns (3) and (4) refers to digital devices such as PCs and tablets.

Table 10. ICT Use and Grit Differences by Students’ Socioeconomic Status (Cohort C: Grade 6 in 2019 to Grade 9 in 2022)

Dependent variable: Grit (standardized)	**ICT Variable (Fixed Effects Estimations)**			
	(1)	(2)	(3)	(4)
	Ratio of PC to students	E-text for students	ICT use in class (Japanese)	ICT use in class (math)
ICT	0.200 ***	0.078 ***	0.057 *	-0.003
	(0.017)	(0.021)	(0.031)	(0.032)
Non-Low SES	0.275 ***	0.059 ***	-0.001	-0.013
	(0.012)	(0.012)	(0.019)	(0.019)
ICT * Non-Low SES	-0.230 ***	-0.082 ***	-0.043	0.003
	(0.016)	(0.021)	(0.032)	(0.034)
Observations	155,814	104,854	70,348	71,404

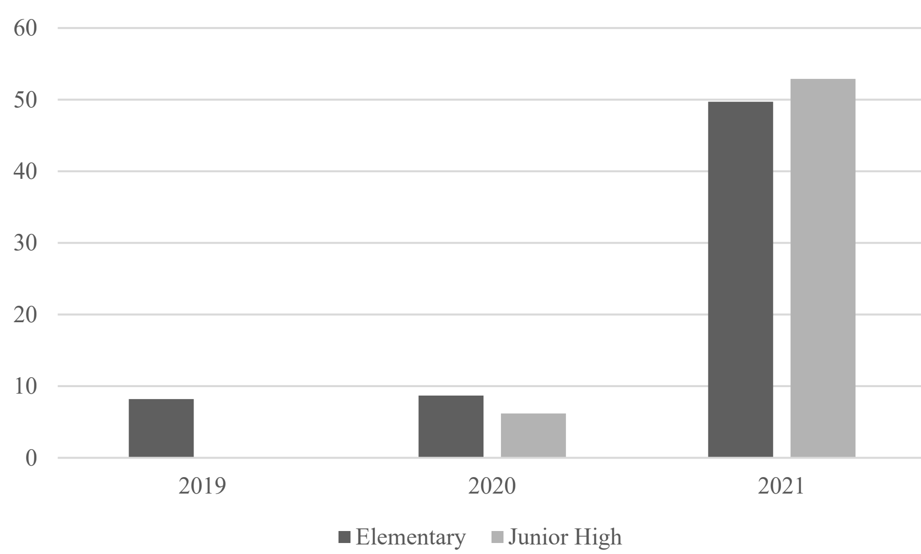
Notes: 1. Robust standard errors, clustered at the school level, are in parentheses.
2. * significant at 10%; ** significant at 5%; *** significant at 1%.
3. Year effects, student fixed effects and a constant are included in all estimations, but not reported for convenience.
4. Due to data availability, the sample period starts at 2020 in column (2) and at 2021 in columns (3) and (4). ICT in columns (3) and (4) refers to digital devices such as PCs and tablets.

Figure 1. Ratio of Personal Computers to Students



Notes: Author's calculations based on the administrative data collected by the Ministry of Education, Culture, Sports, Science and Technology (2018-2021). For junior high schools, only 2020 and 2021 are computed as the regression sample does not include junior high school students in 2018 and 2019.

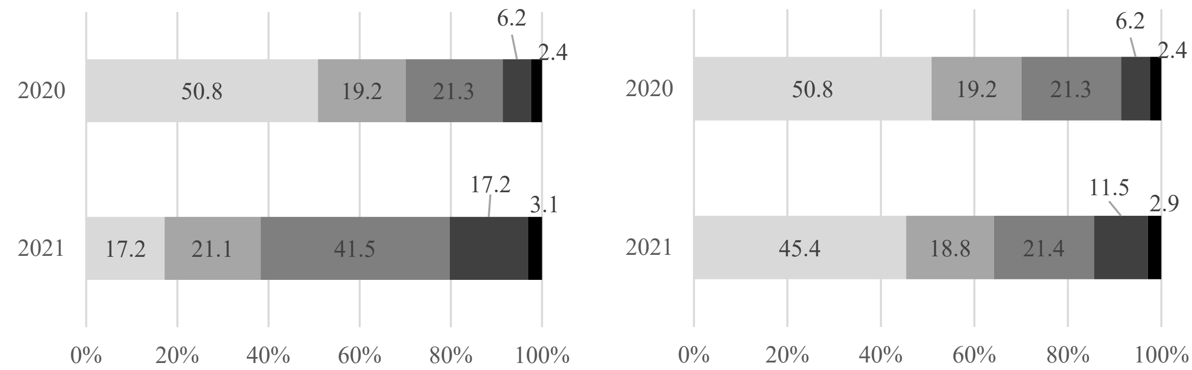
Figure 2. Adoption of Digital Textbooks in School (%)



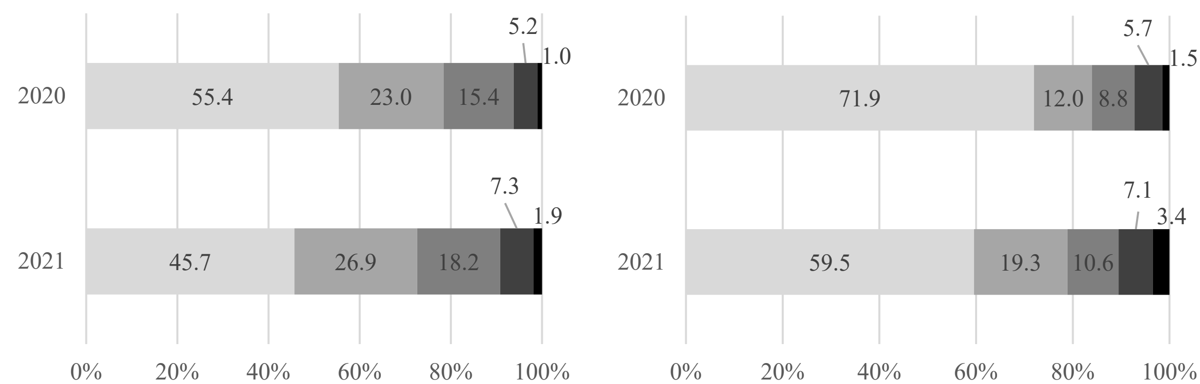
Notes: Author's calculations based on the administrative data collected by the Ministry of Education, Culture, Sports, Science and Technology (2019-2021). For junior high schools, only 2020 and 2021 are computed as the regression sample does not include junior high school students in 2019.

Figure 3. The Use of ICT in Japanese (Left Panel) and Math (Right Panel) Classes

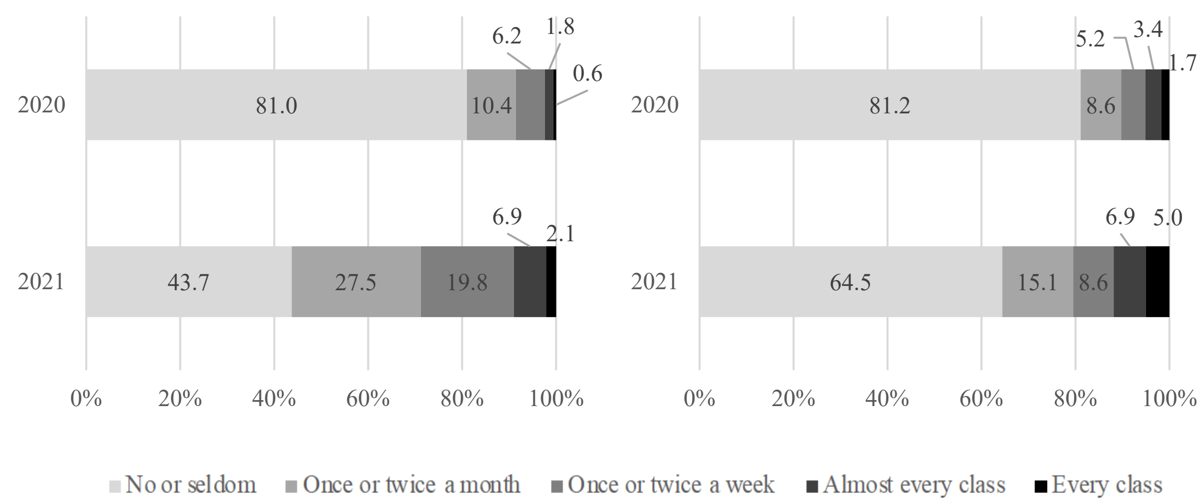
a) Cohort A: Grade 3 in 2020 and Grade 4 in 2021



b) Cohort B: Grade 6 in 2020 and Grade 7 in 2021



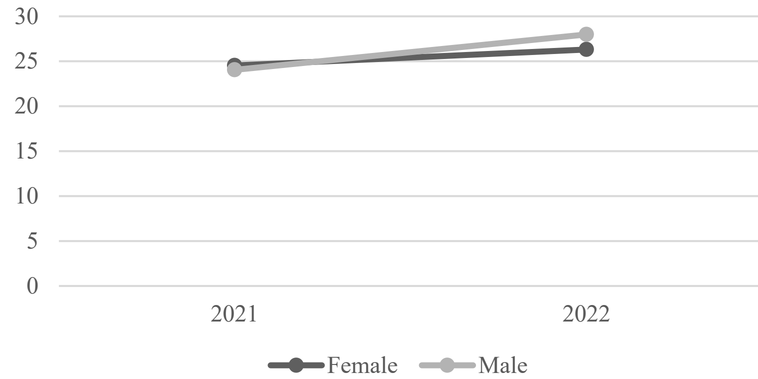
c) Cohort C: Grade 7 in 2020 and Grade 8 in 2021



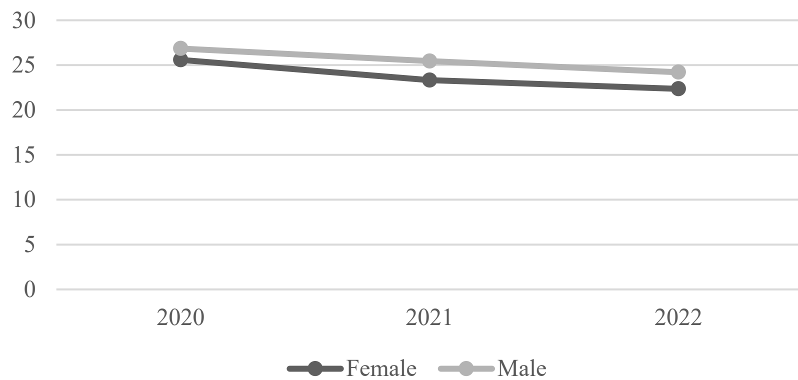
Notes: Author’s calculations based on the student surveys collected by the Department of Education in Saitama prefecture. ICT refers to digital devices such as PCs and tablets.

Figure 4. Self-Efficacy by Gender

a) Self-Efficacy (Cohort A: Grade 4 in 2021 and Grade 5 in 2022)



b) Self-Efficacy (Cohort B: Grade 6 in 2020, Grade 7 in 2021, and Grade 8 in 2022)



Notes: Author's calculations based on the student surveys collected by the Department of Education in Saitama prefecture. The figures use the average raw values of the self-efficacy index by gender, where the maximum value is 40.

Appendix Table A.1: Non-Cognitive Skills Measurements

Category	Questions
Self-Efficacy[1]	I believe I will receive an excellent grade in this class.
	I'm certain I can understand the most difficult material presented in the readings for this course.
	I'm confident I can understand the basic concepts taught in this course.
	I'm confident I can understand the most complex material presented by the instructor in this course.
	I'm confident I can do an excellent job on the assignments and tests in this course.
	I expect to do well in this class.
	I'm certain I can master the skills being taught in this class.
	Considering the difficulty of this course, the teacher, and my skills, I think I will do well in this class.
Grit[2]	I have overcome setbacks to conquer an important challenge.
	New ideas and new projects sometimes distract me from previous ones.
	My interests change from year to year.
	Setbacks don't discourage me.
	I have been obsessed with a certain idea or project for a short time but later lost interest.
	I am a hard worker.
	I often set a goal but later choose to pursue a different one.
	I have difficulty maintaining my focus on projects that take more than a few months to complete.
	I finish whatever I begin.
	I have achieved a goal that took years of work.
	I become interested in new pursuits every few months.
	I am diligent.

[1] These questions are drawn from Pintrich et al. (1991).
[2] These questions are drawn from Duckworth et al. (2007).